

## Implications of Post-Harvest Losses and Acreage Response of Selected Up-Country Vegetables from Nuwara-Eliya District in Sri Lanka on Sustained Food Security

N.R.D.S. Dharmathilake<sup>1</sup>, H.S.R. Rosairo<sup>2\*</sup>, V.D.N. Ayoni<sup>3</sup> and R.M. Herath<sup>4</sup>

Received: 16<sup>th</sup> June 2019 / Accepted: 8<sup>th</sup> July 2019

### ABSTRACT

**Purpose:** Up-country vegetable sector is sensitive in achieving food security as a prominent sub sector within the Sri Lankan agriculture. But a high post-harvest loss (PHLs) along traditional supply chains and competitiveness of alternative crops are a couple of great challenges on availability of these vegetables. This study estimated PHLs of carrots, cabbage and leeks along the most prominent supply chain from Nuwara-Eliya to Dambulla Dedicated Economic Center followed by an acreage response analysis which has a timely importance.

**Research Method:** The most prominent supply chain in Nuwara-Eliya district which has track record on highest production of up-country vegetables was identified by a pilot test. Multi stage purposive sampling technique was used to track key players and data on estimated PHLs were collected through questionnaire surveys. Acreage response analysis was done by secondary data with the application of Nerlovian expectation model.

**Findings:** Incidence of PHLs of leeks was the highest (44%) and major contributing causes were trimming of lengthier but fresh leaves while bundling followed by mechanical damages. Incidence of PHLs of cabbage was 43% and mainly it was due to trimming of outer leaves. PHLs of carrots (30%) were mainly due to rots and mechanical damages. Acreage response analysis revealed that farmers were responsive to yester year prices of vegetables and potato; an alternative crop. Unit increase of vegetable price can increase the acreage of up-country vegetable by 0.21 hectares while unit increase of potato price can reduce acreage of up-country vegetables by 0.26 hectares.

**Research Limitations:** This study was constrained a little bit by lack of time and logistical limitations.

**Originality/value:** Relationships established between the scale of farming operation and the PHLs was a novel finding of this study. PHLs of upcountry vegetables along their common supply chain were also quantified. Policy formulations must be mainly focused on price controlling of vegetable crops to minimize the relative fluctuations in the extents cultivated and preventing high PHLs which may seriously affect food security of the country.


**Keywords:** acreage responses, food security, supply chain, up-country vegetables

### INTRODUCTION

Food security is a worldwide concern at present and will remain a concern in the long-term future. The world will need 70 to 100 percent more food by 2050 (Godfray *et al.*, 2010; Chakraborty and Newton, 2011). Also, the ability of agriculture to produce necessary

<sup>1,2\*</sup> Department of Agribusiness Management, Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka  
[rosairo@agri.sab.ac.lk](mailto:rosairo@agri.sab.ac.lk)

<sup>3,4</sup> Socio Economics and Planning Center, Department of Agriculture, Peradeniya, Sri Lanka.

 <https://orcid.org/0000-0002-9092-6186>

amount of food for growing populations has been a serious concern for generations and continues as a priority in global policy agenda too (Rosegrant and Cline, 2003; Tilman *et al.*, 2013). According to Godfray *et al.*, (2010), although there was a marked growth in food production in the past half-century, still at present more than one in seven people does not have access to sufficient nutrition.

The FAO of the United Nations (2011) has defined food security as the situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. This definition highlights four key dimensions of food supplies as availability, stability, access, and utilization. Savary *et al.*, (2012) indicated food security as the balance between the growing food demand of the world population and global agricultural output, combined with discrepancies between supply and demand at the regional, national, and local levels. The availability of sufficient food is related to the overall ability of the agricultural system to meet the demand for food. Postharvest losses (PHLs) of food products especially vegetables form a part of the deficit between the supply and demand of such commodities (Keating *et al.*, 2011). Naturally all fresh vegetables have a high moisture content which renders them to be highly perishable. Therefore, if not handled properly, a high-value nutritious product can deteriorate and decay in a few days or even hours (Kader, 2002).

Sri Lanka is facing the challenges of food security. According to Thibbotuwawa and Lenard (2017), United Nations Food and Agriculture Organization (FAO) has estimated that about 4.7 million people of the 21 million population of Sri Lanka at present, which is about one-fourth of the population, do not get sufficient and safe food to sustain their lives. According to the FAO statistics, the level of calorie deficit in Sri Lanka is 192 Kcal/capita/day on average in 2014-2016 and this was recorded as the highest in South Asia.

Food security of the country has no any significant improvement even though different policies and programs were implemented by various institutions. The country does not yet have a clear focus and comprehensive strategy on food security status (Thibbotuwawa and Leonard, 2017). Although various institutions such as the Ministry of Agriculture and the Ministry of Health have been working on food security, poor coordination among these institutions and the absence of a central theme could be the factors affecting on prevailing food insecurity and malnutrition over the years (Thibbotuwawa and Leonard, 2017). WFP (2018) also has supported this idea by mentioning that there is a gap in policies and strategies focused on achieving food security. It is suggested that Sri Lanka must take necessary action to mitigate the increasing pressure on food supply which threatens the food security of the country and to ensure availability, accessibility, utilization, and stability of nutritious food.

