Proceedings of 12th International Conference on Business Management
http://ssrn.com/link/12th-ICBM-2015.html
7th and 8th December 2015 | Colombo, Sri Lanka

Sustainable Weed Management in the Commercial Tea Industry: The Case of Hapugastenne Estate, Maskeliya

H.M.P. Peiris, Hapugastenne Estate, Maskeliya Plantations PLC & Postgraduate Institute of Science, University of Peradeniya, Sri Lanka

A.D. Nuwan Gunarathne (adnuwan@gmail.com, nuwan@sjp.ac.lk), Department of Accounting, University of Sri Jayewardenepura, Sri Lanka

Abstract

Tea sector of Sri Lanka earns US$ 1.6 billion net foreign exchange annually while caring over one million direct and indirect employments and 2.5 million dependents. Controlling of problematic weeds is important to maintain steady and quality crop levels in commercial tea. Real effectiveness of plant killer chemicals (weedicides) in commercial tea is questionable against the emergence of various unintended and unforeseen detrimental side effects on the eco-systems, human health and tea bushes. The purpose of this study is to demonstrate the economic, environmental and social benefits of Herbicide Free Integrated Weed Management (HFIWM) over chemical weeding in the commercial tea industry.

A commercial scale trial on HFIWM was conducted in Hapuhastenne Estate, where natural regeneration of vegetation was allowed to form a ground cover, ceasing the usage of weedicides completely, whilst selective periodic removal of harmful weeds grown in the experimental tea area. These results were compared against the control plots of non-HFIWM tea area in the garden. Analysis showed an improvement in overall performance of tea bushes in the long run with HFIWM, enhancing the product quality and soil environment. Moreover HFIWM approach exhibits many direct and indirect benefits over chemical weeding in commercial tea in the lines of crop productivity, cost of inputs, public health, environment and the socio-economic factors. HFIWM approach was therefore, found economically, socially and environmentally more desirable. The study reveals HFIWM approach could be a sound solution to mitigate many of the constraints faced by the present day commercial tea industry in Sri Lanka..

Faculty of Management Studies and Commerce
University of Sri Jayewardenepura
Gangodawilla, Nugegoda
E-Mail: icbm@sjp.ac.lk
WEB: www.icbmusjp.org, mgt.sjp.ac.lk

Keywords: Herbicide Free Integrated Weed Management. Weedicides, Commercial Tea Plantations, Sustainable Plantations, Sustainable Agriculture.

JEL Classification: Q01

Introduction

Tea sector of Sri Lanka reached a total output of 338.4 million kilograms and earned US$ 1.6 billion net foreign exchange in year 2014 (Sri Lanka Tea Board-SLTB, 2014). The tea industry of this island nation cares over 1million direct and indirect employments, plus 2.5 million dependents as well. Further, the country has already earned global reputation for the production of the finest and also the cleanest tea in the world and maintained same almost for the past 150 years. This is purely due to the unique flavor confined to Ceylon Tea along with the least contamination levels recorded with regard to agro-chemical residues when compared with the *Camelia Tea (Camelia sinensis is the botanical term of tea plant. Generally, the term Tea commonly refers to hot water brew made out of any dried plant matter as per general terminology. Camelia Tea specifies the plant origin of the tea.)* of other origins, and hence become the highest paid tea in the world at present (Sri Lanka Tea Board-SLTB, 2014). However, Sri Lanka's plantation workers are the highest paid and also the best looked after employees in tea sector in the world. This same factor in the meantime, resulted in rocketing up the cost of production of Ceylon Tea over 800% within the past two decades. Due to this quick rising cost of production, commercial tea plantations in Sri Lanka have gradually become loss making over the years. Thus, the future of the commercial tea plantations in the country would be uncertain unless there are real breakthroughs achieved in terms of productivity and marketing.

