JSTEI ONLINE JOURNAL
Journal of Science, Technology & Environment Informatics
Journal BiNET Scientific Publication

Volume 01, Issue 01, Article No. 3, pp. 27-35 Sultana *et al.*, 2014
http://www.journalbinet.com/current-issue-jstei.html
Case Study Paper

Conventional to Ecological: Tea Plantation Soil Management in Panchagarh District of Bangladesh

Jakia Sultana*, Md. Noor-E-Alam Siddique[1], Md. Kamaruzzaman[2] and Md. Abdul Halim[3]

Organic Agriculture, Wageningen University, the Netherlands
Soil Resource Development Institute (SRDI), Ministry of Agriculture, District Office, Pabna[1]
SRDI, Regional office, Rajshahi[2]
SRDI, District office, Dinajpur, Bangladesh[3]

Article Info

Key Words:

Tea plantation
Organic manure
Integrated soil management
Farm profitability

Received: 15.10.2014
Accepted: 28.10.2014
Published: 22.11.2014

***Contact author:**
sultanajakis30@yahoo.com

ABSTRACT

Many small-scale farms and several tea estates have started tea plantation in the north-eastern parts of Panchagarh District due to favorable soil and climate. But the conventional approach of tea cultivation using agro-chemicals is negatively affecting soil natural fertility; such tea plantation has resulted in significant soil degradation. The productivity has declined and expansion of the industry has threatened by poor conventional management practices. Excessive and unbalanced use of agro-chemicals has led to increase production costs but decline in farm productivity. Thus, there is growing emphasis in the region for ecological and or sustainable approach in tea cultivation to replace the conventional approach. Now soil management in tea gardens by ecological approach is preferred in these areas. Farm scale integrated natural resource management could be a potential solution for tea soil management, while organic sources may reduce the dependency on chemical fertilizers. It is evident from the estimation of fertilizers in this study that chemical fertilizers should be avoided and/or minimized by adoption of integrated natural resource management based on organic sources such as poultry manure, cowdung, farm yard manure and compost. The chemical fertilizer requirements for young tea plants might be avoided by use of poultry manure as they require comparatively low total amount of N and P, while the chemical fertilizer requirements for mature tea can be avoided or minimized by the use of cow dung; almost 50% of N requirement and total amounts of P and K requirements might be possible to meet up. Thus, farm scale resource use efficiency and farm profitability will be sustainable for tea growers in Panchagarh District.

Citation (APA): Sultana, J., Siddique, M. N. A., Kamaruzzaman, M. & Halim, M. A. (2014). Conventional to Ecological: Tea Plantation Soil Management in Panchagarh District of Bangladesh. *Journal of Science, Technology & Environment Informatics, 01(01), 27–37.*

© 2014, Journalbinet. This is an open access article distributed under the terms of the Creative Common Attribution 4.0 International License.

I. Introduction

The north-eastern parts of Panchagarh District in Bangladesh have come under tea (*Camellia sinensis* L.) plantation due to favorable soil and climate. Many small-scale farms and several tea estates have started production of tea. It has created a good avenue of employment for the deprived locals and created an opportunity of increased tea exports. The government of Bangladesh has been providing assistance for enhancing small-scale tea farming. Besides, breakthrough from private tea estates has been occurred in terms of production, processing and marketing of tea commercially from the year 2000. Still several setbacks are to overcome for tea farming which includes lack of capital, technical know-how and perennial water sources. Furthermore, low price is offered for tea leaves in case of small-scale growers and lower market value of made tea but high tariffs on external inputs are hindering the profitability. Another major concern is the significant soil degradation and hence tea productivity declining. The yield of tea is 1,100 kg/ha which is quite low as compared to other tea growing countries. Tea industry is one of the major sources of income. But it is facing a multitude of problems. For successful tea cultivation, setbacks related to soil health, management options, processing and marketing are required to address soon in Bangladesh (Islam, 2005; Ahsan, 2011; BTB 2009; RTRS, 2012).