According to Thibbotuwawa and Leonard (2017), the main responsibility of addressing the food security is laid on the agricultural sector. The domestic food availability of the country is dependent on local production and imports of food crops, livestock products and fish. Baker and Samad (1998) have identified poor market conditions as a key constraint to agricultural development in Sri Lanka. According to Rambukpitiya (2009) the fresh vegetables are spoiled before they are sold or utilized. This is worst in the seasons having extra production. All aforesaid facts raise the food prices and this ultimately may limit poor households' access to food and cause them to choose less nutritious diets causing certain health consequences (Rambukpitiya, 2009; Thibbotuwawa and Leonard, 2017). As an island nation, Sri Lanka is highly vulnerable to climate change said FWP, (2018). Therefore, the government must invest more in development of rural infrastructure such as roads, electricity, markets and communications, climate smart agriculture, new technology and small-scale industries to ensure food security of the country

(Baker and Samad,1998; Thibbotuwawa and Leonard, 2017).

Vegetable sector is one of the prominent sectors of Sri Lankan agriculture. Up-country vegetable cultivation is recognized as a major vegetable farming system and it is significant mainly due to its identity with the geographical area of cultivation. Many farmers throughout the country, especially most of the farmers in the hill country, derive their primary income from vegetable farming. Also, vegetable is the second most important part of Sri Lankan diet next to rice and a cheap source of many of the nutrients required for human nutrition. Therefore, it can contribute to nutrition security of the people, especially the poor. But there is a considerable gap between the requirements in human nutrition and the availability, as well as the actual consumption of vegetables in Sri Lanka (Rupasena, 1999). Although the Medical Research Institute (MRI) has highlighted the importance of vegetables on nutrient security of people by recommending a daily consumption of 200g per day (73kg per year), present vegetable consumption is recorded as only 94g per day (34 kg per year). Therefore, the vegetable consumption needs to be increased at least by 106g per day (80kg per year) (Dharmasena and Sarananda, 2012). Therefore, it can be stated that the vegetable sector is highly sensitive for achieving food security of the country and hence there is a necessity of increasing the availability of vegetables for local consumption.

However, constraints in increasing acreage of cultivation due to massive competition of other alternative crops, poor land productivity and high post-harvest losses (PHLs) of the produce along traditional supply chains become considerable barriers to ensure food security of the country by increasing availability of vegetables. Bringing new lands into cultivation is constrained by the land scarcity arising day-by-day due to reasons such as expansion in human settlements and rapid industrialization. Productivity of the existing farm lands also degrade daily with unhealthy agricultural practices such as improper use of chemicals

and poor application of conservation methods. Competitions from other alternative crops that can provide better returns to the farmers, comparatively to the up-country vegetables make the situation even worse.

It is assumed that rational farmers are more likely to allocate their resources such as available land for vegetable cultivation in response to higher prices they expect for vegetables than other competitive crops. These price expectations are mainly derived on the basis of prices they realized in yester years. The enhancement of productivity of marginal farm lands is also not so quick or an easy task. Yet the increased productivity can be achieved with increased utilization of fertilizers and other agrochemicals, but it is not sustainable. Therefore, Sri Lanka is facing a great challenge of ensuring sufficient availability of vegetables for local consumption. At this moment, reduction of PHLs along the traditional supply chains and government mediation for control of prices and extents under cultivation of competitive crops come in to play as the best possible alternatives in addressing this issue.

Carrying-out an analysis to understand the complete supply chain which is prominent, its key players and their actions; marketing functions; and the sources and quantities of PHLs with regard to upcountry vegetables is of timely importance. PHLs can be minimized through correct identification of sources and amount of losses along the prominent supply chains. Even though, the losses over the stages of supply chains are cumulative, researchers rarely made comprehensive measurements along the entire supply chains (Kader and Kitinoja, 2015). Meanwhile acreage response analysis can also be used to have a clear idea about how the farmer tends to allocate the available limited resources between the vegetable cultivation and other alternative crops such as potato in response to changes in the relative price expectations. These expected prices are derived from the past experiences. Therefore, an assessment of PHLs of three exotic vegetables; carrots, leeks and cabbages, along the most prominent up-country

vegetable supply chain in Nuwara-Eliya district which delivers the produce to Dambulla Dedicated Economic Center (DDEC) and an acreage response of up-country vegetables were carried out. A concentration curve is also plotted in order to find out the concentration of PHLs of vegetables over the scale of production of the farmers. A major reason for selecting Nuwara-Eliya district was its track record on the highest production of up-country vegetables. DDEC was selected due to its multi functionality as a wholesale market and it's being the major wholesale market in Sri Lanka for vegetables grown in the hill country.

