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Impact of Floods on Productivity in Tea Smallholdings: A Case Study on Lands affected by 2017 Floods in Kaluganga River Basin in Ratnapura District of Sri Lanka

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ABSTRACT

In Sri Lanka, flood incidences have frequently been experienced in low country districts and tea smallholdings in low-lying areas are affected often. A plant may undergo stress situations due to inhibition of metabolic activities as a result of submergence.

This work aims to study the effects of flood on productivity related attributes of tea in smallholding sector, based on the flood incident occurred in 2017 in Ratnapura district. Using the baseline data collected by the Tea Small Holding Development Authority, this study was conducted in seven Tea Inspector (TI) ranges in Ratnapura district. Data were collected using a structured questionnaire from a sample of 98 smallholdings selected on the stratified and random manner and analyzed using descriptive and spearmen correlation tests.

The most of the affected land were located very close to Kaluganga or its tributaries and most of them were completely submerged. Almost half the affected tea holdings have been submerged more than five days period. The silt that was deposited on the foliage was mostly, remained 2– 4 weeks period. Tea bushes showed multiple responses to the stress situation (defoliation, wilting and rotting). More than 20% foliage was fallen in 40% of the flooded tea lands while, 20% of the flooded land shown the defoliation of more than 50%. Defoliation is negatively correlated with age of tea. More than 20% casualties were reported in 40% of the affected holdings and which is negatively correlate with age. This study recognizes the ability of TRI 2023 which can withstand in flood hazards. Majority of the affected holdings have shown the very slow recovery even after 6 months. It was estimated that tea yield of affected holdings has dropped by 65% when compare with the previous yield in the study area and has a correlation with flooding duration.

Keywords: *casualties, defoliation, flooding, low-lying areas, productivity, tea smallholdings*

INTRODUCTION

Flood, cyclone and drought are the commonly occurring natural disasters in Sri Lanka. Out of these naturally occurring disasters, flooding is considered as the major calamities which affect the plant growth in an agricultural system (Voesenka *et al.*, 2016). It has been observed that incidences of flooding have increasingly been occurring since resent past in the world wide (Arnell, 2001). Intergovernmental Panel for Climate Change too has warned that there is a great possibility of occurring the extreme rainfalls as a consequence of man-induced climate change (Nathaniel *et al.*, 2013). Sri Lankan tea industry has also been identified as a vulnerable agriculture based industry for the climate change (Wijerathna, 1996). In Sri Lanka, flood incidences have frequently been experienced in various parts of the country particularly areas comes under districts of Ratnapura, Kalutara, Galle, Matara and Kegalle (Hettiarachchi, 2003; 2016; 2017; and Samarathunga, 2017). About 80% of the tea smallholdings are located in these districts (Anon., 2005). As a result of inundation, substantial amount of tea smallholding lands which are in low lying areas of these districts are affected often.

Flooding can be described as a situation, that there is a water layer above the soil surface as a result of spilling out of water from reservoirs or streams. As far as the crop husbandry is concerned, flooding situation can be categorized in to three categories as water logging, partial submergence and complete submergence (Striker, 2012). Water logging refers as full saturation of soil pores with water and there may or may not be a very thin layer of water above the soil surface. Only the root system is under anaerobic condition, in the water logging condition. In the scenario of partial submergence, entire root system is immersed in water and part of shoot is covered by water. The entire plant is under water, in the situation of complete submergence. In addition to root system, full or fraction of the above ground part of a plant is under anaerobic condition depending on the situation of complete submergence or partial submergence respectively. A plant may undergo series of stress situations as a result of submergence. According to Striker (2012), the effect of stress is depend on various factors such as; nature of the flooding situation (partial or complete submergence), duration of flooding (No. of days submerged), age of the plant subjected to flooding, vigor of the plant subjected to flooding, turbidity of flooding water and rapid changing scenario of the environment (Submergence and De-submergence) (Striker, 2012).

Oxygen available in the soil pores are utilized by the roots for its respiration. When submergence takes places, all the soil pores are saturated with water and root respiration get inhibited and subsequently most metabolic activities get affected, due to saturation of soil pores with water. When the flood level increases or partial submergence turn into complete submergence, photosynthesis can also be disturbed due to depletion of sunlight as a result of cloudiness, water level and turbidity of water. Inhibition of photosynthesis is occurred not only due to depletion of sunlight but also due to dearth of CO_2, in the surrounding environment. In addition to the effect of floods on these two major physiological processes, following events or disorders too will cause further stress to the crop (Striker, 2012; Pucciariella *et al.*, 2012). They are, drop in evapotranspiration rate and there by reduction of nutrient absorption and translocation, producing the potentially toxic compounds such as sulfides, Fe and Mn, lactic, acetic and formic acids *etc*., as a result of reduction of redox potential of soil, accumulation of toxic compound due to anaerobic metabolism, depletion of food reserves and breakdown of chlorophyll.

