ANALYSIS OF COST-EFFECTIVENESS OF AGRICULTURAL YIELD FROM VEGETABLE FARMING

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ABSTRACT: Most developed countries in the world depend heavily on agriculture but scarce attention has been paid to studies on the cost-effectiveness of agricultural yield from vegetable farming, especially by the relevant authority. While the total agricultural yields obtained are high in terms of economic perspective, however the cost of fertilizers and soil loss in agricultural areas are not taken into account. The loss of nutrients from fertilizers and soil in agricultural activities need to be stressed because it can cause significant losses to agricultural producers in term of soil fertility. As such, the objectives of this study were to investigate the agricultural gross revenue earned by the type of crop and current crop price, to estimate the amount of nutrient loss from fertiliser and soil loss by crop type and to analyse the cost-effectiveness of agricultural yield. Four types of vegetables were selected for this study, namely Spinach (*Amaranthus oleraceus L.*), Red Chili and *Chili Padi* (*Capsicum frutescens L.*) and Cucumber (*Cucumis sativus L.*) planted in an open slope of 5º at a plot size of 1.5m x 2.0m. The rainfall in this study was produced by a rainfall simulator at a pressure of 7 psi that can produce rainfall intensity of 67 mm/hr. From this study, the total amount of vegetables harvested from each plot was 2.96 kg for Spinach, 2.67 kg (Red Chili), 0.51 kg (*Chili Padi*) and 4.52 kg for Cucumber. In terms of current market value, Spinach yielded RM 10.03, Red Chili RM 53.37, *Chili Padi* RM 10.20 and Cucumber RM 12.90. The amount of soil loss is 9.43 kg for Spinach, 7.6 kg for Red Chili, 3.94 kg for *Chili Padi* and 9.86 kg for Cucumber. For the nutrient loss, Spinach yielded 12.58 g, Red Chili (11.51 g), *Chili Padi* (8.04g) and Cucumber (11.51g). The total cost of nutrient and soil loss is RM 6.33 for Spinach, Red Chili RM 5.12, *Chili Padi* RM 2.67 and Cucumber RM 9.96 respectively. Hence, the net profit of each vegetable during the study period is RM 3.70 for Spinach, RM 48.25 Red Chili, RM 7.53 *Chili Padi* and RM 2.94 Cucumber. This study suggested that the cost of nutrient loss from fertilizer and the soil loss should be considered in the determination of current market price of vegetables. In agricultural practice, the farmers should consider the amount of nutrient and soil loss in order to sustain the fertility of the soil from the agricultural activities.
Keywords: cost-effective, soil and nutrient loss, vegetable farming

INTRODUCTION

Most developed countries in the world depend heavily on agriculture. Efforts to sustain and improve the sector's productivity are therefore crucial to the region's economic development. Land degradation is thought to pose a severe threat to the sustainability of agricultural production due to prevalent environmental damage. The idea of agricultural sustainability centres on the need to develop technologies and conservation management practices that do not have adverse effects on environment, good and service, while improving food productivity (Crosson and Anderson, 2002).

As the world's population soared, there has been great challenge to reconcile food production and natural conservation in modern agriculture, which embodies a human-controlled agro-ecosystem dependent on inputs from the outer environment, such as sunlight, wind, water, and soil. The ecosystem also includes purchased inputs, such as fertilizers, pesticides, fuels, electricity, mechanical equipment and other industrial products. Systems ecological evaluation and assessment would be essential to build the resource relocation and sustainable development of the agricultural industry (Rudel, 2013).

The agricultural sector in Malaysia has been growing rapidly over the years. Due to the excellent natural conditions in Malaysia such as the level of humidity, tropical weather and fertile soil, the

current production of the agricultural industries in Malaysia is considered as one of the largest amongst the Asia region (Quah, 1999). In agricultural activities, fertilizer application is the main source of phosphorus and nitrogen, with both most likely ending up in streams. Other potential sources of phosphorus and nitrogen include urban and industrial run-off, pesticides, effluent from feedlots of livestock and wastewater treatment plants, and weathering of rock material; nitrogen may also be augmented by fixation from the atmosphere. The amount of nutrient released depend on factors such as the type, amount, method and timing of nutrient application, the susceptibility of the soil to erosion and the rates of chemical and biological transformation (Turner and Rabalais, 2003).
Large scale agricultural activity often requires land clearance. As such, forest area will be logged to make ways for agriculture. Land clearing process affects the natural environment (Guillaume Damris and Kuzyakov, 2015; Midmore Jansen and Dumsday, 1996; Malmer, 1990), hence good management practices are needed, especially with regards to sloping areas. Slope run-off processes can be divided into two phases: the operations on the slope and material handling operations. Operating on slopes is further divided into two, namely the process of surface run-off and groundwater run-off. Surface run-off occurs under two circumstances, namely when the soil is already saturated and unable to absorb water infiltrate into the soil (Shaw, Beven, Chappell and Lamb, 2011; Morvan et al., 2014). Material handling operations also coincide with operations on the surface. This operation refers to the process of transporting materials and minerals down the slope.