Weed control counts for the second highest costliest operation next to harvesting (plucking) among the agronomic practices in commercial tea. Weed management is essential in agriculture near *economic crop damage level (this is the financial loss level where the intensity of economic loss caused by crop damage exceeds the real cost of pest control. Mode of pest control should be decided at this point depending on the effect on profitability by the severity of possible monetary loss.)* to arrest quality and quantity losses in farm products, thus, commercial tea is no exception. Therefore, controlling of problematic weeds is important to maintain steady and better quality crop levels in commercial tea. Hence, as per the today's context of agriculture, usage of toxic, plant killer chemicals, also known as weedicides (herbicides) to meet this objective is a common practice, in general. Sri Lanka imported nearly 8 million kilograms of herbicide chemicals, spending Rs. 4.6 billion and 6 million kilograms, paying Rs. 3.3 billion of foreign exchange in 2013 and 2014 respectively (Sri Lanka Customs, 2014). Though the exact numbers are not available, a major fraction of these herbicide imports are absorbed by the commercial tea plantations where four to five herbicide applications per annum is common.

However, the actual effectiveness of these weedicides in the commercial tea is greatly questionable against the subsequent emergence of various, unintended and unforeseen detrimental side effects, debilitating the eco-systems, human health and also the tea bushes in addition. Hence the real affectivity of permitted weedicides recommended for weed control in commercial tea plantations has become greatly uncertain, due to the intense emergence of herbicide tolerant weed species on treated areas causing persistent economic crop loss. Any additional expenditure incurred under actual weed control is compelled to be absorbed elsewhere in the budget, since the cost of weeding is closely monitored at the corporate level. Therefore, a considerable fraction of the true cost of effective weed control in commercial tea is partially hidden in the expenditure incurred in some other field operations carried out in plantations. The purpose of this study is to demonstrate the economic, environmental and social benefits of Herbicide Free Integrated Weed Management (HFIWM) over chemical weeding (non-IWM) in the commercial tea plantations. By providing a wider economic analysis, this study would therefore would be a catalyst in creating a paradigm shift in the mind set of the plantation community, towards HFIWM, from the presently adapted *Clean and Clear Ground weeding (this refers to maintenance of the ground beneath tea cover and other areas in a plantation, exposed and free from plants of any other sort by using any means)* policy whilst attaining improved productivity and profitability levels.

The rest of the paper is organized as follows: Section Two provides the literature review of the study while Section Three presents the method followed. The next sections provide the discussion and findings of the study and the last section concludes.

Literature review

Plantations in the global economy and sustainable development

Historically, plantations were established to supply raw materials to the industrialized nations in 18th and 19th centuries. Some developing countries still follow this practice and, however, increasingly find the system against them (Sivaram, 2000) chiefly due to the persistent low prices in the world market. Plantation companies also undergo pressures imposed by the buyers led with various international food product and process certifying authorities. Among these pressures, the demand to follow sustainable agricultural practices stemming from the notion of sustainable development is important and having a lasting impact on the industry.

Though the roots of sustainability have a long history the contemporary sustainability concept emerged in the 1960s (McKenzie, 2004). The commonly used sustainable development concept was first defined in The United Nations Commission on Environment and Development (UNCED)'s report Our Common Future (1987), which defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (page 07). Since then sustainable development has become a central issue in political and scientific bodies (Lichtfouse et al., 2009) that led to various global movements. Triple bottom line, developed by Elkington (1997), has become commonplace practice of reporting sustainability performance encompassing environmental, social as well as economic concerns.

Sustainable agriculture

With the rise of global population, agriculture has become an industry of importance due to its contribution as a source of livelihood and employment, supply of food and fodder, international trade, economic development, human health and food security (Agriculturegoods, 2013). While making these contributions, agricultural sector itself has attempted to embrace sustainable practices, like any other industry, leading to sustainable agriculture. According to Swanton and Weise (1991), the concept of sustainable agriculture is a philosophical shift due to current unsustainable systems in relatively recent traditional agriculture.

Sustainable agriculture has been defined in numerous ways (Lichtfouse et al., 2009; Francis et al., 1987; Gafsi et al., 2006). As per Francis et al. (1987), sustainable agriculture addresses social concerns and environmental protection. Gafsi et al. (2006), having similar

Faculty of Management Studies and Commerce
University of Sri Jayewardenepura
Gangodawilla, Nugegoda
E-Mail: icbm@sjp.ac.lk
WEB: www.icbmusjp.org, mgt.sjp.ac.lk

views, emphasize that it is the ability of the agricultural systems to maintain crop productivity in the long run by adapting to changes. All these different perspectives on sustainable agriculture focus on the ability to continue over a long period of time whilst maintaining economic, environmental and social considerations (Lichtfouse et al., 2009). More specifically Mary and Gold (1999) define sustainable agriculture as an integrated system of plant and animal production practices having a site-specific application over the long term.

