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# Soil management for vegetable growing in the Philippine uplands: A bio-economic analysis

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## Abstract

Soil nutrient loss due to soil erosion and removal in harvest with traditional farming methods where farmers do not use any fertilisers threatens the sustainability of vegetable productions in the Philippine uplands. Consequently, poor farmers are losing incomes due to declining yields. The situation is reaching crisis point. A bio-economic analysis is used in this research to investigate the economic returns in terms of gross and net annual income over time for upland farmers from adopting alternative soil management options. Cost benefit analysis is used to compare the net returns to farmers from potential management options. A bio-physical model, SCUAF, is used to simulate the long-run tomato yields and associated soil erosion, over a seven-year period, for different soil management options which are both income enhancing and soil nutrient preserving. Data obtained through experiments and surveys of upland farmers in Claveria in the Philippines island of Mindanao, are used to derive yearly production budget for tomato farming on one hectare of land. The analyses reveal that significantly higher economic returns are achievable a combination of organic and inorganic fertiliser additions. This combination seems to be most attractive since it leads to benefits in both yield increase and reduced soil erosion over time. Therefore, concentrating further research on the use of fertiliser combinations, especially at lower rates where marginal returns are highest seems to be an appropriate focus, and one which is most likely to be adopted by farmers.

## Introduction

A bio-economic analysis is used to investigate the economic returns for upland farmers from adopting alternative soil management options for producing tomatoes relative to a base case option. Cost benefit analysis is used to compare the net returns to farmers from potential management options. A bio-physical model, SCUAF, is used in this research to simulate the long-run tomato yields and associated soil erosion, over a seven-year period, for different soil management options which are both income enhancing and soil nutrient preserving.

## Bio-physical modelling: SCUAF

This research requires a model that can be parameterised with minimal data to accurately simulate yields for vegetables (tomato for this research) and associated soil nutrient loss under the humid tropical environment in the uplands of the Philippines. For this purpose, the SCUAF (*Soil Change Under Agriculture, Agro-Forestry and Forestry*) is chosen because of its capacity to simulate nutrient losses and vegetable yields in the humid tropics and the ease with which it can be applied.

SCUAF, which was first described in detail by Young and Muraya (1990), and later by Young et al (1998) is a

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deterministic model designed to predict the effect of agriculture and agro-forestry systems on soils. A Modified Universal Soil Loss Equation (MUSLE) is used to predict erosion (FAO 1979). Erosion reduces the amount of nitrogen and carbon in a soil profile. The initial crop (vegetable-tomatoes) biomass production entered by the user is modified within the model in proportion to changes in soil nitrogen and carbon. SCUAF's default parameters for modelling carbon and nitrogen transformations in the soil are based on climate, texture, drainage, soil reaction and slop classes. The proportional reduction in crop yield resulting from changes in soil carbon and nitrogen is determined as part of the structure of the model and can be specified by the user.

SCUAF is an annual time step model simulating long term average vegetable yields and soil loss, and therefore cannot be rigorously validated to new applications unless data from field trials extend over many years. However, SCUAF was explicitly designed to simulate erosion and crop yields from agriculture and agro-forestry systems in tropical environments (Young and Muraya 1990). SCUAF combines the international experience in simulating organic matter and nitrogen cycles in tropical soils described by Young and Muraya (1990), with the experience and literature of agriculture, agro-forestry and soil conservation summarised in Young (1989). SCUAF's default parameters for modelling carbon and nitrogen transformations therefore summarise current knowledge of these processes in the tropics.

**Cost benefit analysis (CBA)**

CBA is typically used to evaluate the desirability of a given intervention. The aim is to gauge the efficiency of the intervention relative to the status quo. Inputs are typically measured in terms of opportunity costs - the value in their best alternative use. The guiding principle is to list all of the parties affected by an intervention, and place a monetary value of the effect on their welfare.