The cost-effectiveness of agricultural cultivation area of vegetables is an issue that should be given serious attention. The agricultural activity can be beneficial or detrimental. Commercial agriculture use fertilizer in order to increase the agricultural yield. Less attention has been paid to the study on the cost effectiveness of agricultural yield for vegetable farming especially from the relevant authority. While the total agricultural yields obtained are high in terms of economic perspective, the cost of fertilizers and soil loss in agricultural areas are neglected. The loss of nutrients from fertilizers and soil in agricultural activities need to be stressed, because it can cause significant losses to farmers in term of soil fertility. As such, the objectives of this study were to investigate the agricultural gross revenue earned by the type of crop and current crop price, to estimate the amount of nutrient loss from fertilizer and soil loss by crop type and to analyse the cost-effectiveness of agricultural yield.

RESEARCH AREA AND METHODOLOGY

Five plots located in Universiti Sains Malaysia main campus with a dimension of 2m x 1.5m are chosen for vegetable cultivation. The soil series according to the Department of Agriculture (1970) is Red-Yellow Podzolic soil with Reddish-Brown Lateritic soils and Lithosols. Four types of vegetable are cultivated, namely Spinach, Chili (Red Chili and *Chili Padi*) and Cucumber and another plot had been preserved in its natural state as a control plot. The run-off water was collected in a trough and vacuumed continuously in a 28 litre container for analysis which involved parameters like total suspended solids, nitrite-nitrogen ($N0_2$-N), nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_3-N) and phosphate (PO_4). These parameters were determined by the American Public Health Association standard method (APHA, 1999) and the brief standard procedure by Adam (1990). The parameter for total suspended solids is based on the filtration method (Gordon, McMahon and Finlayson, 1992). The fertilizers used consist of N15, P15 and K15 (Nitrogen, Phosphorus and Potassium).

Rainfall simulator is an approach to produce controllable rainfall, in the context of time and space, and it allows the repetition and simulation of many years of rainfall events. As such, this study uses a pressurised type rainfall simulator that satisfied specific criteria such as run-off sample collection efficiency, rainfall intensity and event duration for run-off and erosion experiment purposes (Erpul, Gabriels and Janssens, 1998). The rainfall simulator has been calibrated in order to produce simulations that have similar characteristics to natural rainfall.

The simulator device used in this study consists of a triangular frame mast with a height of three metres, a three-metre length arm mounted at the top of the mast, and three nozzles spaced 1.1 metre apart installed at the nozzle boom, such that the nozzle's height is 2.4 m (see Figure 1). According to Duncan (1972), this height is adequate for creating terminal velocities similar to natural rainfall for all drop sizes. The Fulljet type nozzles with wide angle square spraying, model 1/2HH-50WSQ (Spraying Systems Co. USA) were chosen for their wide spraying angle, the square wetted zone and the high uniformity of the spray. Water under an adequate pressure was supplied to the nozzles by a 13 horse power water pressure pump, thus enabling the simulator to produce a rainfall intensity of 67 mm/hr that is within the range of two years Average Recurrent Interval (ARI) for natural rainfall in Penang (Department of Irrigation and Drainage, 2012).

CHARACTERISTICS OF CROPS

Vegetable is an important resource providing mineral, vitamin, protein and carbohydrate in human nutrition (Fadelah, Harun, Mooi, Hawa and Noor Rawi, 1990). The selected vegetables are some of the most common vegetables produced in Malaysia (see Table 1).