Integrated weed management

Weeds in general terms, could be defined as plants which arise in all types of agriculture other than desired crops. They become problematic only when continue to cause huge economic damage to the farm. Despite the technological advancements, these problematic weeds trigger great financial loss in both developed and developing countries, (Auld, 2004). Therefore, control of major weeds in a plantation is crucial to maintain healthy crop yield. However, when only one or few techniques are used to control weeds over a longer period, there is a chance that weeds get adapted and become tolerant to those techniques (Bhowmic, 1997). Currently, there are growing economic, environmental and social demands to use alternative weed management practices, such as integrated weed management (IWM) (Pannell, 1990; Swanton and Weise 1991; Clements, Weise and Swanton, 1994; Auld, 2004). Integrated Weed Management (IWM) uses a combination of alternative long term weed management strategies such as cultural techniques, genetic characters, mechanical removal, biological agents, and chemical means of weed control etc. So that, whenever the reliance of one technique is reduced, rest of the techniques could be effective for the future use (Swanton and Weise, 1991). IWM will therefore, using a variety of control techniques, keep weeds less capable of being able to adapt to a constantly changing system.

Farmer's / Planter's unfamiliarity or inexperience with a number of the control options, difficulty in predicting long-term of impacts of multiple control options, difficulties in isolating impacts of individual treatments within an integrated strategy, and identifying the most sustainable options due to the availability of many possibilities are some of the salient challenges in IWM (Pannell et al., 2004). Therefore there is a need to evaluate the effectiveness of IWM strategies over long term in the economic, social and environmental dimensions. However, there is dearth of systematic studies that identify the long term effectiveness of practicing IWM strategies in terms of economic, social and environmental dimensions in various contexts.

Method

In order to provide an in-depth understanding of the use of weedicides and their impacts, case study method was selected in this study (Yin, 2009). The company selected for the study is Maskeliya Plantations PLC, a company listed in the Colombo Stock Exchange. Maskeliya Plantations is in the central highlands of the country and lies in the elevation range of 850m to 1,660m. The company comprises of 5 estates each in Upcot and Maskeliya zones, 4 in Talawakelle zone and 4 estates in Uva tea sector in Bandarawela zone. The commercial scale trial in this study was conducted in Hapugastenne Estate (325 ha), in Maskeliya zone in a demarcated area of one hectare in a *Vegetatively Propagated Tea (VPT) (Commercial tea is propagated by plants developed through rooting of tender single noded stem cuttings with a leaf and a lateral bud, and termed VPT)* field aged 35 years from planting, ceasing the usage of weedicides completely for a period of three years from August 2012 to July 2015. A complete clearing of the undergrowth beneath tea bushes was done on entire experimental area simultaneously, following to cyclic pruning of tea bushes in the field. All chemical resistant weeds present too were completely removed from the ground by manual uprooting during this process. Natural Regeneration of Vegetation was allowed to establish as a ground cover over the soil and controlled by means of frequent manual slashing near ground level depending on the growth (Treatment). The tea area adjoining to above said VPT field was declared as the chemically weeded Non-IWM (Control) section, where weed control was exclusively done by using herbicide chemicals. Sporadic spraying of herbicides, namely Diuron, Paraquat and Glyphosate was done in three monthly intervals depending on the types of weeds present and their stage of growth, as per the recommendations set by the Tea Research Institute (TRI) of Sri Lanka (2003). Selective removal of harmful weeds grown (as per Rajkhowa et al., 2005) in the experimental tea area was done, including both HFIWM and non-IWM extents periodically. All other agricultural practices other than the mode of weed control (tested factor) in both treated and control areas were done alike and parallel during the whole period. Observations were recorded there onwards, whilst monitoring the performance and the variations exhibited by the naturally regenerated vegetative ground cover on both experimental areas periodically. Data on tea crop of the experimental area too was randomly taken in the meantime on the harvested green-leaf basis per equivalent square area of tea cover. Data gathered from treated extent and the control area were collected concurrently, just before the spraying of herbicides over the control area, The results obtained from HFIWM extent were compared against the data collected from adjacent control plots of non-IWM tea area in the tea garden.

