Gaining Insights to the importation of food to Sri Lanka using Data Mining

H.C. Fernando, W. M. R Tissera, and R. I. Athauda

***Abstract*—This paper describes an application of data mining techniques to find patterns in importation of food items to Sri Lanka. There are only ten food items considered in this paper. This study showed imports continuously increases with respect to both quantity and price. The study results in providing insights to the national economy and agricultural policies.**

***Index Terms*—Data mining, time series analysis, food imports**

I. Introduction

In the year 2007, there was a severe shortage of food grains supply resulting in increasing food grain prices in the world. Therefore, the year 2007 is considered to be the worst ever year for global food prices in recent past. There is also an increase in price of whole range of food such as meat, dairy products, fruits, vegetables, sugar etc. This food crisis is mainly due to unequal distribution of food. Therefore, it is necessary to make marketing system more effective particularly among Low Income Food Deficit countries and developing countries like Sri Lanka.

Cross-border flows of food products and international cooporation and partnerships make the food industry function more and more on a global scale. Hence, global competition together with the advances in information technology has stimulated both the need and opportunity for a coordinated approach for industrial partners to establish effective and efficient supply chains, that is, Food Supply Chain Networks (FSCNs). It is not easy to handle FSCNs due to inherent uncertainty of the business environment, conflicting objectives, and variety of policies of governments. The study is carried out to investigate how importation of some food items has occurred since 2007 to date so that we could gain some insights to the FSCNs acting in Sri Lanka.

Data mining is the process of analyzing huge volumes of data to discover implicit but potentially useful information and uncover previously unknown patterns and relationships hidden in data [16]. Data Mining has been successfully applied in e-commerce [3], bioinformatics, computer security [5], web intelligence, intelligent learning database systems, finance, marketing [7], telecommunications [10], and other fields ([8], [14] and others).

The process of data mining consists of three stages: (i) the initial exploration, (ii) model building or pattern identification and (iii) deployment [2]. The initial exploration usually starts with data preparation which may involve cleaning data, data transformations, selecting subsets of records and - in case of data sets with large numbers of variables - performing some preliminary feature selection operations to bring the number of variables to a manageable range. Model building and pattern identification can take various forms such as association rules, classification rules, and decision trees. Deployment means obtaining the resultant knowledge, in a usable format, to the place where it is needed, such as decision makers and operational systems. Data Mining lends techniques from many different disciplines such as databases, statistics [4], Machine Learning/Pattern Recognition [1] and Visualization [6].

The aim of this study is to investigate how data mining techniques can be used to find patterns in importation of food items in Sri Lanka. The data set used for the study was provided by Sri Lanka Customs [12]. We hope that the identified patterns in this study would help to make dynamic analysis of food supply chain scenarios to support supply chain decision making.

II. Methodology

A. Data Set

The data set consisted of following fields: date, country, Charge Insurance and Freight (CIF) value (in Sri Lankan rupees), and quantity for ten food items, namely, rice, dhal, potatoes, red onions, Bombay onions (B-onion), fresh oranges, fresh grapes, fresh apples, maldive fish, and dried sprats. The period considered was from 1st January 2007 to 30th November 2009.

We categorized the food items into three main categories: Category I – commonly used items in Sri Lankan diet, namely, rice, B-onion, red onion, dhal, and potatoes; Category II – items not needed in large quantities, namely, dried sprats and maldive fish; and, Category III – fruits which are non-essential items in a typical Sri Lankan diet, namely, fresh apples, fresh grapes and fresh oranges.

B. Time series analysis

The trends of the variables with time (month) were

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analyzed using time series analysis. SQL Server [11], [17] (see Tools section below) provides the facility to perform time series analysis using Autoregressive tree model (ART) [9]. An ART is a piecewise linear autoregressive model. The boundaries are defined by a decision tree and leaves of the decision tree contain linear autoregressive models. An ART (*p*) model is an ART model in which each leaf of the decision tree contains AR (*p*) model, and the split variables for the decision tree are chosen from among the previous *p* variables in the time series. ART (*p*) models are more powerful than AR models because they can model non-linear relationships in time series data [15]. ART models are particularly suitable for data mining because of the computationally efficient methods available for learning from data. Also, the resulting models yield accurate forecasts and are easily interpretable.