Some of the plant physiologists (Naidoo, 1983 and Striker, 2012) described that stress condition can also be occurred due to the rapid changing scenario of the environment - when submergence turn into de-submergence state. Some of these incidences which can cause the stress condition are; sudden exposure to the sunlight, leaching out of soil nutrients, desiccation of leaf due to reduction of hydraulic conductivity of the tissues of the plant and high risk of spreading secondary infections. It is noteworthy that, the desiccation of leaf can also be taken place, besides the excessive moisture level in the soil. Number of days under submergence (flooding duration) has been identified as a major factor in determining plant survival (Tamanq, 2015). Death of feeder roots, deficiency symptoms, accumulation of toxic compounds, and finally even larger number of casualties are the possible consequences of long-term flooding.

Nevertheless, lowland plants show certain adaptation to overcome the flooding stress especially, as and when they were exposed to long-term and partial submergence. Certain anatomical and morphological changes can be occurred in the roots as well as shoots of a plant such as forming of Aranchima, adventitious roots, Pneumatophores, Lenticels, shoot elongation and changing the leaf angle (Striker, 2012; Parent *et al.* 2008). However, no significant research attempts have been made, with respect to tea on the effect of flooding and thus, the adaptation measures developed in tea bushes have not been identified, except the appearance of the formation of lenticels under the ill drain or waterlogging condition. Yet, De Silva (1967) has noted some characteristics features of tea bushes grown in clayey or ill drain soil, where the soil environment is more or less similar to water logging situation. De Silva (1967) had made certain observations in such tea bushes as a result of the asphyxiation of the root system. Some of them are weak feeder root system, surface rooting, thin layer of maintenance foliage, banji formation, yellowing of flush and eventually, leading to death of tea bushes after pruning due to loss of vigor. Meanwhile, Amarathunga (2002; 2004) also recoded similar kind of observation in tea planted in low-lying lands. Although Wijerathna (1994) and Eden (1941) reported that feeder roots of tea bushes are penetrating into relatively, the deeper soil layers, entire root system of tea bushes grown in low-lying land was found to be confined to shallow layers mostly referred to as surface rooting.

It is important to study the behavior of tea plant under the partial or complete submerge conditions, since there are no adequate studies have been carried out so far to observe the expressions and to understand the recovering ability of tea under such situations. Therefore, a study was conducted to find out the effects of flood on tea bushes, based on the observations made during the flood incidence in May 2017, in Ratnapura district. The specific objectives of this study were: (1) To understand the distinctive attribute associated with flooding condition occurred in small tea lands during May 2017, (2) To study the responses shown by the tea bushes in the event of flooding to combat the stress condition and (3) To estimate the effects on tea productivity and its attributes (related to the tea yield) due to flooding stress.

MATERIALS AND METHODS

Tea Smallholding Development Authority (TSHDA) conducted a census among the smallholders in the low lying areas in four districts to identify the affected smallholders by the disaster condition (both flood and landslides) taken place on 25th May 2017 on the request of the Ministry of Plantation Industries with a view to disburse the compensations. Table 1 shows the data on affected tea lands in respective districts. For this study data relevant to the Ratnapura district were used as a sampling frame. According to the above census carried out by TSHDA, a severe flood damages were occurred in seven TI ranges; namely, Kiriella, Ratnapura, Ayagama, Kuruwita, Eheliyagoda, Kahawatta and Weddagala which are located in the river basins of Kaluganga and its tributaries. A sample of 98 smallholdings were drawn by employing proportionate and random sampling technique from the said sampling frame with respect to the above TI ranges (Proportionate to the affected population of each TI range). A structured questionnaire was prepared to obtain quantitative and qualitative data on different variables such as, land and tea cultivation (location of land in relation to stream, age of tea, cultivar type, initial yield, bush stand and extent of tea lands), flooding (type and duration of floods), effect on tea (deposition of silt, defoliation, number of casualties), yield and performance of tea in post flooding period (tea yield after 2 months and 6 months of flooding, time taken for recovery and qualitative data on pest and diseases). Two methods were followed to collect the data. Basic data were collected through a telephone survey and the information collected through the survey were verified by visual observations and face to face discussions by visiting the fields. The collected data were analyzed by using descriptive statistics and non-parametric statistical methods with the help of SPSS software.