## MATERIALS AND METHOD

### *Assessment of Post-harvest Losses*

*Research location:* The most prominent supply chain, its key players and their locations were identified by a pilot study conducted with the support of key informants. Key players of the supply chain were located in different locations in Sri Lanka, but mainly in Nuwara-Eliya, Dambulla and the areas close to Dambulla including Matale, Nalanda and Palapathwala (Figure 01).

### *Sampling Technique:*

Since key players at each stage of the supply chain was identified through their immediate links, multistage purposive sampling technique was employed. Accordingly, ninety farmers (thirty farmers who grew each of the three vegetables), ten regional collectors, fifteen wholesalers, twenty retailers and ninety consumers (thirty consumers of each of the

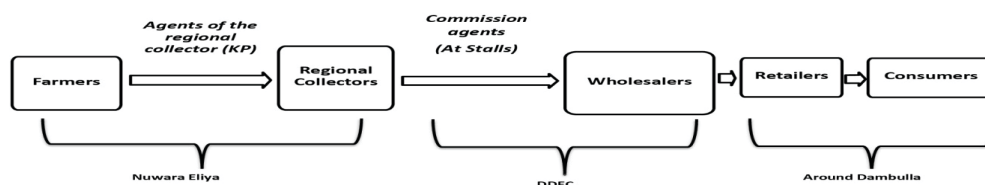
three vegetables) were used to collect data for the study.

### *Collection and Processing of Data:*

Primary data on estimated PHLs at each stage of the supply chain was collected through interviewer administered questionnaires. It was done mainly with face-to-face interviews. Interviews over the phone were conducted with few wholesalers and retailers who were not available for face-to-face interviews. The questionnaires were designed especially for each link of the supply chain.

Incidence of PHLs of each vegetable was assessed as a fraction of PHLs of the total quantity of vegetables handled.

At the farmer level, the PHLs were estimated by considering the difference of quantity harvested and the quantity dumped in the field without any consumption. The difference between quantity purchased from the initial link and quantity sold to the next link of the supply chain was assessed to estimate the PHLs at the regional collector, wholesaler and the retailer levels. The PHLs at the consumer level was estimated based on the difference between the quantity they purchased and quantity consumed. Concentration curve of PHLs was also drawn for the farmer level. The cumulative percentage amounts of produce handled in terms of the scale of production of farmers were taken as the X axis. The origin (0%) represents the set of farmers having the smallest scale of production (who handled the smallest quantity of the produce) and 100% represents the group who had the largest scale of production (who handled the largest quantity of the produce).



**Figure 01:** Most prominent supply chain for up-country vegetables from Nuwara-Eliya district to DDEC.

### Assessment of Acreage Response

Nerlovian expectation model was employed to examine the time series data of extents cultivated with up-country vegetables and potato which is a tuber crop considered to be a competing crop for up-country vegetables and their farm gate prices from year 2000 to 2017 (HARTI, 2000-2017; DCS, 2000-2017). The extent of up-country vegetables cultivated in the present year (2017) was taken as the dependent variable and all the rest as independent variables. Firstly, suitable variables for the regression model were selected by correlating the dependent variable against the independent variables followed by a multicollinearity test to avoid over-fitting of the model. Variance Inflation Factor;  $VIF = 1 / (1 - R^2)$ , was used to interpret the multicollinearity and the following regression model was fitted.

Accordingly, following regression model was set-up;

$$\ln A_{veg,t} = \alpha + \alpha_2 \ln A_{veg,t-1} + \alpha_3 \ln PI_{veg,t-1} + \alpha_4 \ln P_{potato,t-1} + U_t$$

Where;

$A_{veg,t}$  = Weighted average area (ha) of up-country vegetables in year t,

$A_{veg,t-1}$  = Weighted average area (ha) of up-country vegetables lagged by one year,

$PI_{veg,t-1}$  = farm gate price index of up-country vegetables lagged by one year,

$P_{potato,t-1}$  = farm gate price of potato (Rs/kg) lagged by one year,

$U_t$  = Un-observed random factor; it has an expected value of zero (Ayoni *et al.*, 2009)

$\alpha$  = Constant parameters

have been recorded with leeks. Rambukpitiya (2009) and Dharmasena and Sarananada (2012) have also concluded that leeks have the highest PHLs (7.5% and 5% respectively) among upcountry vegetables. The situation with the PHLs of leeks has improved in 2012 but has deteriorated severely thereafter. Therefore, results showed a twofold increment in PHLs of leeks since 2009.

Unnecessary trimming of lengthy, but fresh leaves (Figure 02) during bundling done to ease the handling was found to be the major contributing reason for the losses of leeks (30% of the total loss). As a result, a large portion of the consumable part of the harvest was lost. Physical damage such as squeezing during harvesting and cleaning was the second most influencing reason accountable to 27% of the total loss. Physical damages were taken place mainly by rough pulling during uprooting, rough handling in cleaning i.e. rest of the good leaves were damaged when pulling the damaged leaves roughly, and by excessive squeezing when tying the leeks in to bundles. Key informants reported that the physical damages were worsened by the usage of woven polypropylene as the packing material for bundling instead of using plastic crates which was considered as much product friendly. But many players in the supply chain are reluctant to use these crates as they consume more space in transportation. It was found that 22% of the total PHLs of leeks were accounted for leaf yellowing. Farmers reported that the reasons for this were senescence of tissues with delayed harvesting, sun burning and exposure to adversely high temperature conditions and nutrient deficiencies. Twelve percent of the total PHL of leeks was recorded due to the frost damage linked with adverse weather conditions. Only nine percent of the total postharvest loss was recorded by damages due to rotting (Figure 03).