The process estimates initial and ongoing expenses vs. expected return. Constructing plausible measures of the costs and benefits of specific actions is often very difficult. In practice, analysts try to estimate costs and benefits either by using survey methods or by drawing inferences from market behaviour. CBA attempts to put all relevant costs and benefits on a common temporal footing. A discount rate is chosen, which is then used to compute all relevant future costs and benefits in present-value terms.

CBA can be used to compare the economic returns over time from different soil management options. It can be performed over different scales and from different perspectives and in this research CBA is conducted from a farm level perspective rather than the research investment point of view. Adjusted prices and rates of time preference can be used to introduce a social perspective to the analysis. A range of valuation techniques have been developed to extend CBA to environmental and off-site impacts of soil erosion; however, these techniques are not used in the present analysis.

There is an extensive literature describing the theory and application of CBA which has been comprehensively reviewed by Perkins (1994). It is a technique for comparing the stream of net benefits produced over time by competing investment opportunities, in this case alternative soil management options. The cumulative net present value of each soil management technique over n years can be calculated from the following equation where $B_t$ and $C_t$ are benefits and costs in year t and r is a discount rate:

$$NPV = \sum_{i=1}^{n} \frac{(B_t - C_t)}{(1 + r)^t}$$

Discounting is used to reflect the extent to which the investor prefers present, compared to future income and consumption.

CBA can be used to assess whether the costs of implementing different soil management options are offset by the returns from sustained crop yields or reduced soil erosion. Over a defined time period, soil management options with a net present value greater than zero are profitable, and soil management options with high net present value dominate those with low net present value. A net present value ranking provides a decision criterion for comparing the economic returns from alternative soil management options over time.

The objective of the CBA presented in this research is to investigate the incentives of farmers to adopt alternative soil management options at a point in time. The most appropriate scale of analysis for investigating adoption incentives for this research is the field level, because farmers decide whether to adopt the management options based on their own objectives, production possibilities and constraints (Pagiola 1994).

**Data Collection**

Some data for this study have been collected from the surveys conducted by one of the Australian Centre for International Agricultural Research (ACIAR) projects. The surveys were conducted in Claveria, Mindanao. Also some of the data related to soil characteristics and depth are obtained from experiments by the scientists of the ACIAR.

A data set of all required variables and tomato production budget on one hectare of land is prepared based on the data obtained from the ACIAR. However, further required data on different other variables are obtained from secondary sources such as relevant literature or through personal communication with soil scientists and experts.

**Parameterising SCUAF**

SCUAF was parameterised to model tomatoes as an example of an upland vegetable crop. Tomatoes have been identified as crop of potential (ACIAR 2007). Availability of data is another reason for choosing tomatoes for this analysis. The time horizon was chosen to be seven years to allow the expression of longer term changes but recognising that consequences beyond about seven years are not likely to influence farmer behaviour. Environment parameters were set to reflect the characteristics of climate and soil of Claveria. The climate at Claveria placed it in the lowland humid class of the Köppen climate classification used in SCUAF (Young et al. 1998). The soil was a well drained clay oxisol of relatively low erodibility and a pH of 4.5 – 5.0. The slope gradient varied from 20-22.5 percent between treatments, placing the site in SCUAF's moderate slope class.

Since local level information was not available on the carbon and nitrogen cycles at Claveria, SCUAF's default parameters for carbon and nitrogen transformation in this type of environment were accepted. These default parameters represent the knowledge summarised in Young (1989).

Soil carbon and nitrogen percentages and bulk densities were initialised at levels suggested by Mercado (personal communication) and shown in Table 1.