Table 1. Damages encountered in Small holdings on regional basis

District	Complete damages		Partial damages	
	No. of holdings	Extent of lands (ha)	No. of holdings	Extent of Land (ha)
Galle	1887	133.0	3819	523.1
Matara	803	44.4	2730	406.0
Kalutara	730	58.0	1155	294.0
Ratnapura	618	84.6	1277	248.2

Source: TSHDA regional offices, 2017

RESULTS AND DISCUSSION

The nature of flood and tea lands

Positioning of affected smallholdings in relation to the river or streams

This study revealed that most of the flood affected lands due to flood were situated within 100 m of radius from the Kaluganga or its tributaries (Figure 1) and in most cases the entire tea lands (Figure 2) of the respective smallholders have been affected. Moreover, in most cases the flood level has been above the tea bushes and therefore, it can be considered as a completely submerged situation. These observations revealed that, most of these lands are located in the areas declared as reservations for water streams (Figure 3) and thus these tea cultivations can be considered as a misuse of lands as per the guideline set by Department of Land Use Policy Planning of SriLanka, (http//www.luppd.gov.lk).

Flooding duration

The flooding duration is the most important factor which determines the survival ability of tea bushes after flooding. The flooding duration or number of days under submergence is given in the Figure 4. It is evident that 49% of the tea holdings had been submerged for more than 5 days period which is possibly the main factor for the irreparable damage for tea bushes depending on the influence of the other factors such as age of tea, vigor of the bush, cultivar and stage of the pruning cycle (whether in recovering stage of pruning). In addition to this, 30% of the tea lands had been under flood for a period of 2-4 days which too can cause temporary setback such as defoliation, loss of feeder roots and eventually, drop of yield. Furthermore, it is also possible that, initiation or further enhancing of fungal diseases such as Horse hair blight (Dassanayake, 2007) and Wood-rot as a -term effect.

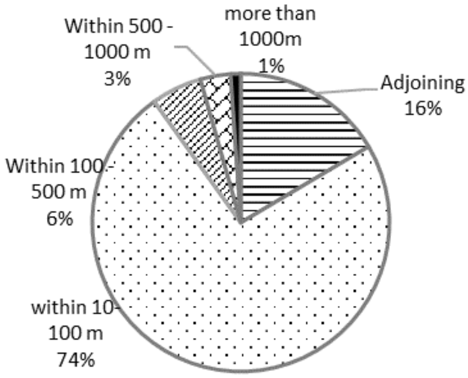

Figure 1. Location of affected holdings with respect to the water stream

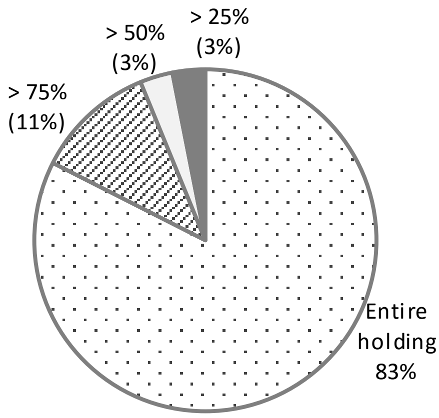

Figure 2. Fraction of the tea land affected by flood

Figure. 3. Tea land bordering the River

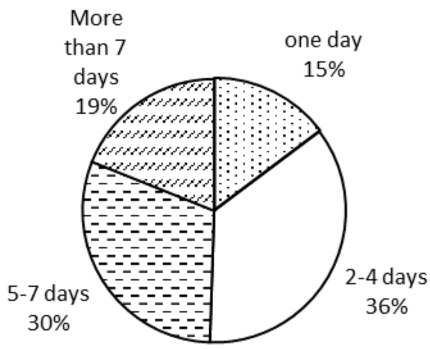

Figure 4. Duration of flooding in affected tea fields

Effect of flood on tea bushes

Deposition of silt on tea bushes

After the water level subsided, silt had been appeared on the foliage, bush frame, collar area and the surface of the land (Figure 5). This was due to turbidity of flooded water. It was observed that, the silt deposited on tea bushes remained for a certain period of time until few showers are continued.