ART (*p*) model is given by:

$$f(y_t|y_{t-p},\ldots,y_{t-1},\theta)=\prod_{i=1}^{L} f_i(y_t|y_{t-p},\ldots,y_{t-1},\theta_i)^{\Phi_i}=\prod_{i=1}^{L} N(m_i+\sum_{j=1}^{p} b_{ij}y_{t-j},\sigma_i^2)^{\Phi_i}$$

where L is the number of leaves, $\theta=(\theta_1,\ldots,\theta_L)$, and $\theta_i=(m_i,b_{i1},\ldots,b_{ip},\sigma_i^2)$, are the model parameters for the linear regression at leaf l_i, $i=1,\ldots,L$.

C. Tools

Microsoft SQL Server [11], [17] is a powerful Database Management System (DBMS) that offers different DM algorithms and techniques and is user friendly. We used Microsoft SQL Server 2005 for our analysis work.

III. Results

A. Preliminary Analysis

This section presents our preliminary analysis and results.

The quantity of rice imported shows an unusual increase from September 2007 to March 2008 but this pattern has not repeated during the same period thereafter (Fig. 1). Sri Lanka has been able to reduce the quantity of imported rice significantly (Fig. 1).

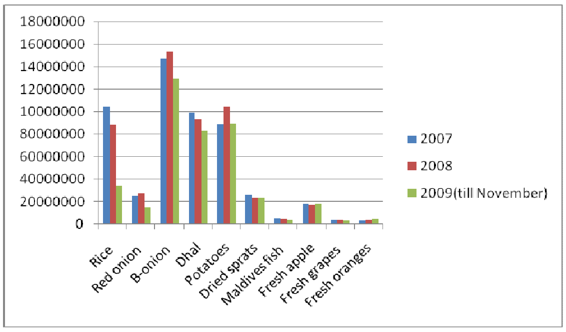

Figure 1. Graph of quantity by food item

The highest portion of the total CIF value is for dhal. It has increased from 26.8% of total CIF in 2007 to 40% of total CIF in 2009 (Fig. 2).

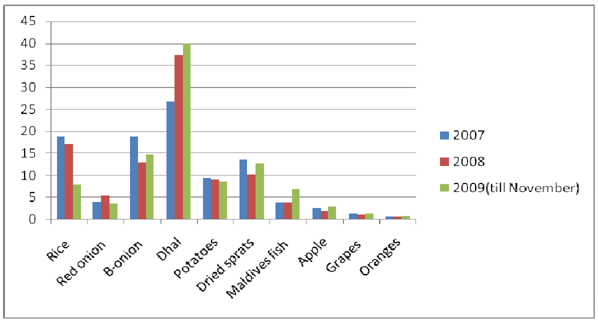

Figure 2. Graph of percentage of total CIF value by food item

In general (except for B-onion and potatoes), CIF value per kg has increased in 2009 compared to 2007 (Fig. 3). However, there are changes in 2008 to this trend. For certain food items, (i.e. rice, red onion, B-onion and potatoes) CIF per kg has decreased in 2008 compared to 2007. In other situations (i.e. dhal, dried sprats, maldive fish, apple, grapes and oranges), the CIF per kg has increased in 2008 compared to 2007 (see Fig. 3).

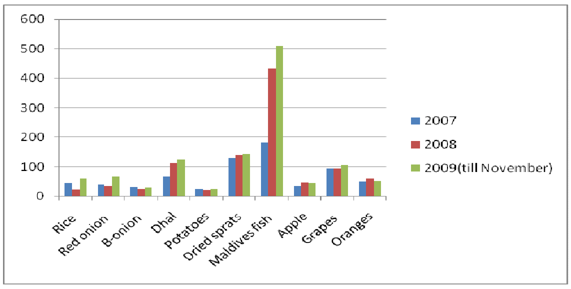

Figure 3. Graph of CIF value per kg by food item

Among the food items of the Category I (Fig. 4), CIF value per kg for dhal has increased considerably. Also, in the months between July and September 2009, Sri Lanka has not imported red onions.