Discussion

The analysis and the discussion of the study was carried out in two aspects, a) economic benefits to an estate and, b) broader benefits to society. The first aspect, economic benefits to an estate, is discussed under three cost/income categories. The second aspect, broader benefits to society, is discussed in terms of economic, social and environmental perspectives.

Economic benefits to an estate

The economic benefits are the quantifiable monetary benefits for an estate as a result of the HFIWM strategy followed. Although there can be many other monetary and non-monetary benefits to an estate, the study focused on three cost/income categories such as value of compost equivalent biomass, cost of weeding and the impact on profit by variations in tea crop. The following sections describe these three cost/income categories in detail before the total benefit/cost analysis is presented.

a) Biomass generated by understory and the resultant compost equivalent value

Initially, the total green matter (biomass) generated by the undergrowth appeared through *Natural Vegetative Regeneration (NVR)* (*Naturally grown plant cover on a disturbed soil. Generally, the plant composition of these vegetations are largely governed by soil seed bank, previous vegetation and also the vegetation on nearby lands*) in treated and control plots exhibited similar pattern. The compost equivalent of the biomass added to the soil was estimated at 10 % of the fresh biomass weight (see note 2 for more details). The following table shows the biomass, compost equivalent and value of compost equivalent added (refer Table 1). This compost equivalent (i.e. 22, 224 kg over the three year period) is three folds greater than the standard minimum compost requirement of a tea land under local terms.

Faculty of Management Studies and Commerce
University of Sri Jayewardenepura
Gangodawilla, Nugegoda
E-Mail: icbm@sjp.ac.lk
WEB: www.icbmusjp.org, mgt.sjp.ac.lk

Table 1: Biomass generation and benefits of HFIWM section Vs. non-IWM section

Year	HFIWM section			Non-IWM Section		
	Biomass (kg ha^{-1})	Compost equivalent (kg ha^{-1})	Value of compost (Rs.)*	Biomass (kg ha^{-1})	Compost equivalent (kg ha^{-1})	Value of compost (Rs.)*
First	67,750	6,775	125,202	14,390	1,439	26,593
Second	124,470	12,447	230,020	12,760	1,276	23,580
Third	32,210	3,221	54,524	4,230	423	7,817
Total	**224,430**	**22,443**	**409,746**	**31,380**	**3,138**	**57, 990**

* Compost is valued at Rs. 18.48/kg which represents the making and application of compost under present day estate conditions.

Non-IWM section of the experiment delivered 3,138 kg ha^{-1}compost materials to the ecosystem, managing to supply only around 50% of the minimum recommended compost requirement for tea soils. Monetary value of same was Rs.57,990 for the whole period of the investigation which was only 14% of the compost yielded by HFIWM section of the experiment.

b) Weeding cost

The total expenditure on weed management in the HFIWM section was Rs. 128.709 for the period with an average of Rs 42,903 ha^{-1}year^{-1} (refer Table 02). The total weeding cost of non-IWM portion was Rs.224,292 for the period with an average of Rs.74,764 ha^{-1} year^{-1}.

Table 2: Weeding cost of HFIWM section Vs. non-IWM section

Year	HFIWM section	Non-IWM Section
	Cost of weeding (Rs.)*	Cost of weeding (Rs.)*
First	43,463	91.188
Second	51,744	69,504
Third	33,502	63,000
Total	**128,709**	**223,692**

c) Profit generated by tea crop

A gradual drop of about 03% to 05% in tea crop level was noted in the HFIWM area up to about 15th Month, except for drought periods. Interestingly, HFIWM area maintained the crop level during the prolonged rain-free periods which is an indication of better moisture retention ability in the soil. The overall crop improvement compared to control area was in the range of 06% to 08% in the second year with a gradual increase. Non-IWM tea section

Faculty of Management Studies and Commerce
University of Sri Jayewardenepura
Gangodawilla, Nugegoda
E-Mail: ichm@sjp.ac.lk
WEB: www.ichmusjp.org, mgt.sjp.ac.lk

displayed signs of moisture stress under rain free conditions which was followed on by a 20% to 30% decline in the crop availability.

As given in Table 3, when the comparative crop surplus converted into monetary terms it was observed that performance of HFIWM section had even offered marginal benefits in tea crop which clearly shows a positive trend.