In most of the cases, the silt remained for more than 2 weeks on the foliage of tea bushes. It is also noted that silt remained for more than one month in considerable number of tea lands (19%). This may contributed not only to inhibit the photosynthesis, but also to induce certain conditions such as rotting of tender shoots, defoliation and fungal infestations. However, very few growers have somehow managed to washout the debris on the foliage. This is the reason for the presence of debris only for less than 1 week on tea bushes of nearly 4% of tea lands. During the de-submergence time, rains have been ceased and the deposited silt on foliage have dried-up making it difficult wash away by the subsequent showers. This could be the reason for the muddy silt appearance on the foliage of tea bushes in considerable number of tea lands.

Figure. 5. Silt deposited on tea bushes

Defoliation in tea bushes

The defoliation is one of the earliest and a major response that has a greater influence on bush survival shown by the tea bushes as a result of floods (Figure 6). According to Figure 6, more than 20% of the defoliation of tea bushes occurred in almost 40% of the flooded tea lands. On the other hand, 20% of the flooded lands showed a defoliation of more than 50% (Figure 7).

Figure. 6. A severally defoliated tea land

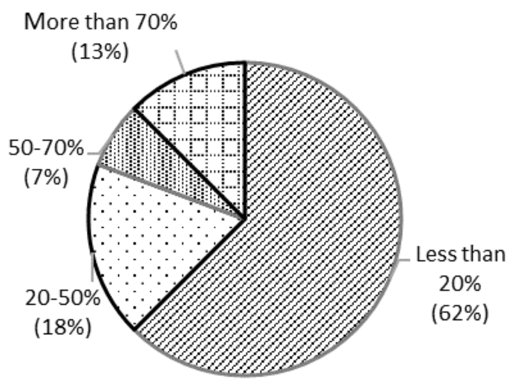

Figure 7. Percentage of tea bushes which expressed defoliation

It was revealed that there is a negative correlation between defoliation and age of tea (Spearman's rho –0.304, $p<0.05$). The younger tea bushes (Age < 4years) are more sensitive than older plants for the flooding stress, possibly due to inadequate development of the root system.

Other immediate consequences on tea bushes due to floods

In addition to defoliation, wilting and rotting of foliage has also been observed when water level was subsided. Generally, many of these symptoms could be seen simultaneously in tea bushes (Table 2).

Table 2. Different type of immediate consequences observed on tea bushes

Consequences observed	**Fields reported (%)**
Rotting of leaves	3
Defoliation of mature foliage	24
Rotting and wilting of leaves	4
Defoliation of mature foliage and wilting of leaves	4
Rotting of leaves and defoliation of mature foliage	28
Defoliation of mature foliage, rotting and wilting of leaves	37

Flooding condition created a physiological stress to the tea plants. As given in Table 2, the tea bushes have reacted with multiple symptoms, in response to the flooding stress. Out of these, defoliation can be considered as the commonly occurring reaction to a flooding stress, appearing in tea bushes.

Casualties in tea lands

Certain tea plants fail to survive after combating against the stress caused by flood due to loss of vigor. Degree of casualties in tea lands, investigated in the study is given in Figure 8.

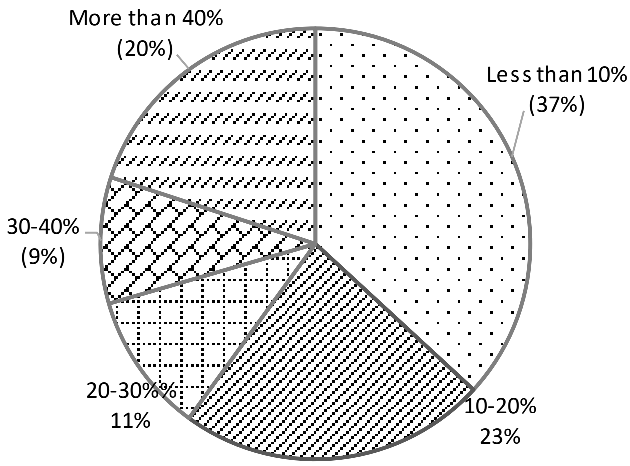

Figure 8. Casualty percentage observed in affected tea land

Accordingly, more than 20% casualty incidence have been reported in 40% of the affected lands, of which half of the tea lands had lost more than 40% of the tea bushes. Spearman correlation test was done to see the correlation between casualty percentage and age of tea and it was revealed that negative correlation between casualty and age of tea (Spearman's rho – 0.524, $p<0.05$). The highest number of casualties were observed in new and young clearing which are less than 4 years old, possibly due to the same reason mentioned above.