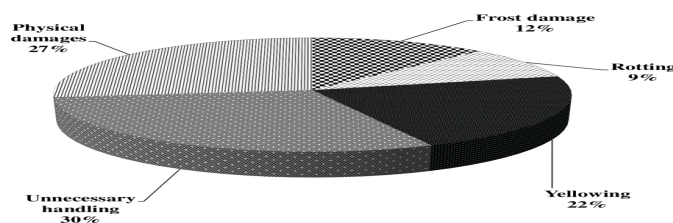
## RESULTS AND DISCUSSION

### Postharvest Losses Along the Common Supply Chain

At the farmer level: The highest PHLs (15%)



**Figure 02:** Removal of tips of long leaves protruding out of the bundle (note the white color woven polypropylene wrapping material used for bundling)



**Figure 03:** Sources of post-harvest losses in leeks at the farm level.

A concentration curve (Figure 08) was also obtained by plotting the cumulative percentage of PHLs against the cumulative percentage of farmer sample ranked by the scale of production. The concentration curve for leeks that lie below the line of equality, describes that higher PHL was incurred by the farmers with large-scale of production. It lies far below the equality line for the small-scale farmers indicating a low level of PHLs. But it moves up towards the line of equality around the third quintile resembling a significant increase in PHLs and then steadily moves further being closer to the line of equality. This further confirmed the finding that a highest degree of PHLs for leeks was incurred at the farmer level due to the reasons explained above. It was revealed that the farmers endeavored to transport maximum quantity of fresh leeks per unit area of the vehicles to reduce the transportation cost. Therefore, exerting high pressure on fresh leeks

to compress when bundling and tying, and over loading have increased when the amount of the produce handled increased.

Cabbage sustained the second highest (eight percent) PHLs which is much complementary to the findings of Rambukpitiya (2009) as nearly seven and a half percent. However, the current level of PHLs with cabbage is much higher than what was reported (four percent) by Dharmasena and Sarananda (2012). Trimming of outer leaves with mild pest attacks and discoloration in cabbage was done to obtain high price via better visual quality. However, this practice which was done irrespective of the scale of production was the main cause contributing to 55% of the total PHLs in cabbage (Figure 04). Twenty three percent of the total loss was caused by the pest attacks which made the produce totally damaged when at least a part of the produce could not be recovered by

trimming. It was recorded that 20% of the total PHLs were due to rotting while rest was caused by head cracking which occurred due to over maturation owing to delay in harvesting.

The concentration curve for cabbage (Figure 08) lies above the line of equality except in the last quintile, describing more concentration of PHLs on small scale producers. It shows a high rate of loss with the medium-scale farmers and drops below the line of equality among the large-scale farmers, representing the lowest PHLs at the largest scale producers. It was reported that the physical handling of the fresh produce by the small-scale farmers was high compared to the large-scale producers who have achieved economies of scale. Therefore, the finding, that the higher degree of losses on small scale cabbage farmers was established by this study.

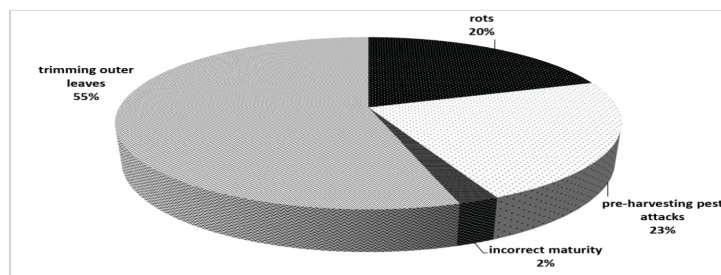
The lowest PHLs (seven percent) among the upcountry vegetables selected were recorded with carrots. Rambukpitiya (2009) and Dharmasena and Sarananda (2012) reported the PHLs in carrots as six percent and five percent respectively. Therefore, the status of PHLs of carrots has increased marginally during the past ten years. More than half of the total PHLs (54%) of carrots recorded at the farmer level was due to rots (Figure 05) such as soft rot, watery soft rot and black rot. These diseases arose due to excess moisture and RH conditions coupled with poor field sanitation. Thirty percent of PHLs in carrots were due to splitting (or cracking) occurred due to a combination of factors such as inadequate moisture; sharp fluctuations in moisture typically when a period of less soil moisture is followed by a period of too much moisture; high Nitrogen content in soil; and heavy soil texture. Attacks by pests

such as rats were responsible for another 12% of the total loss. When considering all these facts, these PHLs of carrots could be minimized with good agronomic practices. Another 4% of the produce was discarded as they were not marketable due to poor quality standards such as not attaining to marketable size, poor color development etc. Farmers reported that this may have been due to poor quality seed material which was largely imported hence not under their control.

