



RESEARCH

Introducing a 'Postharvest Loss Index (PHLI)' for Some Selected Highly-consumed Vegetables in Sri Lanka to Enhance Food Security

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ARTICLE INFO

Article history:

Received: 18 May 2023

Revised version received: 24 July 2024

Accepted: 05 June 2024

Available online: 01 July 2024

Keywords:

Dambulla Economic Center

Postharvest Loss Index

SARIMA

Vegetable Value Chain

Citation:

Jayasinghe, C.V.L., Dassanayake, D.M.C.M.K., Madhushani, R.D.T.D., Edirisinghe, J.C., Wasana, H.M.S., and Wijewardane, M.A., (2024). Introducing a 'Postharvest Loss Index (PHLI)' for Some Selected Highly-consumed Vegetables in Sri Lanka to Enhance Food Security. *Tropical Agricultural Research*, 35(3): 212-220.

DOI:

<https://doi.org/10.4038/tar.v35i3.8543>

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ABSTRACT

Developing a Postharvest Loss Index (PHLI) is important for filling the data gap to gain awareness about real economic loss (quantity x price) that occurs due to postharvest losses in the country, and to take measures for enhancing food security. Estimating PHLI for agricultural commodities is a novel concept. Thus, in this study, PHLI for bean, carrot, leeks and beetroot was developed on a monthly basis at the Dambulla Economic Center (DEC), the focal point in the fruit and vegetable value chain in Sri Lanka. Data were collected on the daily postharvest losses and the prices at the DEC during the period of October 2015 to March 2017. Moreover, SARIMA model was employed in the time series analysis to forecast future PHLI values for each vegetable. According to the results, during the months where there was a decreasing trend in the supply of vegetables to the market, the PHLI was relatively low. However, when the supply was high, it showed an increasing trend in the PHLI. The forecasted PHLI values for the beans for the next three months were 74.73, 61.31, and 61.71, while for the carrots the forecasted values were 112.03, 81.28, and 47.67, respectively. Further, the forecasted values for the leeks were 271.33, 194.19 and 174.97, whereas for the beet PHLI values for the next three months were 177.78, 208.15, and 231.9, respectively. As the PHLI of the selected crops showed a seasonal fluctuation, it can be used as the base value to forecast the postharvest loss of a crop to enhance food security.

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INTRODUCTION

Agriculture plays a vital role in the national economy of Sri Lanka while contributing 7.9% to gross domestic production (GDP). Vegetables contributed 0.6% and 0.5% to GDP in 2017 and 2016, respectively. Private consumption expenditure (PCE), which measures consumer spending on goods and services was 29.1% for foods in 2017, and among that, consumers spent 8.8% on vegetables (Central Bank of Sri Lanka 2016, 2017). Thus, as an agriculture-based country and considering the food consumption pattern of the country, vegetable production plays a key role in its economy. The Dambulla Economic Center (DEC) is the focal point in the fruit and vegetable value chain in Sri Lanka to supply basic facilities for farmers and to make the marketing process efficient. Presently, 65-75% of the fruit and vegetable supply in Sri Lanka is handled by the DEC. However, it is estimated that in Sri Lanka, postharvest losses of vegetables vary from 20% to 40% (Rajapaksha et al., 2021). Furthermore, the information on impact of postharvest loss from each vegetable on the Sri Lankan economy is limited. Thus, developing a Postharvest Loss Index (PHLI) for agricultural commodities is important to fill the data gap and perform a situation analysis of the actual economic loss (quantity x price) that occurs due to the postharvest losses in the country. Furthermore, PHLI will facilitate the estimation of the annual economic loss of fruits and vegetables, and prioritize agricultural commodities to reduce postharvest losses through correct interventions. This in turn would reduce economic losses to the country, while enhancing food security.

Estimating the PHLI for agricultural commodities is a novel concept. The present study is focused on introducing a PHLI for the first time in Sri Lanka for four types of vegetables; bean, carrot, leeks and beetroot, based on the data gathered from the DEC during the period of October 2015 to March 2017. The selected agricultural commodities are the commonly-consumed vegetables grown in the upcountry of Sri Lanka, and their transactions are normally done *via* the DEC.