Table 1: Description of vegetables produced in Malaysia

Name	Description/Characteristics
Spinach	Spinach (locally known as *Bayam*) with the scientific name *Amanranthus oleraceus L.* included in *Amaranthaceae* family is less than one metre high. Spinach is a leafy vegetable that contains vitamin A, B, C and minerals such as calcium and iron. The tree has small flowers and tiny black seeds. Harvesting takes place after about a month by removing the entire tree (HalimathulSaadiah, 1998). Cultivation of Spinach on plot studies requires deep plough soil friable about 15-20 cm. Spinach adapts to a range of soil types, especially light clay loam and sandy clay. Soil rich in organic matter, with good drainage and soil pH around 5.5 to 6.5 provide the most conducive environment. Spinach leaves are lanceolate and the life expectancy is three months. Spinach needs a substantial amount of water to grow (Department of Agriculture, 1996).
Chili	The scientific name is *Capsicum frutescens L* and belongs to the family of *Solanaceae* also known as the Bird Chili (*Chili Burung*) and *Chili Melaka*. Chilies are lowland vegetables and originated from South America and are currently widely grown in tropical climates. There are some flowers on stems and branches. Two types of chilies are cultivated in this study, which are Red Chili and *Chili Padi*.
Cucumber	Cucumber (locally known as *Timun*) is known by its scientific name as *Cucumissativus L.* and belongs to the family of *Cucurbitaceae*. Cucumber is a creeping vine that roots in the ground and trellis along other supporting frames, wrapping around supports with thin, spiralling tendrils. The plant has large leaves that form a canopy over the fruit. It can be harvested approximately eight weeks after planting and the life expectancy is 70 days. Young fruit is eaten raw as a salad or used to decorate dishes (Halimathul Saadiah, 1998).

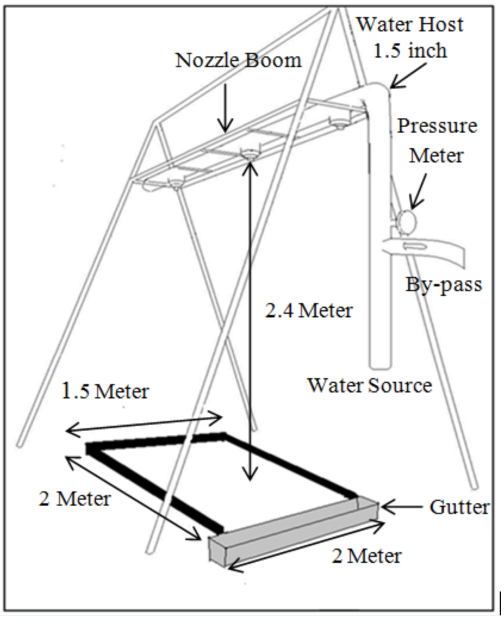

Figure 1: Rainfall simulator and plot design

RESULTS AND DISCUSSIONS

The total agricultural yield from each vegetable plot during the study period is shown in Table 2. The highest vegetable yield is Red Chili, producing a total weight of 2.67 kg and based on the current market price of RM19.99 per kg, the total yield is RM53.37. The lowest vegetable yield is Spinach, although producing the total weight of 2.67 kg but due to its current market price at RM3.39 per kg, the total yield is only RM10.03. Total yield for *Chili Padi* and Cucumber are RM19.99 and RM12.90 respectively. *Chili Padi* only produces a total weight of 0.51 kg and 4.52 kg for Cucumber during the study period.

Table 2: The total yield for each vegetable during the study period

Vegetable	Weight (kg)	Current Value (RM/kg)	Total Yield (RM)
Spinach	2.96	3.39	10.03
Red Chili	2.67	19.99	53.37
Chili Padi	0.51	19.99	10.20
Cucumber	4.52	2.85	12.90

Table 3 shows the agricultural cost and net yield for each vegetable during the study period. In formulating the agricultural cost, the price of fertilizer (multiply with nutrient loss) and soil price (multiply with total soil loss) were determined. The total agriculture cost for each vegetable will then be deducted from the total agricultural yield to obtain the net agriculture yield. The highest total nutrient loss (from fertilizer) is Spinach (12.58 g) followed by Red Chili and Cucumber (11.51 g respectively) and *Chili Padi* (8.04 g). The highest total soil loss is Cucumber (14.94 kg), followed by Spinach (9.43 kg), Red Chili (7.60 kg) and *Chili Padi* (3.94 kg). The highest cost for agriculture activity during the study period is Cucumber, resulting in total of RM9.96 per kg and the lowest is *Chili Padi* (RM2.67 per kg). Taking into account these values, net agriculture yield for each vegetable is obtained. The net agricultural yield provides a clear picture of the actual cost involved in vegetable production. Agricultural activities must take into account the loss of soil and nutrients to determine the actual price of each type of vegetable. According to Spencer (2004), major drivers of prices and costs are farm production factors, value chain integration, marketing approach, regulation and compliance, trade impacts, technology and innovation, consumer and retail market dynamics. None of these factors considered environmental variable as one of the market price determination.