The concentration curve for carrots (Figure 08) lies above the line of equality in first three quintiles, showing that the higher PHLs are concentrated on the small and medium-scale producers. But it is not too high since the curve moves closer to the line of equality. At the lower quintiles, curve runs below the line of equality showing less PHLs. Therefore, it seems that the PHLs of carrots have a weak relationship with the scale of production. Carrots were less subjective to both mechanical and physiological damages due to its hard texture being a root crop.

#### *At the regional collector level:*

At the collector level, only the dry weight loss due to dehydration and respiration could be assessed because bulk breaking (division of larger packs in to packs of smaller quantities upon reaching the final nodes of the supply chain) was not done during this level. Further, losses due to other reasons were unable to measure due to absence of bulk breaking at this stage. Accordingly, the highest incidence of PHLs which was 3% was reported with leeks at this level too. Both carrot and cabbage had equal amounts of PHLs at 2% (Figure 07).



**Figure 04:** Causes for postharvest losses of cabbage at the farm level

**At the wholesale level:**

Bulk breaking of the vegetables after the farm gate took place at the wholesale level. Therefore, PHLs caused after the product left the farm i.e. while transporting from farm gate to wholesale stall by collectors, were finally surfaced at this level. The highest incidence of PHLs (18%) at this level was recorded by cabbage (Figure 07) while leeks and carrots recorded 10% and 9% respectively. Major proportion of PHLs in cabbage (82% of the total loss) was due to trimming of outer leaves with mechanical damages, diseases and discolorations. Fourteen percent of the total loss was due to rots and 4% of these vegetables were damaged by crushing and these proportions of cabbages were totally dumped.

Major contributory factor for the PHLs of leeks was leaf wilting and discoloration occurred together due to senescence and sun drying (52% of the total loss). It generally took around two days after harvesting for the produce to reach the wholesaler. Also, soft leaves that have high water content wilted and dehydrated with exposure to higher temperatures over long-distance transportation between the upcountry areas and the DDEC. Leaf crushing damages due to improper handling caused the second highest PHLs of leeks (40% of the total loss) and the rest of the PHLs (8% of the total loss) were due to rots.

The largest proportion of the carrots was damaged due to breaking (or physical damages) (55% of the total loss) occurred mainly due to rough handling during loading, unloading and weighing at the commission agents' stalls of DDEC. The study observed that the hawkers

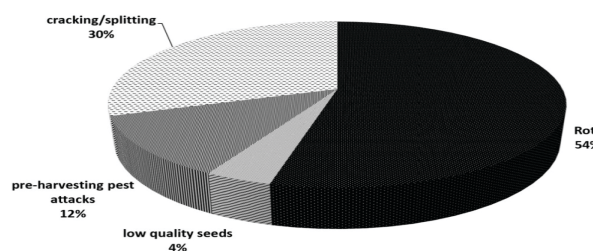
who were responsible for carrying the lots to the lorries usually just threw the produce on to the weighing balances and lorries over a distance. This rough handling of the produce caused breakages of carrots inside the lots. Forty one percent of the total loss of carrots was caused by the thermal damages such as overheating during transport over long distances exposing the produce to high temperatures. Only four percent of the total loss of carrots was due to soft rots.

**At the retailer level:**

As retailers handled small amounts of vegetables comparatively to the other key players of the supply chain, they were not sensitive distinctly about the different amounts of losses caused by different sources of PHLs. Therefore, only the total amount of losses was assessed. Accordingly, the highest incidence of PHLs was shown by cabbage as 7% followed by leeks and carrots (6% and 5% respectively) (Figure 07).

**At the consumer level:**

Consumers were inquired about their last purchase of up-country vegetables. The highest incidence of PHLs at this level was recorded by leeks (10%) followed by cabbage (8%) and carrots (7%) (Figure 07). The study identified two patterns of utilizations by the consumers as cooking soon after purchasing and storing after purchasing without immediate cooking. It further revealed that PHLs is higher in all the three vegetables when they were stored for several days before cooking compared to cooking immediately after purchasing (Figure 06).



**Figure 05: Causes for PHLs of carrots at farm level.**



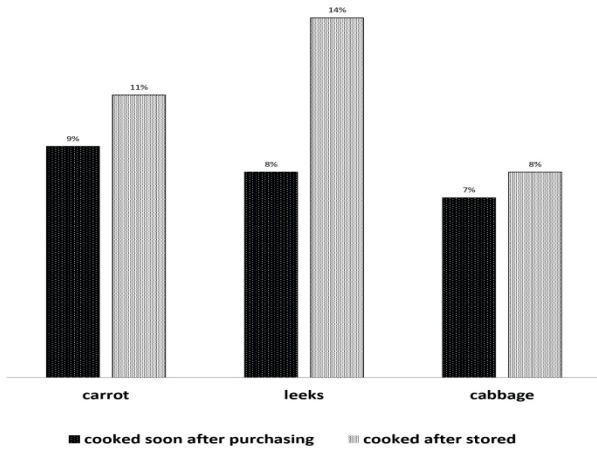


Figure 06: Postharvest losses at consumer level according to the pattern of utilization.