The conventional approach of tea cultivation based on agro-chemical is causing soil degradation in the Panchagarh district of Bangladesh. The development of land for tea cultivation in the area has resulted in significant soil degradation (Ahsan, 2011); decline in soil organic matter (OM), loss of N and P through erosion and leaching, fixation of P, reduction of soil microorganisms, and acidification associated with nitrogenous fertilizers. The productivity has declined and expansion of the industry has threatened by poor conventional management practices. The traditional cultivation practices, such as excessive cultivation, continue cropping, removal of crop residues and excessive use of chemicals are contributing in land and environmental degradation. The excessive and unbalanced use of agro-chemicals has led to increase production costs but decline in farm productivity. Thus, there is growing emphasis in the region for ecological and/or sustainable (integrated natural resource based farming) approach in tea cultivation to replace the conventional (chemical fertilizer based farming) approach (BTB, 2009; RTRS, 2012). Moreover, tea growers are using chemical fertilizers for higher production of tea but this approach is harmful for the productivity of tea farm. Now sustainability of conventional tea farm production in the region is under threat. Farm yield has declined substantially due to indiscriminate use of agro-chemicals and conventional practices. Thus, sustainable and or ecologically suitable management is highly demanded to sustain tea plantation in the region. However, the key research question of this project is whether integrated natural resource management is a viable alternative for the conventional soil management of tea plantations?

This case study will focus on soil management by integrated approach that will reduce the demand of external fertilizers, increase farm resource utilization and soil fertility restoration. Successful adoption of integrated approach through efficient resource management might have positive impacts on soil health, tea productivity and farm sustainability. Thus, farm economic viability and social impacts will sustain longer. The objectives of this case study were to promote productivity and sustainability of tea plantation soils at farm scale through an integrated natural resource management system, and to estimate fertilizers from organic sources that may reduce the dependency on chemical fertilizers for tea plantation in the Panchagarh district of Bangladesh.

II. Materials and Method

This case study is about integrated soil and plant nutrients management of tea plantation in Panchagarh District of Bangladesh. Information was collected through personal communication, interview with tea growers and publications (annual reports, biennial reports, books, reading materials etc.) of the Bangladesh Tea Board (BTB), Regional Tea Research Station (RTRS), Soil Resource Development Institute (SRDI) and Bangladesh Agriculture Research Council (BARC). Furthermore, it is prepared with the help of information from other secondary sources such as books, reading materials, publications, and articles found in the Wageningen University, the Netherlands library and from other sources, such as information are collected from internet sources. Additionally, relevant subjects, lectures on integrated natural resource management, field tours also remain helpful for understanding and preparing of this case study report. The estimation of fertilizer was calculated based on Fertilizer Recommendation Guide, 2005 of Bangladesh Agriculture Research Council.

III. Results and Discussion

Tea Production

Tea plantation was started with only 300 acres of land in Panchagarh District of Bangladesh but now it is being cultivated on over 2,750 acres of land. It has the potential to expand more areas of about 60,000 acres. Bangladesh Tea Board (BTB) has stated that over 16,000 hectares land is suitable for tea farming there. Currently, tea is being cultivated over 275 small gardens (3-5 acres), 17 medium sized gardens (>5 acres) and 18 big estates (>20 acres) involving over 500 small-scale farmers in the Panchagarh District. Nearly 7,500 skilled and unskilled workers have been working in tea gardens (RTRS, 2012, BTRI, 2010 and BTB, 2009). The production, product values of tea, job created and productivity status have shown in the Table 1.

Table 1. Production and product value of tea estates in the Panchagarh district

Name of Tea Estates	Production per year	Value of product	Job created man days/year	Comment
	Conventional Farm			
Tetulia Tea Company Ltd. (TTCL)	180 ton tea/year	Tk. 63.00 million	371452	Productivity stagnant
Korotoa Tea Farm (KTF)	135 ton tea/year	Tk. 47.25 million	309213	Productivity declining
Kazi & Kazi Tea Estate Ltd (KKTE)	**Organic Farm**			
	250 ton tea/year	Tk. 87.50 million (USD 1.27 million)	683750	Potential is High

(Source: Rahman, 2009 and BBS, 2009)