Table 3: Tea crop of HFIWM section Vs. non-IWM section

Year	Profit per kg (Rs.)	HFIWM section		Non-IWM Section	
		Crop (kg ha^{-1})	Value (Rs.)	Crop (kg ha^{-1})	Value (Rs.)
First	77.54	1,214	94,124	1,245	96,537
Second	54.33	1,539	83,630	1,466	79,648
Third	33.94	1,733	58,832	1,605	54,474
Total		**4,487**	**236,586**	**4,316**	**230,659**

d) Total benefits/cost analysis

The above three items, weeding cost, biomass generation and profit from crop were compared against HFIWM and non-IWM sections on a yearly basis (refer table 4). It revealed that from the first year onwards there is a net benefit of HFIWM approach. HFIWM offered the plantation a package of overall monetary benefits worth more than Rs.450,000 ha^{-1} over non-IWM section.

Table 4: Total annual benefits/cost analysis of HFIWM section Vs. non-IWM section

		First		Second		Third	
			Savings /(additional cost/loss)		Savings /(additional cost/loss)		Savings /(additional cost/loss)
Cost of weeding	HFIWM	43,463	47,725	51,744	17,760	33,502	29,498
	Non-IWM	91,188		69,504		63,000	
		–					
Bio mass generated	HFIWM	125,202	98,609	230,020	206,440	54,524	46,707
	Non-IWM	26,593		23,580		7,817	
Crop value	HFIWM	94,124	(2,413)	83,630	3,982	58,832	4,358
	Non-IWM	96,537		79,648		54,474	
Total			**143,921**		**228,182**		**80,563**

In addition to these quantifiable benefits to an estate, HFIWM strategy further brings in many additional benefits to the society, some of which are hard to quantify. The next section describes these benefits.

Faculty of Management Studies and Commerce
University of Sri Jayewardenepura
Gangodawilla, Nugegoda
E-Mail: icbm@sjp.ac.lk
WEB: www.icbmusjp.org, mgt.sjp.ac.lk

Broader benefits to society

The broader benefits are quantifiable as well as non-quantifiable benefits for the society (country) as a result of the HFIWM strategy followed. These benefits are discussed in terms of the three perspectives of sustainability namely, economic, social and environmental. The following sections describe these three perspectives in detail.

a) Economic benefits

Benefit to the working community

Earnings of workers are directly related to the crop availability on a tea garden. HFIWM improved the crop availability by 03kg to 04kg per day over non-IWM in 02nd and the 03rd years (refer note 3 for more details). For a regularly working plucker this could increase annual earnings between Rs. 17,250 $year^{-2}$ to Rs.23,000 $year^{-3}$ whilst improving the total family income by multiples of same depending on the number of family members working in the estate.

b) Social and environmental benefits

Improved work place for employees

HFIWM would gradually improve the quality of water flow generated by the water sheds within the estate as herbicide usage is ceased, providing healthy drinking water to the estate community. Further the same would create herbicides free, healthier working environment for all field workers in the estate, whilst ensuring many other indirect benefits to ecosystems as well.

Improved drinking water quality to Colombo and Gampaha districts

None of the water treatment plants in Sri Lanka has the facilities to remove herbicide residues from contaminated river/stream water in the purification process. Therefore, water delivered for drinking and other domestic usage in urban areas through purification plants contain numerous types of toxic chemical residues including herbicide residues. Residents in Colombo and Gampaha districts are greatly dependent on River Kelani for their drinking water and any effort made to minimize contamination of this water has utmost importance.

Positive impacts on bio-diversity

Both land plots were dominated by broad leaved plant species within the first six months pushing the grass species to second place (see note 1 for more details). However, the variety of plant species started to differ within two sections as the time passed. HFIWM area was covered with over 75% of the soil surface with vegetative undergrowth by around six months and reached near 100% in 08 to 09 months after initiation of the study. The degree of ground cover was highly fluctuating in between 10% and 35% in the non-IWM area. Green matter produced by the understory in non-IWM section also remained comparatively at a low stagnant level. Possible variances in diversity of fauna species, fungi and other microbiota and their activity levels were not investigated in this study.