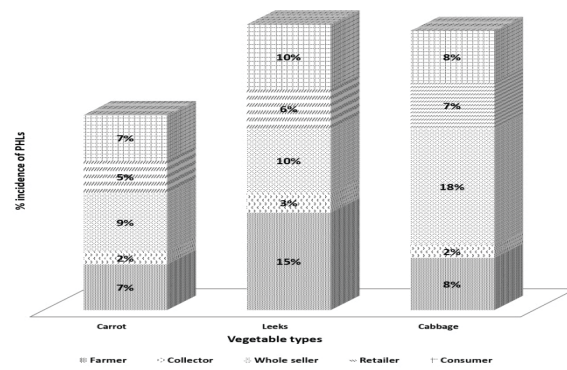


Figure 07: Postharvest losses of three vegetables during different levels of the common supply chain.

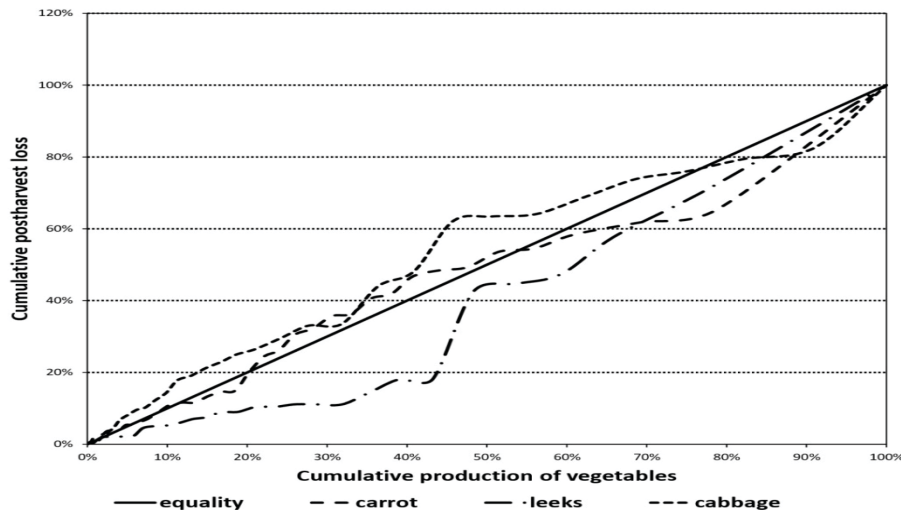


Figure 08: Concentration curves of the three vegetables for the distribution of PHLs at farmer level.

**Assessment of the Acreage Response**

According to the results of PHLs analysis within the common supply chain, physical damage of the produce due to rough handling and inadequate usage of recommended postharvest technologies and natural senescence of the produce within the long supply chain were identified as the major contributing factors for PHLs of up-country vegetables. High PHLs along supply chains widened the gap between the demand and the supply. This was contributory for a rise in price precluding low-income consumers from purchasing during

periods of high prices which affected the availability and the access of these vegetables causing malnutrition within the country.

The extent of potato cultivated during the lagged year did not have any significant association with the dependent variable; the extent of vegetables cultivated in the present year. Rest of all the variables were identified to be having significant associations with the dependent variable and free from multicollinearity and the associated regression coefficients were estimated (Table 01).

**Table 01: Results of the regression model**

Veg area in year (t)	Coef.	Std.err	t	P>[t]
Lag year extent of vegetables	0.2664	0.1631	1.63	0.113
Lag year price (index) of vegetables	0.2155*	0.0909	2.37	0.024
Lag year price of potato	-0.2693**	0.1439	-1.87	0.071

Note:  $R^2 = 0.28$  Adjusted  $R^2 = 0.2156$

\* Significant at  $\alpha = 5\%$

\*\* Significant at  $\alpha = 10\%$

Coefficients of correlations of 0.39 (P=0.02), 0.31 (P=0.31) and -0.01 (P=0.99) were resulted between the dependent variable  $\ln A_{veg,t}$  and the independent variables  $\ln A_{veg,t-1}$ ,  $\ln PI_{veg,t-1}$  and  $\ln P_{potato,t-1}$  respectively. Therefore, the strengths of correlations of all selected independent variables with the dependent variable were acceptable with expected signs. Even though the adjusted  $R^2$  was reported as 22%, it did not have much influence in the goodness of fit of model since the extent of vegetables cultivated was possibly influenced by numerous latent variables unaccounted in this study such as farmers' experience, peer pressure, availability and the price of seeds, price of other inputs, and pest and disease infestation levels associated with the crops.