Soil type and fertilizer requirements

Tea is a perennial evergreen shrub. Tea growing soils are usually acidic in nature. Soil acidity is further aggravated by the extended use of nitrogenous fertilizers (urea and ammonium sulphate) to obtain higher yield. The maintenance of an optimal soil pH (4.5-5.5) is important in tea cultivation (Natesan, 1999). Generally lime and dolomite is applied to soil as an amendment when the p^H is <4.5. Furthermore, tea is a crop that takes up large quantities of $A1^{3+}$, thus it requires an adequate supply of exchangeable Al and Fe (Foy et al., 1978). High mortality and stunted growth of tea plant is caused by high pH and low content of exchangeable AI, Zn and Fe in soils. Adjustment of soil pH and addition of organic matter are the most common methods of decreasing P deficiencies in tea soils; it also improves

soil fertility status (Zhang et al., 1997). Nutrient requirements for commercial tea production are high as the harvestable portions of tea contain the largest percentage of nutrients in the plant. N is the most important nutrient element for tea cultivation because it is required in large quantities. The next important nutrients are K and P respectively for tea plantation (Kamau, 2008; Ranganathan and Natesan, 1985).

Soil fertility status of tea farms

The soil fertility statuses of three tea farms are shown in table 2. The soil fertility status of Tetulia Tea Company Ltd. (TTCL) and Korotoa Tea Farm (KTF) is poor than Kazi and Kazi Tea Estates Ltd. (KKTE) of Panchagarh district in Bangladesh. This might be due to the result of conventional management of TTCL and KTF. Most of tea growing farms are conventionally managed based on agro-chemicals. KKTE is the only organically managed farm in the region, thus the soil fertility status is comparatively better. However, the productivity of KTF is declining rapidly (Table 1). The decrease in crop yield is related to the decrease in soil quality of tea plantation of Korotoa Tea Farm (KTF). The soil fertility status of KTF farm is poor for most of the nutrient elements. This degraded soil has caused the production to be very low, even less than 500 kg/ha (RTRS, 2012). Among different soil and crop management factors, fertilization has substantial effect on the quality of tea farm soil. Thus appropriate fertilizer management for tea plantation is essential in order to increase per hectare yield of tea and to maintain soil productivity (Ahsan, 2011). It is evident from the quantitative soil test data (Table 2) that the overall soil quality is declining with increasing age of the tea plantations in the regions. There are evidences of acidification, decease in soil OM, N, K, S, available P and K contents in the tea farm soils of Panchagarh district (ULSRUG, 2011). The only organically managed farm of the area Kazi and Kazi Tea Estates Ltd. is maintaining profitability and farm productivity through integrated natural resource management and improved technical know-how adaptation. On the other hand, the land degradation is evident in most of the commercial tea farms of the regions which is being indicated by the yield decrease and rise of production cost. Thus, the restoration of natural soil productivity is very crucial. To maintain soil productivity and farm profitability in case of KTF, an ecological approach through integrated natural resource management is highly essential.

Table 2. Mean soil fertility status of TTCL, KTF and KKTE tea farms

Name of Tea Farms	PH	OM (%)	meq/100g			TN (%)	µg/g		
			K	Ca	Mg		P	Zn	S
Conventional Tea Farm									
Tetulia Tea Company Limited(TTCL)	4.6	1.73	0.20	0.71	0.54	0.09	22.8	0.16	8.8
Korotoa Tea Farm (KTF)	4.2	1.59	0.14	0.62	0.32	0.08	21.4	0.14	7.2
*FRG critical soil test level	Strongly acidic	Low	Low	V. Low	V. Low	V. Low	Medium	V. Low	V. Low
Organic Tea Farm									
KKTE	5.1	2.73	0.32	0.83	0.61	0.16	25.3	0.32	13.6
BARC critical soil test level	Strongly acidic	Medium	Optimum	Medium	Low	Low	Optimum	Low	Medium