The highest number of casualties were observed in new and young clearings which are less than four years old possibly due to the same reason cited in the above. Also, the plants which have less vigor due to accumulation of pest and diseases over the past period were highly vulnerable for dying. Moreover, the affected tea lands mostly planted with TRI 2026 cultivar and thus variances in resistance with respect to casualty among the cultivar can't be clearly seen. Yet, wherever TRI 2023 was there, it appeared to be escaped from flooding stress (Figure 9). This finding is in line with the observations made by Amarathunga (2002), under the similar situation.

Figure 9. Survival ability of TRI 2026 *vs.* TRI 2023

Recovering ability of tea

After defoliation, the affected tea bushes recover slowly as shown in the Figure 10.

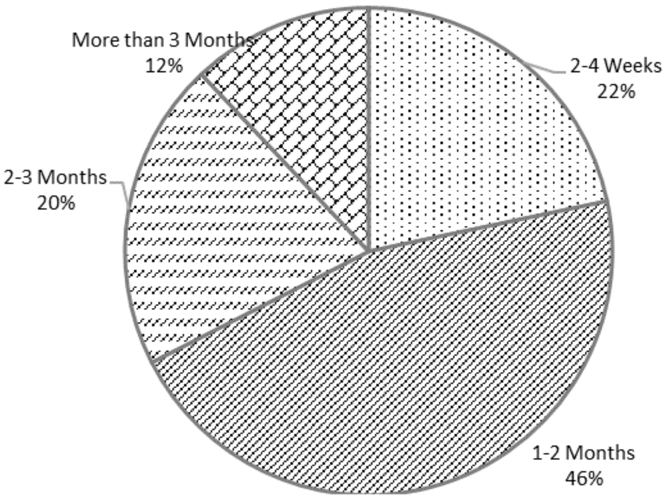

Figure 10. No of days taken for re-foliation after de-submergence

Re-foliation ability after de-submergence

Although 20% of the affected holdings had taken less than a month period to initiate the new generation of shoots, 80% of the affected holdings had taken more than a month period to initiate the re-foliation. This has indicated the level of stress occurred on the tea as a result of flood. It is noteworthy, that about 30 % of the affected holding had been taken more than 2 months period to initiate the shoots on the maintenance foliage, those tea bushes would have severely defoliated due to longer duration of submergence.

Extent of recovery after 6 months of de-submergence

Recovering ability of the flood affected tea bushes was assessed after 6 months period and results are illustrated in the Figure 11. It revealed that, just only 37% of the affected bushes achieved at least 50% recovery status while half of the affected bushes haven't achieved at least one third of recovery when compare with the original status, even after the 6 months from the flood. Several farmers have reported that the bushes which had been partially recovered few months after the flood, have been turned back to the direction of death again. When closer inspection, the researchers found that those are the bushes which had been infected with sever Canker, Wood-rot and Horse Hair blight, before. Therefore, it can be assumed that the plant would have lost their immunity due to flooding stress or certain weak parasite which have become more virulent due to environmental change, have infected the bushes, subsequently. (Arulpragasam *et al.,*1983) Dassanayake *et al.,* (2007)

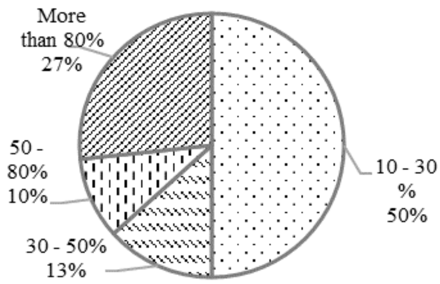

Figure 11. Percentage (%) of Tea bushes recovered after 6 months of flooding

Effect on yield

The production is the ultimate parameter which could reflect all these consequences which have been discussed in the above. Thus, the behavior of the tea production has been considered as an important factor in the present study. The yield of tea lands just after 2 months and after 6 months from flooding were compared with the pre-flooding average yield and shown in the Figure 12. It revealed that there is remarkable drop in yield at both occasions considered after flooding.