The difference between the amounts consumers pay for the final product and the amount the producer receives is generally referred to as the marketing margin (MM). It includes all the costs of moving products from the point of production to the point of consumption (Kohls and Joseph, 1985). Marketing efficiency can be defined as the maximization of the output (consumer satisfaction with goods and services)-input (labour, capital) ratio and can be measured on the basis of the size of MM and cost in the ultimate consumer price (Jasdanwalla, 1996).

The MM identifies the disparity between the cost of purchasing items wholesale and the income made by selling them. Marketing efficiency (ME) is the maximization of the input-output ratio. Thus, ME can be used as a determining factor of the postharvest loss of agricultural commodities through each point of the value chain from the farm gate to the retailer. As the DEC is the focal point in fruit and vegetable value chains in Sri Lanka, investigating marketing efficiency at the DEC will provide important information on factors affecting postharvest losses through particular marketing channels. Thus, the present study further discussed MM and ME at the DEC during the study period from October 2015 to March 2017.

METHODOLOGY

Commonly-consumed four agricultural commodities were selected for this study: bean (*Phaseolus vulgaris*), carrot (*Daucus carota* sub sp. sativus), leeks (*Allium ampeloprasum*) and beetroot (*Beta vulgaris*). Data were collected on daily postharvest losses and the prices at ten randomly selected stalls out of 166 functioning stalls at the DEC. The study was performed based on the daily logger data available at DEC, personal interviews and using representative samples of solid waste. The solid waste samples were separated into categories and weight of each separated component was measured by using a weighing balance. Then the percentage of each waste component was calculated for each month. This procedure was monthly repeated. The collection of data pertaining to total loss of these vegetables at the DEC took place during the period of October 2015 to

March 2017. The Postharvest Loss Index (PHLI) was calculated considering October 2015 as a base month.

The Laspeyres formula (Laspeyres Index 2008) was used to calculate the PHLI as shown in Equation 1 and 2.

$$L(p) = \frac{\sum_{j=1}^N p_{j,t} q_{j,0}}{\sum_{j=1}^N p_{j,0} q_{j,0}} \quad \text{Eq. 1}$$

Where, $L(p)$ = Laspeyres index, $p_{j,t}$ = Price at t^{th} month, $q_{j,t}$ = Quantity of losses in base month, $p_{j,0}$ = Price at base month, and $q_{j,0}$ = Quantity of losses in t^{th} month. Here, the Laspeyres index of October 2015 was used as the base value, and the Postharvest Loss Index was calculated using Equation 2.

$$\text{Postharvest loss Index} = [L(p)m / L(p)Bm] \times 100 \quad \text{Eq. 2}$$

Where, $L(p)m$ = Laspeyres Index of the month and $L(p)Bm$ = Laspeyres Index of the base month.

The marketing efficiency of DEC during the period of October 2015 to March 2017 was measured based on the marketing margins. To calculate the marketing margins of selected crops at Dambulla, the wholesale prices at the DEC and the farm-gate prices of the selected vegetables announced by HARTI (Hector Kobbekaduwa Agrarian Research and Training Institute) were used.

The marketing margins (MM) were calculated using the Equation 3

$$\text{Marketing margin (MM)} = [(CP - FP) / CP] \times 100 \quad \text{Eq. 3}$$

Where, CP = Price paid by consumer and FP = Farm gate price

The SARIMA model under time series analysis was employed to forecast future postharvest loss index values for each vegetable type. The SARIMA is a generalization of an autoregressive integrated moving average model

that represents an important example of the Box and Jenkins (1976) approach to time series modeling. The SARIMA model contains a seasonal component and is widely used for time-series analysis and forecasting.

A time series $\{X_t | t = 1, 2, \dots, N\}$ is generated by a SARIMA(p,d,q)(P,D,Q) process if;

$$\varphi(B)\phi(B^s)(1-B)^d(1-B^s)^D X_t = \theta(B)\vartheta(B^s)\varepsilon_t$$

When N is the number of observations, p,d,q,P,D and Q are integers; B is lag operator; s is the seasonal period length.