(Source: ULSRUG, 2011 and RTRS, 2012), *Fertilizer Recommendation Guide-2005

To address soil degradation for Korotoa Tea Farm (KTF), the dependency on chemical fertilizers such as N, P, K for tea plantations need to be reduced as early as possible. This might also increase the profitability of the KTF. A better understanding of how productivity and resource use of tea agro-ecosystems run through years in the farm must be analyzed. At present, KTF depend on conventional management options and the soil fertility status has become lower than required for profitable tea plantation. Due to conventional farming, i. e., agro-chemicals, excessive and continuous cultivation, the soil has become exhausted and mineral supply from soil has declined. Thus, tea plantation growth is

being hampered and hence yield has been reduced substantially. The growth rate of tea plant is also disrupted by imbalance fertilization. The economic optimum rates of fertilizers have been exceeded as confirmed by the Regional Tea Research Station (RTRS) of Panchagarh district. Nitrogenous fertilizer is applied in higher rate in the conventional farms to obtain higher yield. The acidification and nutrient imbalance is triggered by excess N-applications (Bonheure and Willson, 1992). Moreover, the ecological sustainability of tea production is threatened as well. The conventional farms can maintain farm productivity at required level only through utilization of farm natural resources and other management options. Maximization of integrated natural resource use and a defined tea fertilization plan is required for KTF. Farm management should be strategic and tactical to improving profitability of tea farming business. The management options should be economically and ecologically sound as well so that sustainability prevails for tea plantations over the years. The integrated approach of fertilizer application might be a good cost effective low-input system. It is meant to increase the farm resource use efficiency by integrated natural resource management technique. Integrated natural resource management at farm scale could be a sustainable management tool for the conventional farms like KTF and many others of the Panchagarh district in Bangladesh.

Integrated natural resource management (INRM)

Sustainable production integrates the idea of natural resources utilization to generate increased output and income by less or no depletion of the natural resource base. In this context, INRM maintains soils as storehouses of plant nutrients that are essential for plant growth. INRM's goal is to integrate the use of all natural and man-made sources of plant nutrients so that plant productivity increases in an efficient and environmentally suitable manner. This will ensure soil productivity for future generations. Nutrient conservation and uptake of nutrients from the soil is another critical component of INRM. Addition of fertilizer from various organic sources is supposed to prevent the physical loss of soil and nutrients through leaching and erosion, and maintenance of natural soil fertility (Groot, 2003). Green manuring, mulch application, cover crops, intercropping and biological nitrogen fixation might help to improve soil health. Organic manures such as animal and green manures substantially aid in improving soil structure and replenishing secondary nutrients and micronutrients (Peter et al., 2002). Sufficient and balanced application of organic and inorganic fertilizers is a component of INRM.

The following natural, organic and inorganic sources might consider establishing INRM for soil improvement and management in tea farms of Panchagarh district:

Natural resources:

The existing natural resource base (soil, water, rivers, wetland, irrigation, rain etc.) can supply nutrients to tea farm soils.

Organic nutrient sources

- Crop residues (recycling of nutrients, addition of OM to soil etc.)
- Green manures: It will contribute to soil fertility improvement by the following ways:
    a. Nutrient mobilization (take up nutrients and release through decomposition)
    b. N-fixation
    c. Saving nutrients from leaching
    d. Organic material added to soil (incorporation of green manures)
- Organic matter management (Cow dung, Poultry manure, FYM etc.)
- Compost preparation (organic materials, water hyacinth etc.)
- Organic wastes management

Mineral resources

Judicial application of inorganic fertilizer depends on soil test values and fertilizer recommendation. For example, dolomite application when soil acidification becomes a problem and it suppose to increase nutrient availability (Ca and Mg) also.

Organic material sources and their management at farm scale

The major possible sources of organic matter at farm level in Panchagarh District include animal manure (dairy), crop residues (farm other seasonal crops such as rice, wheat, maize, potato etc.), Farmyard wastes (animal dung and urine, feed/fodder refuse, harvested crop residues, poultry excreta etc.), bio slurry from farm biogas plants, green manuring practices and other organic wastes of various kinds such as water hyacinth available in the wet lands of the region (FRG, 2005).