Findings

The above analysis reveals that the main benefit of HFIWM is derived from the cost of compost saved. The HFIWM plot displayed a way ahead performance compared to non-IWM area in terms of green matter and resulted compost yields. Therefore it is obvious that HFIWM has an incomparably greater ability to improve soil conditions which favour plant growth, in this case, commercial tea. Secondly, HFIWM prevents the tea bush from short and long term detrimental effects caused by exposing to spray drifts (Nathanial, 1985). Thus, the HFIWM strategy improves the overall performance of plantations in the long run while enhancing the land productivity and soil environment. These benefits are clearly magnified during drought periods due to the improvement in moisture retention ability in the soil. As Gafsi et al. (2006) suggest, the ability of the agricultural systems to maintain crop productivity in the long run by adapting to changes, is a benefit of sustainable agriculture practices. Yet, analyzing only the crop yield may not sometimes reveal the full benefits of a HFIWM strategy. Therefore there is a need to consider broader factors such as soil environment, weeding cost, etc when evaluating the financial viability of using traditional or innovative weed management practices.

In addition to economic benefits at estate level, HFIWM strategy exhibits many indirect social benefits over chemical weeding in terms of public health, environment and the socio-economic factors. The non-quantifiable benefits of HFIWM such as improvements in drinking water quality are quite important. Most of the plantations house precious sources of water that are supplied to urban areas and any contamination may have long term implications on public health, especially in developing countries. This is mainly because developing countries lack facilities for herbicide purification due to undeveloped of technology. Further, it was revealed that an improvement in tea crop availability could increase a tea plucker's nett earnings substantially and the total family income by multiples of same depending on the number of family members working in an estate. Therefore it is necessary to look at broader social and environmental implications when evaluating the viability of using HFIWM strategies than simply looking at financial viability. In this regard, the triple bottom line approach that highlights economic, social and environmental perspectives (Elkington, 1997) is a more desirable way of analysis. The approach to consider economic, environmental and social demands in using alternative weed management practices has been highlighted way back by Pannell (1990) and Swanton and Weise (1991) and thereafter by Auld (2004) also.

Conclusions

It is well evident that HFIWM is therefore economically, socially and environmentally more desirable as highlighted by Lichtfouse et al. (2009) who discussed the benefits of sustainable agriculture among many others. The study suggests that HFIWM approach could be a sound solution to mitigate many of the constraints faced by the present day commercial plantations industry in Sri Lanka and in developing countries in general. The support and commitment of regulators will be needed to convince the 'hard to tangibalize' benefits to the plantation sector on a systematic basis. Further, gradual improvement in tea crop over time along with quantity and higher quality can certainly support worldwide promotion of Ceylon Tea as the cleanest tea in the planet at a time when the food security is demanded by the developed countries who introduced plantations to the developing nations (Sivaram, 2000).

The benefits and the conclusions highlighted in the study can be restricted due to certain limitations inherent in the study. The unique location, limited time period of three years and many other factors in this case study may make the findings of the study difficult to generalize (Yin, 2009). The authors therefore, attempted to highlight the broad benefits, directions and the trends, rather than being confined to specific measurements in this study. Moreover, in evaluating the cost or benefits the author considered the worst-case scenario. This could therefore offer better benefits in the future if similar studies are replicated. Moreover, these limitations call for future studies under different soil conditions, climate conditions, crop varieties, etc to identify and generalize the findings. Another limitation of the study is the limited number of benefits/costs that were quantified. The authors believe that there can be many other broader items that could have been measured such as bio-diversity, public health, soil environment, etc. Thus the future studies should encompass the involvement of professional of diverse disciplines working together in broader perspectives in the long run to measure direct and indirect costs as suggested by Pannell et al. (2004).

Notes

[1] Ageratum conyzoides (Hulanthalaa), Polygonum nepalense (Kangani Machan Pullu), Crassocephalus crepidioides (Thandam pullu), Hedyotis auricularia (Maha Getakola), Hedyotis neesiana (Heen Getakola), and Commelina benghalensis (Giraapalaa), were the leading plant species observed.

[2] Plant leaf materials consist between 70% to 80% moisture, and dry plant leaf matter to compost conversion ratio is ranging around 50%. Therefore the slashed green matter to compost conversion on dry weight basis was calculated. Compost equivalent of the biomass added to the soil per annum was estimated at 10 % of the fresh biomass weight by weed residual decomposition.