$\varphi(B) = 1 - \varphi_1 B - \varphi_2 B^2 - \dots - \varphi_p B^p$, is the regular autoregressive operator (AR) of order p,

$\phi(B^s) = 1 - \theta_1 B^s - \theta_2 B^{2s} - \dots - \theta_p B^{ps}$, is the seasonal autoregressive operator (AR) of order p,

$\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \dots - \theta_q B^q$, is the regular moving average operator (MA) of order q,

$\vartheta(B^s) = 1 - \vartheta_1 B^s - \vartheta_2 B^{2s} - \dots - \vartheta_Q B^{Qs}$, is the seasonal moving average (MA) of order Q. d is the number of regular differences; D is the number of seasonal differences. (If there is a seasonality effect, D=1 in most cases; there is

no seasonality effect=0); ε_t is the estimated residual at time t that is identically and independently distributed as a normal random variable with an average value equal to zero ($\mu=0$) and a variance sigma (σ^2) (i.e., ε_t is a white noise signal).

RESULTS AND DISCUSSION

Figure 1 illustrates that PHLI of bean, carrot, leeks and beetroot fluctuated seasonally from October 2015 to March 2017. The pattern of the fluctuation for each vegetable was different. The highest index value was reported in carrots in December 2016 and June 2016 compared to other three types of vegetables. The PHLI of beans did not fluctuate much compared to other commodities, and the highest index was

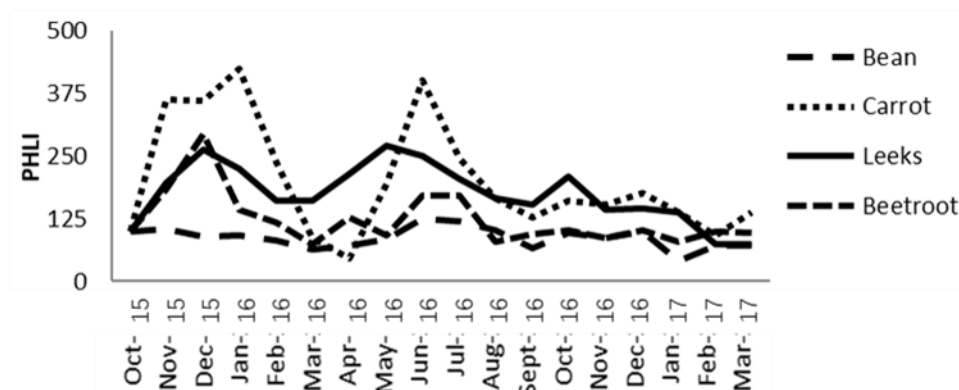


Figure 1: Postharvest loss index (PHLI) of bean, carrot, leeks, and beetroot from October 2015 to March 2017.

recorded on June 2016, while for leeks it was recorded in January 2016 and May 2016. The highest PHLI for beetroot was reported during November to December 2015, but afterwards, no drastic changes were observed during the study period. According to the results, significant changes in the PHLI were observed in carrots and leeks, and no major changes were observed for beans and beetroots. Compared to beans and beetroots, carrots and leeks have soft damageable tissue. Due to the soft tissue structure, the amount of postharvest losses of carrots and leeks was higher than the rest (Rajapaksha et al., 2021).

The PHLI of all selected vegetables showed a significant increment between October 2015 and January 2016, excluding beans. During the base month of October 2015, crop establishment commenced in all districts in the up country, mid country and low country with the early onset of rains in the *Maha* season. Upcountry vegetables were received mainly from Nuwara Eliya, Badulla, Kandy, Matale and Ratnapura, and the daily supply of vegetables to the DEC was approximately 1,200-1,500 Mt. The prices of all vegetable varieties, except leeks, increased in October 2015 due to a decreasing trend in market supplies (HARTI, 2017). However, the supply of vegetables began to show an increasing trend for both up- and low-country varieties because the *Maha* season supplies have reached the market since early January 2016 (HARTI, 2016). The results imply that when the supply of vegetables increases to the DEC the amount of losses increases. Climate

change and the season of vegetable cultivation have highly influenced the PHLI of the agricultural commodities in Sri Lanka.

There was a sharp decrease in the PHLI between January and March in both 2016 and 2017 (Figure 1). The prolonged dry weather conditions usually present in the country is one reason for the low supplies of vegetables to the market from January to March. However, the PHLI increased between June 2016 and July 2016 due to the commencement of harvesting and the increment of supplies of vegetables.