Animal manure: It might include the excreta (dung and urine) from the farm animals and also from the animals of farm cooperative system, even collection of cow dung from individual farmer is also possible. Animal manure should be stored in pits preferably under a roof. The urine of cattle is rich in nitrogen and should be preserved with the dung. The manure in the pit should be kept moist in order to reduce the volatilization of nitrogen in gaseous forms. In the Panchagarh district, poultry industry is extensive and established; thus poultry excreta is cheaply available and in large amounts. Use of poultry manure for tea plantation could be an economic source of fertilizers. The conventional farm management could develop on farm dairy which might be good source of cow dung and FYM. It can also be developed through dairy cooperative by involving the rural people of the area. The only organic tea estates in the region, namely Kazi and Kazi Tea Estates Ltd. (KKTE) has developed a good on farm and cooperative dairy system and engaged the deprived community of the region for their economic benefits.

Crops residues: Leftover parts of various crops after harvest are called crop residues. Crop residues of all kinds including roots, straw & stalks and vegetable tops are valuable as a source of organic matter and plant nutrients. Crop residues can be recycled either by composting or by mulching or by direct incorporation into the soil. Tea is not the only crop grown in the area; other seasonal crop cultivation might good source of income and crop residues such as rice, maize, potato etc.

Compost: The organic fertilizer that is produced by decomposing different waste materials of plant and animal origin is called compost. Ingredients that might be used to make compost in tea farms include cow dung, dead leaves, straw, weeds, water hyacinth, fruit and vegetable parts, sugar mill bagasse, rice husk etc. There is a good source of sugar mill bagasse in the region as few sugar mills are running in Panchagarh district.

Green manure: Green manure adds substantial quantities of organic matter and nitrogen to soils. Any herbaceous plant may be used for green manuring but plants of the family leguminosae are preferred because of the added advantage of getting fixed nitrogen. The common GM plants include Dhaincha *(Sesbania aculeata),* Sunhemp (*Crotalaria juncea*), Cowpea, Grasspea, Soybean, Mungbean, Blackgram etc. A green manure crop may add 10 - 15 ton of biomass (fresh weight) and 60-90 kg of N per hectare to the soil (FRG, 2005; RTRS, 2012).

Estimations of fertilizers from organic sources at farm scale

Tea plantation fertilizer requirement at the young and mature growth stage are shown in appendix 1 and 2. The fertilizer requirement for young and mature tea plantation that might be possible to meet up from various organic resources are estimated in the Table 3 and 4 respectively for the Korotoa Tea Farm (KTF). Thus, additional fertilizer requirement from external source can be determined for KTF.

Table 3. Fertilizer requirements and estimation for Young Tea (first year*) of Korotoa Tea Farm (KTF)

1.Recommended dose** (Kg/ha), Appendix 1	N	P	K
	80	40	80
2. Supply from organic sources 7 ton/ha	**Options*** (Appendix 3)**		
Cow dung (decomposed)	31.5	10.5	35
FYM	21	4.9	17.5
Poultry manure	**80.5**	**73.5**	**49.0**

Compost	17.5	7.0	21
Choice	**Poultry Manure**		
1. To add from chemical fertilizers (1-2)	-0.5	-33.5	+31.0

*the second year fertilizer requirement is about 10% higher.
**the recommendation has been made on the basis of production (about 1000 kg/ha) of made tea yield. The fertilizer requirement is more for higher yield goals.
*** The organic sources need to be defined by the farm authority depending on resources and farm situations.

Table 4. Fertilizer requirements and estimation for Mature Tea* (third year) of Korotoa Tea Farm (KTF)

1. Recommended dose (Kg/ha) Appendix 2	N	P	K
	50	4.5	25
2. Supply from organic sources 5 ton/ha	**Options (Appendix 3)**		
Cow dung (decomposed)	**22.5**	**7.5**	**25**
FYM	15	3.5	12.5
Poultry manure	57.5	52.5	35
Compost	12.5	5.0	25
Choice	**Cow dung**		
3. To add from chemical fertilizers (1-2)	+27.5	-3.0	0

Table 03 and 04 is showing estimated amounts of NPK fertilizers which might be available by the efficient utilization of farm resources. For the computation of contribution from organic materials as fertilizer source the 'Fertilizer Recommendation Guide (FRG)' published by the 'Bangladesh Agriculture Resource Council (BARC)' has been consulted briefly. To meet up the fertilizer demand of tea plantation, a systematic organic manuring schedule is required right from the nursery stage up to maturity. The doses of fertilizers application might vary according to the age of plantation, type of tea, its performance, soil fertility and the yield goals of tea.