Since, the interest was in the relationship between variables, but not in prediction, the  $R^2$  is less important as significant coefficients of the model still represent the mean change in the response for one unit of change in the variable while holding other variables in the model constant. Accordingly, vegetable price elasticity was revealed to be positive and an increase of one unit of the vegetable price in the lagged year would have increased the extent of up-country vegetable cultivated in present year by 0.21 hectares. Meanwhile, price elasticity of potato was revealed to be having a negative impact on the extent of up-country vegetables and rise of one unit of price of potato in the lagged year would have reduced the acreage of up-country vegetables cultivated in present year by 0.26 hectares.

Also, the study identified that the farmers are highly responsive to the outdated information

such as yester year prices of vegetables. Weddagala *et al.*(2016) also confirmed that no sufficient information is reaching the downstream nodes of the supply chains. This was partly due to the complexity and the distribution of decision-making power within the traditional supply chains. This study suggests that it is important to set up mechanisms to provide them with updated information. Therefore, in order to close the information gap between the farmers and other stakeholders, effective and efficient Decision Support Systems should be implemented. Advanced ICT-based technologies can be positively applied to minimize these information gaps. E-marketing and mobile marketing with mobile Decision Support Systems can be used for smooth flow of information through supply chains (Matsatsinis and Siskos,2003; Weddagala *et al.*, 2016).

## CONCLUSIONS

According to the results of PHLs analysis, leafy vegetables are highly prone to physical damages than other types of vegetables. Physical damages coupled with natural senescence were highly contributing for PHLs along the supply chain. These were initiated mainly by poor application of recommended post-harvest technologies at un-necessarily repeated activities including loading, unloading, weighing and intermediary extended holdings along lengthier supply chains. PHLs of leeks were more concentrated on large scale producers while PHLs of cabbage were more concentrated on small scale producers. But there was no considerable issue of PHLs for carrot farmers at any scale of production. According to the results of acreage response

analysis, farmers are responsive to the yester year prices of vegetables and potatoes when allocating the land resources in current year. When the previous year potato prices increased it can reduce the acreage of up-country vegetables in present year and hence potato is highly competitive. Also, when the price of vegetables experienced by farmers in yester year was high, this can increase the acreage of vegetables in the present year.

Therefore, policy formulations must be mainly focused on the reduction of very high incidence of PHLs in supply chains of up-country vegetables along with measures to secure their prices in order for them to withstand the acreage response issue with potato. This can minimize the relative fluctuations in the

extents of up-country vegetables cultivated by farmers and ensure the national supply making them affordable to low income consumers. This would also ensure the accessibility to vegetables hence national food security. Also, advanced technologies such as e - marketing and mobile decision support systems to include the crop forecasting, price forecasting, land use, resource allocation and marketing assistance should be used and popularized among the key players of the supply chains to make the functions smooth with efficient flow of updated information. This can reduce the deficiencies in the supply of up-country vegetables which can seriously improve the food security status of the country.

## REFERENCES

- Anonymous (2018), Supply response model- a theoretical frame-work, Agriculture development in Kerala, Retrieved from [http://shodhganga.inflibnet.ac.in/bitstream/10603/267/8/08\\_chapter%203.pdf](http://shodhganga.inflibnet.ac.in/bitstream/10603/267/8/08_chapter%203.pdf) at 14.00 hrs on 5th January 2018.
- Ayoni, V.D.N., Karunagoda, K., Waranakulasooriya, H.U. (2009). The regional differences in productivity of potato in Sri Lanka, *Annals of the Sri Lanka Department of Agriculture*, 11, 9-21
- Bamunuarachchi, A., Palipana, K. and Fernando, D. (2017). Problems with quality and safety in the Sri Lankan horticultural sector and steps taken to overcome these issues, Retrieved from <http://ucce.ucdavis.edu/files/datastore/234-1471.pdf>.
- Barker, R. and Samad, M. (1998), Irrigation development and Food security in Sri Lanka, *Economic Review March*.
- Central Bank of Sri Lanka. (2015). National output, expenditure and income. *Annual report of Central Bank of Sri Lanka*, 40.
- Central Bank of Sri Lanka. (2016). National output, expenditure and income. *Annual report of Central Bank of Sri Lanka*, 54.
- Chakraborty, S. and Newton, A. C. (2011). Climate change, plant diseases and food security: an overview. *Plant Pathology*, 60, 2–14.
- Department of Census and Statistics (DCS) (2000-2017). Cultivated extents of up-country vegetables, DCS, Colombo.
- Department of Census and Statistics (DCS) (2000-2017). Cultivated extents of other field crops, DCS, Colombo.