During the periods of July 2016 to September 2016 and December 2016 to February 2017, the PHLI of selected crops decreased marginally. This may be due to the decreasing trend of the supply of vegetables in the above-mentioned months. During the latter phase of harvest of the *Yala* season (in September 2016), the supply of vegetables decreased (data not shown). In the same manner, during December 2016, supplies of both up- and low-country varieties of vegetables further dropped due to slow cultivation progress in the *Maha* season. In February 2017, this decrease was due to the latter phase peak harvesting period of the *Maha* season. These supply variations were also confirmed by the management of the economic center and the laborers of the municipal council during the personal interviews.

A marginal increase in PHLI was shown during the periods of September 2016 to October 2016 (Figure1), November 2016 to

December 2016 and February 2017 to March 2017. According to HARTI (2016) in October 2016, the cultivation extent in the intermediate season (in between two main seasons) was negatively affected by the delayed onset of the northeast monsoon; thus, the supply of vegetables considerably decreased and affected the PHLI. Hence, it can be concluded that the PHLI decreases during the months where there was a low supply of vegetables to the market, while it increases with the increasing supplies to the market.

The postharvest loss is influenced by the amount of production and the climatic condition. When production was high, the postharvest losses were high (personal interviews at DEC). In particular, when there is surplus production in economic centers, it is observed that there would be a loss of demand (Murthy et al., 2009). Nearly 10 MT of fruits and vegetables are discarded at the DEC for many reasons. The main reason is that farmers dump their products at DEC due to the low demand for their products, although the products are in consumable condition. The atmospheric humidity condition in the *Maha* season with high rainfall also influences the postharvest losses of Sri Lankan fruits and vegetables across the value chains. As mentioned by Idah et al. (2007), postharvest losses and quality deterioration of horticultural crops are mostly caused by pests, microbial infections, natural ripening processes and environmental conditions such as heat, drought, improper postharvest handling and vibration resulting from the transport vehicles as they traverse undulation and irregularities on the roads, and use of unsuitable packaging containers.

With reference to the market margins, a timely increase in market margins is considered as a factor contributing to decrease in the efficiency of vegetable marketing (Sabu and Tripathy, 1998). For beans, the highest market margin was recorded in January 2017, while for carrots and leeks, it was recorded on February 2017 (Figure 2).

For beetroot, the highest market margin was recorded on November 2016. Compared to

base month October 2015, the marketing margins fluctuated differently, and thus, the marketing efficiency at DEC for the selected vegetables changed over time (Figure 2).

As illustrated in Figure 2, the MM fluctuated throughout the study period, however, a similar pattern of fluctuation was observed for beans, carrots, leeks, and beetroots. The decreasing trend of MM in the periods of October 2015 – January 2016, April 2016 – July 2016, October 2016 – December 2016 and February 2017 – March 2017 implies that the marketing efficiency at DEC has increased in the above periods. Similarly, MM increased during January 2016 – April 2016, July 2016 – October 2016 and December 2016 – February 2017, indicating that the marketing efficiency of DEC decreased in these periods. The pattern of fluctuation of the MM is negatively correlated with the fluctuation of PHLI of the selected crops, which is illustrated in Figure 2 and Figure 3.

The R^2 values for the correlation between PHLI and MM of carrots and leeks showed a strong negative relationship, while that of bean and beetroot showed a weak negative relationship between PHLI and MM. As illustrated in Figure 1, the PHLI of bean and beetroot did not drastically fluctuate over time, which could have contributed to a strong negative relationship between PHLI and MM. Murthy et al. (2007) reported that the marketing efficiency is inversely proportional to the volume of postharvest losses. Losses during and after harvest resulted in major problems in marketing, reducing availability and resulting in an intensification in the unit cost of marketing (Buyukbay et al., 2011).

According to the time series analysis, the most fitting model for the postharvest index of beans was SARIMA (0, 1, 1) (2, 0, 1)₁₂. All the parameters in the model were statistically significant ($p < 0.05$). The p value for the modified box pierce (Ljung-Box) chi-square statistic was 0.089. Therefore, it concludes that the model meets the assumptions that the residuals are independent. As illustrated in Figure 4, the forecasted PHLI values for the next three months were 74.73, 61.31, and 61.71.