**Table 1** Selected soil properties at Claveria

| Soil profile layer | Depth (cm) | C (%) | N2 (%) | Bulk density (g $cm^{-3}$) |
|---|---|---|---|---|
| 1 | 0-10 | 3.85 | 0.27 | 1.00 |
| 2 | 10-20 | 2.43 | 0.19 | 1.00 |
| 3 | 20-30 | 1.61 | 0.14 | 1.00 |
| 4 | 30-70 | 0.85 | 0.08 | 0.9 |
| 5 | 70-100 | 0.81 | 0.07 | 0.9 |

Source: derived from experimental data provided by the ACIAR

The default parameters for USLE in SCUAF were modified to predict average observed rates of soil erosion measured at Claveria, since the model default values for the erosion parameters over predicted erosion at the study area. Acceptable predictions of erosion were obtained by setting the rainfall factor to 1000 to reflect lower rainfall erosivity. The slope factor was reduced from 3.5 to 1.5 to be consistent with the moderate slope gradient and limited slope lengths of farmers' fields in the undulating terrain. The crop cover factor was reduced slightly from 0.5 to 0.4 to reduce the initial rate of erosion observed from different soil management options. Vegetable biomass and yields within SCUAF were parameterised using the experimental data provided by Component 1 of the ACIAR Program. The apportionments of plant production were parameterised for 0.15 in leaf, 0.85 in fruit and 0.00 in terms of dry matter at harvest.

**Economic data**

CBA is used to compare the net economic returns from different soil management options. The CBA presented in this study focuses on the field level returns. No attempt is made to quantify the off-site benefits of soil management options. They may be significant, but are unlikely to affect farmers' adoption decisions. A relatively long term time horizon of seven years is considered to capture most of the long term returns to investments in soil management.

Economic data for the CBA are derived from the data obtained from Component 1 of the ACIAR Vegetable Program. Experimental crop production budgets for tomato are obtained by field surveys with and without fertilisers. Production budget list the costs and returns of tomato growing over a period of one year for a hectare of land. SCUAF is used to predict tomato yields and soil loss over time from alternative soil management options. Three discount rates are used for the analysis based on the cost of capital. A real discount rate of 20 percent is derived from the known high costs of credit facing farmers. Two lower discount rates of 10 percent and 5 percent are used to more closely reflect the cost of capital to the government.

### Cost-benefit analysis

The CBA is calculated in an Excel spreadsheet. Existing tomato yields reported by the ACIAR Component 1 are used to predict long term tomato yields using SCUAF. Net returns for each option are calculated by subtracting the annual cost of material inputs and labour from the gross farm level value of tomato yields. Each scenario of the CBA is presented by reporting expected net present value from the alternative soil management options over time.

### SCUAF simulations

Seven different soil management options were simulated using SCUAF: Baseline (no fertiliser), Organic additions (Full), Organic additions (Half), Inorganic additions (Full), Inorganic additions (Half), Combined (Full), Combined (Half). Table 3 provides the description for each of these options.

**Table 3** Description of soil management options simulated using SCUAF

| Soil management options | Descriptions |
|---|---|
| Baseline(no fertiliser) | No fertiliser added |
| Organic (Full) | Addition of chicken dung and litter. Total addition 5 tonnes/ha/year. |
| Inorganic (Full) | Inorganic fertiliser is added in the proportion of N:P:K = 14:14:14.Total addition 0.4 tonnes/ha/year. |
| Combined (Full) | Both inorganic and organic type of additions used. Total organic addition 5 tonnes/ha/year and total inorganic addition 0.4 tonnes/ha/year. |
| Organic (Half) | Addition of chicken dung and litter. Total addition 2.5 tonnes/ha/year. |
| Inorganic (Half) | Inorganic fertiliser is added in the proportion of N:P:K = 14:14:14.Total addition 0.2 tonnes/ha/year. |
| Combined (Half) | Both inorganic and organic type of additions used. Total organic addition 2.5 tonnes/ha/year and total inorganic addition 0.2 tonnes/ha/year. |

The baseline simulation does not involve any fertilisers. The rest of the options involve various combinations of fertilisers ranging from organic chicken dung and litter to inorganic fertilisers. The simulations predicting tomato yields with organic fertilisers use 5 and 2.5 tonnes/ha/year of chicken dung and litter. These fertilisers have impact on yield and also impact via mulch on reducing soil erosion. In other words, the organic options inherently include soil conservation mechanisms.