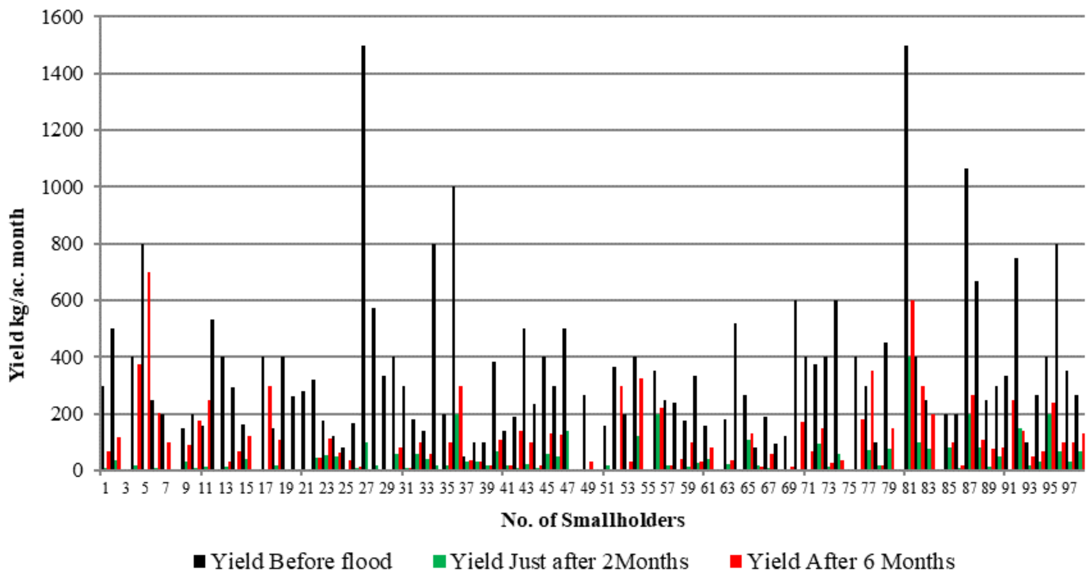

Figure 12. Variation of Average tea yield in pre-flooding and post-flooding period

It is noteworthy, that significant reduction of yield even after 6 months from flooding, even though the environmental situation has been completely settled in favor of tea cultivation. It was estimated that the mean yield drop of the flood affected tea land was 65 % with a 30% standard deviation. This yield reduction can be attributed to dying of feeder roots, Defoliation and weaken the bush vigor due to fungal infestations (De Silva, 2005). It was found that there is correlation between flooding duration and percentage of yield reduction (Spearman's rho 0.394, $p<0.05$).

Further, this yield reduction is seen in all the TI ranges under review. Moreover, this yield reduction observed in the flood affected tea land has too been reflected in the national level statistics as shown in the Figure 13. It describes the tea production data in the period of June to September in 2014-2017 in the Low Country. A massive drop in yield in 2016 is due to the severe drought that was experienced. Moreover, there was a drop in yield of 7%, in 2017, when compared to yields of 2014.

In addition to the impact of flood, two major policy-level changes that can affect the tea smallholders were also observed; *viz.* fertilizer subsidy scheme, banning of Glyphosate with respect to the period under review. Although, it is not possible to exactly figure out what factor has contributed more towards the particular difference, the impact of the flood on low country yield cannot be totally ignored.

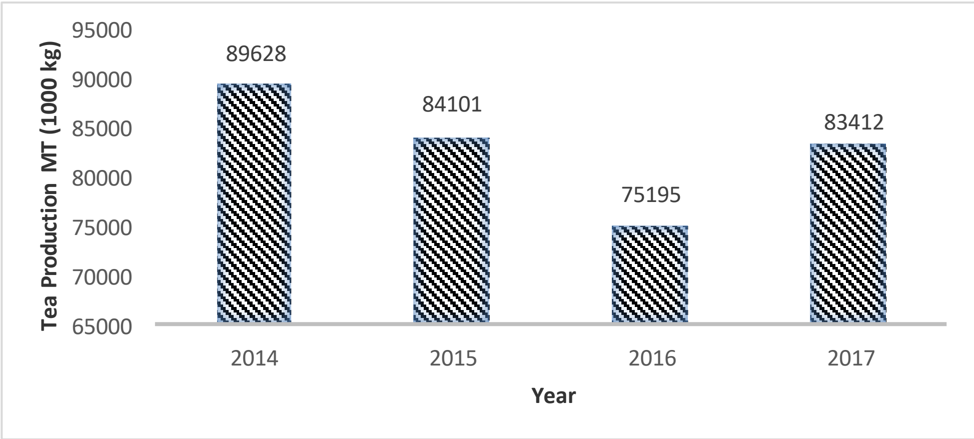

Figure 13. Low country tea production in post flooding period (June – September) Source: Sri Lanka Tea Board