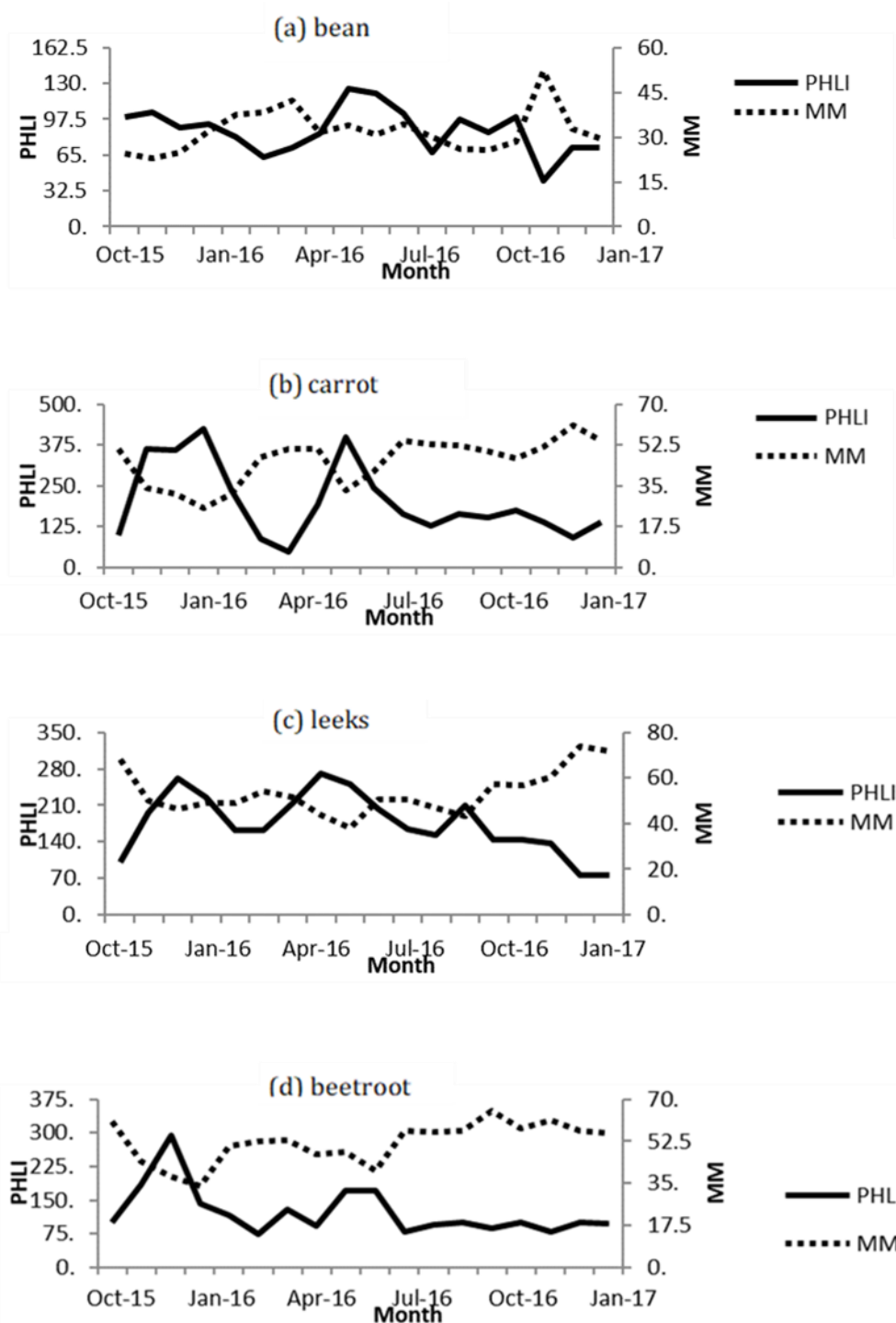


Figure 2: Comparison of Postharvest Loss Index and Marketing Margins of (a) bean, (b) carrot, (c) leeks, (d) beetroot

The fitted model for the Post Harvest Index of Carrot was SARIMA (2, 0, 1) (0, 0, 1)₁₂. All the parameters of the model were statistically significant ($p < 0.05$), and the p value for the modified box-pierce (Ljung-Box) chi square statistic was 0.159. According to Figure 4, the

forecast values for the next three months were 112.03, 81.28, and 47.67.

The obtained model for Leeks was SARIMA (2, 0, 2) (1, 1, 0)₁₂. All the parameters of the model were statistically significant ($p < 0.05$),

and the model met its assumptions that residuals were independent, as the p value of the modified box-pierce (Ljung-box) chi-square statistic was 0.085. The forecasted values for the next three months were 271.33, 194.19 and 174.97 (Figure 4).