Biomass dry weight basis	=	Biomass wet weight basis – 80% moisture
	=	20% * biomass wet weight basis
Compost out turn	=	50% * dry biomass
Compost volume	=	10% * Biomass wet weight basis

[3] *Benefits to the working community*

Year	Average plucking (kg day-1)	Actual plucking (kg day-1)	Over plucking (kg day-1)	Yearly additional earnings (Rs)*
First	25	24	-1	-5,750
Second	25	28	3	17,250
Third	25	29	4	23,000
Total				**34,500**

* Over plucking quantity was valued at Rs. 23 kg-1 assuming 250 days of average annual working days.

References:

AGRICULTUREGOODS. (2013) The Importance of Agriculture, available online http://agriculturegoods.com/the-importance-of-agriculture/ accessed 06 July, 2015.

AULD, B. A. (2004) The persistence of weeds and their social impact, *International Journal of Social Economics*, 31(9), pp. 879-886.

BHOWMIC, P. C. (1997) Weed Biology: Importance to Weed Management, *Weed Science*, 45, pp. 349-356

CLEMENTS, D. R., WEISE, S. F. and SWANTON, C. J. (1994) Integrated weed management and weed species diversity, *Phytoprotection*, 75(1), p. 1-18.

ELKINGTON, J. (1997) *Cannibals with Forks: The Triple Bottom Line of Twenty-First Century Business*. Oxford: Capstone.

FRANCIS, C.A., SANDER, D. and MARTIN, A. (1987) Search for a sustainable agriculture: reduced inputs and increased profits. *Crops Soils Management*, 39, pp. 12–14.

GAFSI, M., LEGAGNEUX, B., NGUYEN, G. and ROBIN, P. (2006) Toward sustainable farming systems: effectiveness and deficiency of the French procedure of sustainable agriculture. *Agricultural Systems*, 90, pp. 226–242.

LICHTFOUSE, E., NAVARRETE, M., DEBAEKE, P., SOUCHERE, V., ALBEROLA, C., and MENASSIEU, J. (2009) Agronomy for sustainable agriculture. A review. *Agronomy for Sustainable Development*, 29(1), pp.1-6.

MARY, V. and GOLD, M. V. (1999) *Sustainable Agriculture*. Beltsville: National Agricultural Library, U.S. Department of Agriculture.

MCKENZIE, S. (2004, *Social Sustainability: Towards Some Definitions*. Hawke Research Institute, Working Paper Series No 27, Magill: University of South Australia.

NATHANIEL, R. K. (1985) *A Manual on Tea Cultivation*. Sri Lanka: Ministry of Janatha Estate Development Board.

PANNELL, D. J., STEWART, V., BENNETT, A., MONJARDINO, M., SCHMIDT, C. and POWLES, S . B. (2004) RIM: a bioeconomic model for integrated weed management of Lolium rigidum in Western Australia, *Agricultural Systems*, 79, pp. 305–325.

PANNELL, D.J. (1990) Responses to risk in weed control decisions under expected profit maximization. *Journal of Agriculture Economics*, 41, pp. 391-404.

RAJKHOWA, D. J., BARUA, I. C., BHUYAN R. P. and YADURAJU, N. T. (2005) *Weed Management in Tea*. Technical Bulletin, Jabalpur, India: National Research Centre for Weed Science.

SIVARAM, B. (2000) *Plantation Management in the New Millennium*, Sri Lanka: National Institute of Plantation Management.

SRI LANKA CUSTOMS. (2014) *Annual Statistics- 2014*, Sri Lanka: Sri Lanka Customs.

SRI LANKA TEA BOARD (SLTB). (2014) *Tea Market Update*, 10(4), Colombo: SLTB.

SWANTON, C.J. and S.F. WEISE. (1991) Integrated weed management in Ontario: the rationale and approach, *Weed Technology*, 5, pp. 657- 663.

TEA RESEARCH INSTITUTE (TRI). (2003) *Advisory Circular No. WM-01. Integrated Weed Management in Tea*, Sri Lanka: TRI.

UN - WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT, (1987) *Our Common Future: Report of the World Commission on Environment and Development*. Switzerland: WCED.

YIN, R. (2009) *Case Study Research: Design and Methods*, 4th ed., Sage, CA: Thousand Oaks.

Faculty of Management Studies and Commerce
University of Sri Jayewardenepura
Gangodawilla, Nugegoda
E-Mail: icbm@sjp.ac.lk
WEB: www.icbmusjp.org, mgt.sjp.ac.lk