- Department of Census and Statistics (DCS) (2013). *District statistical handbook- Nuwara-Eliya*, Retrieved from <http://www.statistics.gov.lk/DistrictStatHBook.asp> at 10.00h on 2nd June 2018.
- Dharmasena, D.A.N. and Sarananda, K.H. (2012). *Present status, Issues, and future trends in fruit and vegetable handling, distribution and marketing in Sri Lanka*. Paper presented in Workshop on postharvest technology and cold chain management, 31/03/2012.
- District Secretariat- Nuwara-Eliya. (n.d). *Annual performance report and accounts 2015- Nuwara-Eliya district* at 16.00h on 2nd June 2018.
- FAO, (2011). Global food losses and waste: extent, causes and prevention.
- Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., Toulmin, C., (2010). Food Security: The Challenge of Feeding 9 Billion People, *Science*, American Association for the Advancement of Science.
- Gunawardena, P.J. (1982). Some issues in marketing of vegetables in Sri Lanka. *Agricultural Administration*, 11(1), pp. 23-37.
- Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI) (2000-2017). Monthly average producer prices of up-country vegetables at Nuwara Eliya, Marketing Food Policy & Agri-Business Division, HARTI, Colombo.
- Kader, A.A. (2005). Increasing food availability by reducing postharvest losses of fresh produce. *Acta Horticulturae (ISHS)* 682, 2169-2176.
- Karim, R. and Biswas, J. (2016), Value stream analysis of vegetable supply chain in Bangladesh: a case study. *International Journal of Managing Value and Supply Chains (IJMVSC)*, Vol. 7.
- Kasso, M. and Bekele, A. (2016). Post-harvest loss and quality deterioration of horticultural crops in Dire Dawa Region, Ethiopia. *Journal of the Saudi Society of Agricultural Sciences*, 17, pp 88–96.
- Katinoja, L. and Karder, A.A. (2015). Measuring postharvest losses of fresh fruits and vegetables in developing countries, PEF white paper 15-12, *Postharvest Education Foundation*.
- Kiaya, V. (2014). *Post-harvest losses and strategies to reduce them*. Technical Paper on post-harvest losses, Scientific and Technical Department, Action Centre la Faim (ACF), ACF International.
- Kitinoja, L. (2010). *Identification of appropriate postharvest technologies for improving market access and incomes for small horticultural farmers in Sub-Saharan Africa and South Asia*, report prepared for WFLO Grant, Grant number 52198.
- Keatinge, J. D. H, Yang, R. Y, Hughe, J.A, Easdown W. J. and Holmer R.(2011), The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium Development Goals, *Springer Food Security*.
- Matsatsinis, N. and Siskos, Y., (2003). Intelligent support systems for marketing decisions, Kluwer academic publishers, Dordrecht, pp 111-169.

- Minitab Blog Editor. (2018). Regression Analysis: How do I interpret R-squared and assess the goodness-of-fit? Retrieved from <http://blog.minitab.com/blog/adventures-in-statistics-2/regression-analysis-how-do-i-interpret-r-squared-and-assess-the-goodness-of-fit> at 16.00h on 2nd June 2018.
- Munheweyi, K. (2012). Postharvest losses and changes in quality of vegetables from retail to consumer: a case study of tomato, cabbage and carrot (Doctoral dissertation, Stellenbosch: Stellenbosch University).
- Munhuweyi, K., Opara, U.L. and Sigge, g. (2016). Postharvest losses of cabbages from retail to consumer and the socio-economic and environmental impact, *British Food Journal*, Vol. 118 Iss. 2 pp. 286 - 300
- Oppedisano, V. and Turati, G. (2011). *What are the causes of educational inequalities and of their evolution over time in Europe? Evidence from PISA*. Unpublished thesis.
- Rambukpitiya, S.D. (2009). *Assessment of post-harvest losses in the supply chain of up-country vegetables*. Unpublished thesis on BSC Agricultural Technology and Management, Department of Agricultural Economics and Business Management, University of Peradeniya, Sri Lanka.
- Rosegrant, M.W. and Cline, S.A (2003). Global Food Security: Challenges and Policies. *SCIENCE MAG*, 302 12.
- Rupasena, L.P. (1999). *Production and marketing of vegetables*. Hector Kobbekaduwa Agrarian Research and Training Institute: Colombo.
- Savary, S., Ficke, A., Aubertot, J. and Hollier, C. (2012). Crop losses due to diseases and their implications for global food production losses and food security. *Food Security; The Science, Sociology and Economics of Food Production and Access to Food*.
- Thibbotuwawa, M. and Leonard, E., (2017) Achieving food security: A plausible reality or a pipe dream for Sri Lanka?. Retrieved from a blog based on a chapter written for the forthcoming Sri-Lanka: State of the Economy 2017 report, Institute of Policy Studies annual flagship publication at [http://www.island.lk/index.php?page\\_cat=article-details&page=article-details&code\\_title=170522](http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=170522) at 14.00 hrs on 26<sup>th</sup> March 2019.
- Tilman, D., Balzer, C., Hill, J. and Befort, B.L. (2013), Global food demand and the sustainable intensification of agriculture, *PNAS*, vol. 108.
- Weddagala, W.M.T.B., Basnayake, B.M.R.L., Wijesekara, H.M.L., Dharmathilake, N.R.D.S., Kiriveldeniya K.K.A., and De Silva, D.A.M., (2016). Mobile market decision support system and its application in agricultural marketing in Sri Lanka. International research conference, Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka. pp 92-94.
- World Food Programme (2018), Where we work; Sri Lanka. Retrived from <https://www1.wfp.org/countries/sri-lanka> at 11.30hrs on 24<sup>th</sup> March 2019.