Landscape scale of INRM approach

The lands for tea plantations in Panchagarh district were totally fallow over last few decades. Tea plantations are creating green carpet on the vast and fallow sandy areas. Through integrated natural resource management, it is possible to cover the area under green cultivation for tea sustainably. The community people might use natural resources for synergizing various interests and activities in the development of partnerships and actions for social changes. The integration of INRM with other terrestrial ecosystem is important to sustain INRM approach in a landscape. Agricultural practices and farm management also have an impact on different plantation (Groot, 2012). However, a nature friendly and or ecologically viable farming activity might spread out in the region if INRM technique becomes acceptable and sustainable. Thus, community people might be benefitted either working with tea farms directly or by engaging as suppliers by supplying various inputs including organic materials (cow dung, crop residues), sand, top soil for nursery, stone for the construction works, dairy feed, straws, bamboo and other materials for farming activities. The barren landscape might set a good example of socio-economic benefits for local, regional or national levels through the contributions in economic growth, poverty reduction, human development and green farming (Islam, 2012). Socio-economic upliftment and livelihood development is the scope of landscape level by adoption of INRM for tea plantations.

Social impacts of tea farm profitability

Impacts that has been created by tea farming includes social (education, health, food and income security, social services, youth development), economic (community change and livelihood development, community services, employment) and environmental (greening land and environment) dimensions (Islam, 2012). The overall socio-economic condition of common people is changing fast in

Panchagarh district following a faster growth of the tea sector. At the same time, hundreds of Panchagarh district's females, who lived in utter miseries due to abject poverty for years together, are now changing their fate and achieving self-reliance by earning wages as plucking workers in the dozens of tea gardens at the officially recognized third tea zone of the country. The growing tea sector in the Panchagarh district has boosted in a new hope for enhancing the standard of socio-economic life and woman empowerment.

IV. Conclusion

It is evident from the estimation of fertilizers that the requirement of chemical fertilizers might be avoided or minimized by the adoption of INRM based on organic sources of fertilizers and OM management. The chemical fertilizer requirements for young tea might be avoided by the use of poultry manure; the total amount of N and P requirement might be possible to meet up from poultry manure. While the fertilizer requirements for mature tea might be avoided or minimized by the use of cow dung; almost 50% of N requirement and total amounts of P and K requirements might be possible to meet up. These may increase the resource use efficiency and farm profitability. It might be concluded that INRM has the potential to promote productivity and sustainability of soils under tea plantation, and organic sources are meant to reduce chemical fertilizer requirements substantially for tea plantation in the Panchagarh district of Bangladesh.

Acknowledgement

This case study was conducted for the partial fulfillment of Master of Organic Agriculture, Wageningen University, Wageningen, the Netherlands. The author acknowledges support, suggestion and cooperation from the staffs of Wageningen University.

V. Reference

Ahsan, Q. (2011). Maximizing yield of tea in some selected problematic acidic soils through improved management practices. Bangladesh Tea Research Institute (BTRI), Bulletin No. 17, 2011, Center for Agri-Research and Sustainable Environment and Entrepreneurship Development (CASEED), Dhanmondi, Dhaka.

BBS (2009). Statistical year book of Bangladesh. Bangladesh Bureau of Statistics.

Bonheure, D., Willson, K.C., 1992. Mineral nutrition and fertilizers. In: Willson, K.C., Clifford, M.N. (Eds.), Tea: Cultivation to consumption. Chapman and Hall, London, pp. 269-329.

BTB, (2009). Annual Report-2009. (http://www.teaboard.gov.bd/index.php?option=historyteaarea)

BTRI, (2010). Biennial Report. Bangladesh Tea Research Institute, Government of people's republic of Bangladesh, pp. 94-98, Srimangal, Moulvibazar, Bangladesh.

Foy, C. D., Chaney R. L. and White M.C. (1978). The physiology of metal toxicity in plants. *Ann. Rev. Plant Physiol.* 29: 511-526.