The SARIMA (0, 1, 1) (1, 1, 1, 1)₁₂ was the resultant model for Beetroot. The modified Box Pierce-(Ljung-Box) chi-square statistic was 0.095 while the PHLI values of 177.78, 208.15, and 231.90 were the forecasted values for the next three months (Figure 4).

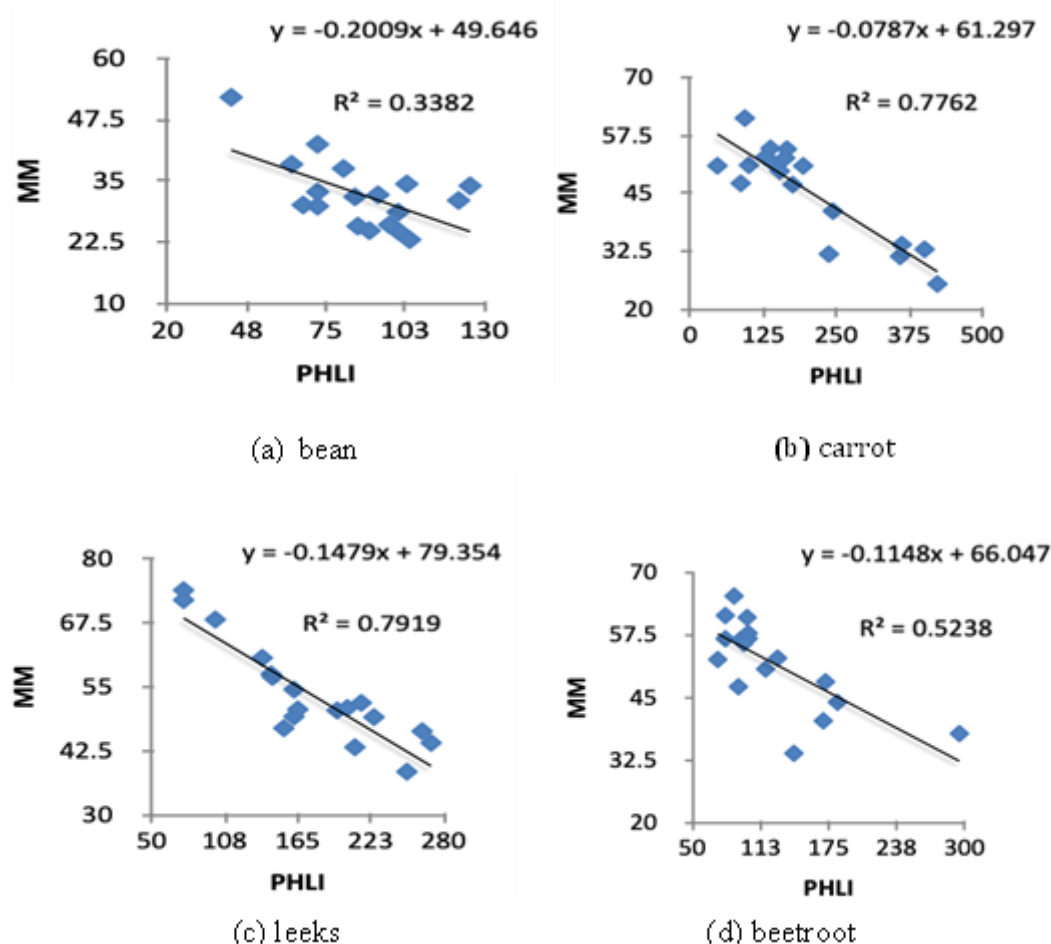


Figure 3: Relationship of Postharvest Loss Index and Marketing Margins of (a) bean, (b) carrot, (c) leeks, (d) beetroot



Figure 4: Time series plots with forecasted PHLI values for bean, carrot, leeks and beetroot.

CONCLUSIONS

As the Post-Harvest Loss Index (PHLI) of the selected crops has shown a seasonal fluctuation, developing PHLI will support forecasting of the postharvest loss in future years for a particular crop. Further, the marketing margin can be used to identify the efficiency of vegetable marketing at the Dambulla Economic Center.

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