CONCLUSIONS

Tea smallholdings situated in the low-lying area and closer to the river basin can seriously be affected due to flood. Due to the flooding stress, defoliation, setting back of growth and even casualties and can be occurred depending on the flooding duration, age, cultivar and the vigor of the tea bushes. If tea plantation submerge for the period more than 5 days would cause serious impact in terms of causalities and production. Immature tea has exhibited the highest sensitivity for the flooding stress. Once the growth is set back, it would take longer period to recover and which leads to substantial drop of yield even up to 65%. Therefore, it is important to implement the certain remedial measures to manage the flood affected tea bushes for their quick recovery.

Recommended action for managing flood affected tea lands

Based on the findings of this study, certain short term (immediate) and medium term cultural and non-cultural practices can be recommended.

Short term measures

1) Cleaning the debris and silt deposited on the foliage and the frames with the water wherever possible.
2) Condition of the drainage structures in the tea lands (lateral and leader drains) should be systematized to drain out the excess water in the soil.
3) Debris and waste material accumulated in the collar region should be removed to enhance the aeration.
4) Gradually improve the level of sunlight (Light intensity) receives on the land by gradual lopping of medium shades and thinning out of high shades.
5) If any partially fallen tea bushes found, they can be erected by providing necessary supports.
6) Shoot initiation become ceased in the affected field for a certain period depending on the various factors. However, it is necessary to give a desirable resting period for tea bushes until they assure their own survival. Suggested resting periods are as follows.
   a) 3-4 weeks resting period for tea bushes submerged for less than 2 days

b) 4-8 weeks resting period for tea bushes submerged for 3-5 Days
c) 8-12 weeks resting period for tea bushes submerged for more than 5 days

7) Light plucking should be practiced for at least 3-4 rounds even after the resting period.
8) A recommended systemic fungicide could be applied for those tea land submerged for more than 3days to prevent the secondary fungal infestation.

Medium term measures

1) 15% Brunolium solution or Kandasan can be applied on the stem, if any physical damage was observed.
2) Light skiffing can be done, if the sever rotting or die back was commenced.
3) Light forking in alternative tea rows, will help to improve the drainage and enhance the aeration in the root zone. However, this practice should be done with maximum care to avoid further damages to the roots.
4) Application of 10-20% lime solution may be help to prevent spreading of Horse Hair Blight and some other secondary parasites.
5) Application of fertilizer should be suspended until the re-growth is initiated.
6) Neither any recommended foliar application (Zinc/Urea/Epsom salt) nor any other liquid form of application should be done.
7) If the field is due for pruning in the current season, pruning should be postponed by 6 - 12 months period.

Management implications

Flood damage makes losses to the national economy in both way- disrupting the production and for compensating the affected farmers. Therefore, it is important to have in-depth dialogue among the Researches, Extension Workers and Policy makers in related to the following aspects.

- Adoption of proper land use pattern

Tea cultivation in the considerable portion of the affected lands has been done in the river reservation and some of them found to be not suitable for tea cultivation. Compensating for such cases would lead to tax the entire people in the country. Thus proper land use policy should strictly be implemented.

- Introduction of an insurance scheme

When compensating the affected growers, it would be best to introduce an insurance scheme, rather than putting the burden to the entire population. This scheme, can be worked out, based on the risk factor associated with the related belt. For that proper study should be done to identify the factors to be considered and willingness of the smallholders to be adhered.

- Developing a technology for low-lying tea growers.

It was observed that the quite a large number of farmers in low lying area, (away from the river reservation) have been cultivating tea. (May be not only in the studied area but also in the elsewhere). Their contribution to the national economy is substantial. However, their socio-economic perspective has not been adequately taken into consideration when giving the general recommendation and thus, their farming practices are mostly not complied with the TRI recommendations. During the survey, it was observed that they haven't been receiving proper extension services from any extension agencies thus whose farming practices are less accordance with scientific principles due to insufficient knowledge. Characteristics features, limitations and potential of their land and significance of this group of farmers should be studied and special package of solutions which may consist of farming methods, suitable cultivar, and method of land preparation and specific level of inputs should be given.

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