FRG, (2005). Fertilizer Recommendation Guide, Bangladesh Agriculture Research Council (BARC), Dhaka. (www.barc.gov.bd)

Groot, J. C. J. (2003). Exploring the potential for improved internal nutrient cycling in dairy farming systems, using an eco-mathematical model. *NJAS*, pp. 165-194.

Groot, J., (2012). Lecture on Organic agriculture, biodiversity & environmental services at the farm and landscape scales. Wageningen University, Netherlands.

Islam G. M. R. (2005). Present status and future needs of tea industry in Bangladesh. Pakistan Acad. Sci. 42(4) : 305-314.6. ITC. (2001). International tea committee report.

Islam M. S., (2012). Measuring Impact of Kazi & Kazi Tea Estate Limited, Panchagarh-An Organic Garden in Bangladesh. *IOSR Journal of Business and Management* (IOSRJBM), ISSN: 2278-487X Volume 3, Issue 3 (Sep-Oct. 2012), pp 01-09. (www.iosrjournals.org)

Kamau, D. M. (2008). Productivity and resource use in ageing tea plantations. PhD thesis, Wageningen University, Wageningen, The Netherlands.

Peter G. Francesco G. and Montague Y. (2002). Integrated nutrient management, soil Fertility and sustainable agriculture: current issues and future challenges. Food, Agriculture, and the Environment Discussion Paper 32. International Food Policy Research Institute, 2033 K Street, N.W. Washington, D.C. 20006 U.S.A.

Natesan, S. (1999). Tea Soils. In: *Global advances in tea science* (Ed N. K. Jain), pp 519-532 (Aravali Books International Pty Ltd, New Delhi).

Rahman, M. M. (2009). Green job assessment in agriculture and forestry sector of Bangladesh. Final report of International Labour Organization, Dhaka 1209, Bangladesh. International Labour Organization. (www.ilo.org/publns)

Ranganathan, V. and Natesan. S. (1985). Potassium nutrition of tea. In: Munson R.D. (ed). Potassium in Agriculture. *ASA-CSSA-SSSA*, USA. Pp. 981-1015.

RTRS, 2012. Regional Tea Research Station, Annual Report, 2011, Panchagarh. Pages – 7 to 19.

ULSRUG, (2011). Upazila Land and Soil Resource Utilization Guide, Tetulia, Food Security Programme, 2006, Soil Resource Development Institute, Ministry of Agricultrure, Bangladesh. (www.fssfc.gov.bd, www.srdi.gov.bd)

Zhang, Y. L., Luo, S. H., Zeng Y. H. and Pengo P. Y. (1997). Study nutrient scale of sufficiency or deficiency in tea soils in Hunan province and fertilizing recommendation. *J. of Tea Soil* 17 (2): 161-170.

VI. Appendices

Appendix 1. Fertilizer recommendations of tea at young stage

Age of tea plants (year)	Fertilizer Recommendation (kg/ha)		
	N	P	K
1st	80	40	80
2nd	90	45	90
3rd	120	40	80
4th	135	45	90

Appendix 2. Fertilizer recommendations of tea at mature stage of growth

Yield (kg/ha)	Fertilizer Recommendation (kg/ha)			
	N	P	K	Zn
Up to 1000	50	4.5	25	-
1001-2000	51-1000	4.6-9.0	26-50	3.6
2001-3000	101-160	9.1-13.5	51-75	3.7-5.4

Appendix 3. Possible sources of organic materials with amount of nutrients

Organic Materials	**Nutrient supply (kg) from 1 ton organic material**		
	N	P	K
Cowdung (decomposed)	4.5	1.5	5.0
Farmyard Manure	3.0	0.7	2.5
Poultry Manure	11.5	10.5	7.0
Compost (rural)	2.5	1.0	3.0

(Source: FRG, 2005; RTRS, 2012)

Citation for this article (APA Style):

Sultana, J., Siddique, M. N. A., Kamaruzzaman, M. & Halim, M. A. (2014). Conventional to Ecological: Tea Plantation Soil Management in Panchagarh District of Bangladesh. *Journal of Science, Technology & Environment Informatics, 01(01), 27–35*.

Retrieved October 30, 2014, from http://www.journalbinet.com/current-issue-jstei.html