The simulated soil management options demonstrate that tomato yield is much higher even in the first year compared to the baseline case (Figure 1). The baseline yield is only 5.2 tonnes/ha, whereas, with different soil management options tomato yields increase to 6.2 tonnes/ha in organic-half, 7.1 tonnes/ha in organic-full, 8.5 tonnes/ha in inorganic-half, 9.4 tonnes/ha in combined-half, 10.2 tonnes/ha in inorganic-full and 10.2 tonnes/ha in combined-full,

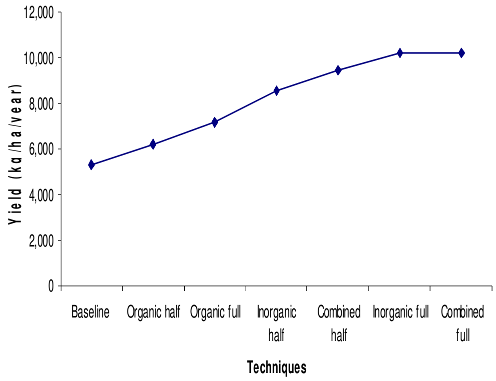


**Figure 1** Yields differences under different options in year 1

The simulated options not only show improvement in yields of tomato but also demonstrate substantial reduction in soil erosion compared to the base case (Figure 2). The reduction is soil erosion is remarkable in some of the options. In the case of the baseline, amount of soil erosion at the end of first year of cropping equals to 34.7 tonnes/ha, whereas, erosion is reduced to 21.5 tonnes/ha in inorganic-full, 18 tonnes/ha in inorganic-half, 5.9 tonnes/ha in organic-full, 5.1 tonnes/ha in organic-half, 3.6 tonnes/ha in combined-full and 3.8 tonnes/ha in combined-half.

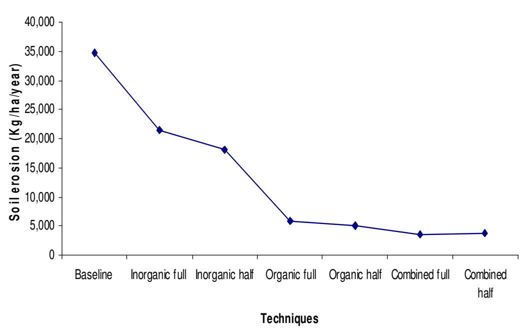


**Figure 2** Reduction in soil erosion under different options in year 1

Analysing yields over seven years of time frame reveals that, predicted tomato yields decline substantially over time under two soil management options (baseline, inorganic–half) yet they consistently increase in two (organic–full, combined-full) of them (Figure 3). In inorganic-full option, yield declines slightly overtime, however, overall increase in yield in this option is attractive compared to most other. Nevertheless, yields are substantially higher in all of the options involving fertiliser application compared to baseline that does not involve any. Along with yields, soil erosion (Figure 4) is also decreased dramatically over time in all options involving fertiliser additions.