Table 3: Agriculture cost and net yields for each vegetable during the study period

Vegetable	Fertilizer Price (RM/kg)	Total Nutrient Loss (g)	Fertilizer Cost (RM/kg)	Soil Price (RM/kg)	Total Soil Loss (kg)	Soil Loss Cost (RM/kg)	Total Cost (Fertilizer + Soil Loss) (RM/kg)	Net Agriculture Yield (RM)
Spinach	8.75	12.58	0.11	0.66	9.43	6.22	6.33	3.70
Red Chili	8.75	11.51	0.10	0.66	7.60	5.02	5.12	48.25
Chili Padi	8.75	8.04	0.07	0.66	3.94	2.60	2.67	7.53
Cucumber	8.75	11.51	0.10	0.66	14.94	9.86	9.96	2.94

The total soil and nutrient loss cause a substantial loss to the agricultural sector. Soil loss will affect soil productivity as it removes the top layer of soil at the land (McCormack, Young and Kimberlin, 1981: USDA, 1998). When nutrient resources are so depleted by erosion, plant growth is stunted and overall productivity declines (Lal and Stewart, 1990; Pimentel et al., 1995). To offset the nutrient losses erosion inflicts on crop production, large quantities of fertilizers are often applied. The replacement strategy with the application of commercial fertilizers is expensive for the farmer and nation. Current market price of fertilizer is RM8.75 per kg while market price for pot soil is RM0.66 per kg. Therefore, although Spinach and Cucumber can contribute to the higher yield in terms of amount harvested, but the total cost of fertilizer and soil loss is amongst the highest (RM6.33 per kg and RM9.96 per kg respectively. Hence, the net agricultural yields from these vegetables are lower than Red Chili and *Chili Padi* (Table 3). The total yield for Spinach and Cucumber are RM10.03 and RM12.90 respectively (see Table 2) but taking into account the total cost as a result of loss from soil and fertilizer, the net agricultural yield are only RM3.70 (Spinach) and RM2.94 for Cucumber.

When referring to the total soil loss for each vegetable (Spinach, Cucumber, Red Chili and Chili Padi) during the study period, it should be noted that Spinach plot is contributing much more soil loss than other vegetables. Pimentel et al. (1995) estimated the average rate of soil loss due to erosion of soil in agricultural areas around the world is around 0.13-0.40 tons/km^2/year. Morgan (1974) estimated that the rate of soil loss for a vegetable farm in Peninsular Malaysia is 1,009 tons/km^2/year. Intensive soil erosion will attenuate layer of fertile soil and reduce soil productivity. Weibe (2003) estimated that the worldwide shortage of agricultural produce as a result of soil erosion is 0.6 per cent per year for potato, 0.48 per cent a year for millet crops and 0.42 per cent a year for corn. Lack of agricultural products is due to the low productivity of the land resulted by soil erosion which fails to support the growth of plants.

Run-off also plays an important role in agricultural activities resulting in the loss of nutrients from agricultural areas into water bodies. According to Cole (1993), the major nutrients required for plant growth are nitrogen and phosphorus. Slow growth and stunted crops in agricultural areas will cause losses to agricultural producers or farmers. This is because plants grown will take longer time to produce yield and thereby increase the cost of agricultural capital. Aminudin et al. (2001) describes the rate of erosion at vegetable farms in Cameron Highland as very high (82 tons/ha). Soil erosion is one of the physical processes that contribute to the soil degradation and generate environmental problems, such as landslide. In addition, (FAO, 1990) reported that one-third of the world's agricultural land planted with crops are easily eroded by erosional agents. Shortages of cropland are already having negative impact on world food production (Brown, 1997). Another impact of soil erosion is the export of surface sediment from farms into a nearby river system that degrade water quality (Jaafar, 2012). Total losses from soil and nutrient loss due to the erosion process in agricultural areas can be reduced by implementing contour planting to reduce the velocity of surface run-off (Brye, Norman, Bundy and Gower, 2000). Vegetation canopy can also play an important role in reducing the raindrops impact. Their main role is to reduce the kinetic energy by intercepting the rainfall to avoid direct impacts to the soil surface (Morgan, 1979), thus reducing the run-off and nutrients transported.

CONCLUSION

This study focused on analysing the cost-effectiveness of agricultural yield based on plot scale using rainfall simulator. Rainfall simulator is able to simulate rainfall intensity similar to natural rainfall events. Soil erosion can have a significant negative impact on crop yields because as soil erosion continues, the soil is further degraded. Poor soil quality is reflected in the decrease of organic matter, aggregate stability, phosphorus levels, and potential plant-available water. The net result is a decrease in soil productivity. This study suggested that the cost of nutrient loss from fertilizer and the soil loss should be considered in the determination of current market price of vegetables. Therefore, when selling agricultural produce, farmers should take into account the loss of soil and nutrients in determining the actual price of each type of vegetable.

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