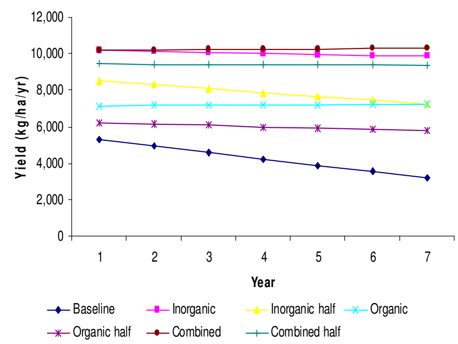


**Figure 3** Tomato yields projected using SCUAF, Claveria

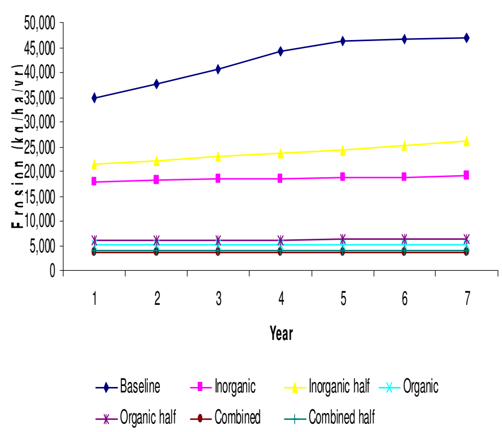


**Figure 4** Projected soil erosion using SCUAF, Claveria

## Bio-economic analyses

The net annual revenue from tomato growing for the upland farmers was calculated by multiplying yield by the market price of tomatoes, then subtracting costs. Then a discount factor was used to calculate net present value for each scenario (Table 4)..

**Table 4** NPV of net profits from tomato growing over seven years in different options
Unit: PHP (thousand)

| Soil management options | | NPV Discount Rate | |
|---|---|---|---|
| | **20%** | **10%** | **5%** |
| Inorganic (Full) | 347 | 378 | 396 |
| Combined (Full) | 318 | 347 | 364 |
| Combined (Half) | 294 | 320 | 336 |
| Inorganic (Half) | 204 | 223 | 233 |
| Organic (Full) | 174 | 190 | 199 |
| Baseline (no fertiliser) | 102 | 111 | 117 |
| Organic (Half) | 82 | 89 | 94 |

With a discount rate of 20 percent, each NPV predicted from simulated soil management options is significantly greater than NPV predicted from baseline simulation. (The only exception is in the case of organic additions with the lower (half) rate of fertiliser). According to the NPV, simulated soil management options can be ranked as follows: Inorganic–full, Combined–full, Combined–half, Inorganic–half, Organic–full, Baseline and Organic–half.

For sensitivity, two lower discount rates for example, 10 percent and five percent have been used. Although reducing the discount rates change the absolute financial returns from each of the management options, they have little impact on the ranking of the various soil management options developed based on a 20 percent discount rate. For example, with both 10 percent and five percent discount rates, return is still the highest from inorganic-full, and lowest from organic-half. The absolute values of returns are higher when discount rate is lower (Table 4).

The NPV analysis revealed that, irrespective of a discount rate of 20 percent, 10 percent or 5 percent, most simulated soil management options produced significantly greater NPV than the baseline simulation. The simulations of inorganic-full additions and combined-full additions predicted the highest and second highest NPV respectively.

The outcomes of this research are not considered to be mature enough to disseminate at the farm level, rather they are to guide scientists, so that they can focus their research on the most relevant aspects of soil management.

## Concluding comments

The objective of the research was to identify potentially profitable soil management options for the upland areas of the Philippines. Based on the results and analyses the application of various combinations of organic and inorganic fertilisers particularly at the higher end of examined application rates were found to be the focus for upland farmers. Although these higher levels give maximum net return, obviously they will be commensurately more expensive. Therefore attention to maximising possible synergistic effects between inorganic and organic fertilisers, as identified in this study, would be a recommended avenue to pursue, as would searching out local materials that might be used in lieu of imported materials.

The tradeoffs between applying lower than 'optimal' fertiliser levels and economic returns are worth exploring. There are insignificant tradeoffs in terms of giving up profit - less than eight percent and 15 percent over seven years compared to combined-full and inorganic-full respectively. Such reduction in fertiliser amount may be beneficial in the real world scenario, where farmers may not be interested in applying heavier rates of fertilisers due to credit constraints.

Based on the overall analysis, following broad conclusions can be drawn from the study:

- Application of fertilisers is generally found to be profitable for the upland vegetable growers in contrast to their existing practice where they do not add any.
- Combining application of both organic and inorganic fertilisers generally produces better outcome in terms of profit and soil erosion reduction than either alone.
- Application of heavier levels of fertilisers is generally more profitable than that of lighter levels. However, lower levels of fertilisers while less profitable have only small impacts on returns on revenue over time and therefore may be preferred by farmers facing cash constraints.

Therefore, concentrating further research on the use of fertilisers, particularly in combination of organic and inorganic can be an appropriate future focus.

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