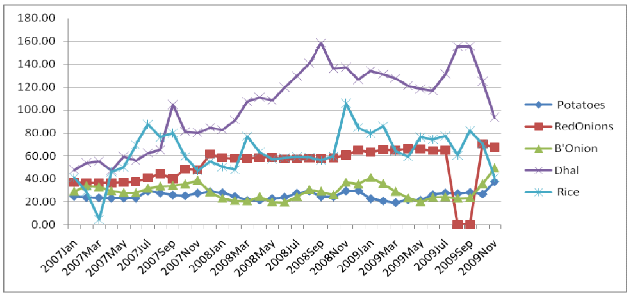

Figure 4. CIF values per kg for Category I items

CIF values per kg for dried sprats and maldive fish are comparatively high. The CIF value of dried sprats varies from 127.92 rupees per kg in 2007 to 142.63 rupees per kg in 2009. Maldive fish shows a drastic change in the price amounting to 181.29 rupees in 2007 to 509.54 rupees in 2009. Although, the quantity of maldive fish decreases from January 2007 to November 2009, the CIF value increases by 186% of that of 2007 (see Fig. 5).

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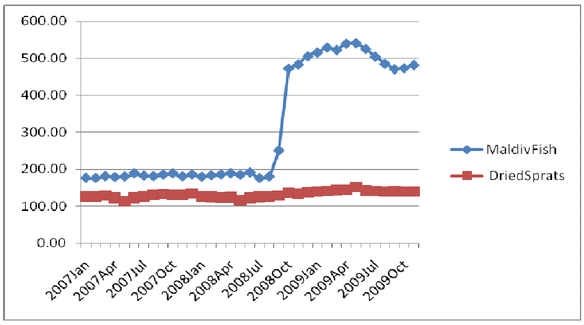

Figure 5.CIF values per kg for Category II items

We observe a slight increase in the CIF per kg for fruits – Category III (see Fig. 6). The quantity has increased despite the increase in CIF per kg. Nearly 5% of total CIF value is spent on importing these three fruits during this period.

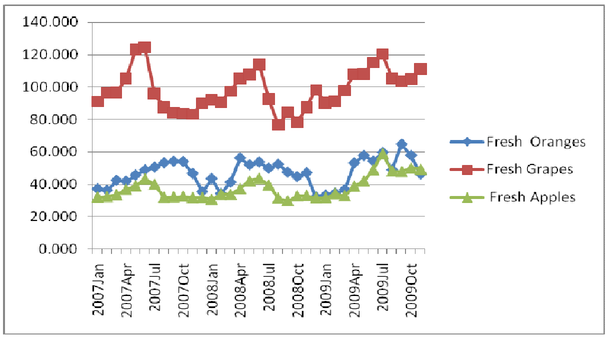

Figure 6.CIF values per kg for Category III items

B. *Time-series Analysis using ART*

This section presents the time series analysis performed using ART [9] for each food item considered in this study. The analysis was performed on quantity in kg and CIF value per kg for each food item. This allows us observe the patterns existing in importation of food items. Also, we can predict the recent future.

Rice: The decision tree for the quantity of rice has two distinct nodes; one node represents the period of January 2007 to February 2008 and the other node thereafter. This implies that the importation of rice has significantly changed after February 2008.

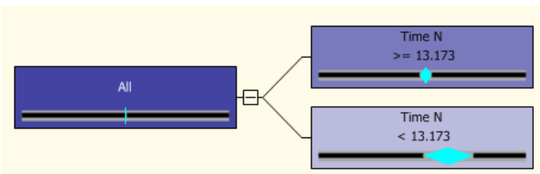

Figure 7. Decision Tree of ART model for quantity of rice

During 2007, the quantity of rice imported per month has been about 15134940 kg. After 2008, it has reduced to 2586950 kg which accounts for about 83% reduction in quantity of rice imported (Table I).

Table I. ART model for quantity of rice

Region	ART model
Time N >= 13.173	Quantity = 2586950.798 + 0.183 * Quantity(-3) + 0.059 * Quantity(-1)
Time N < 13.173	Quantity = 15134940.376 -1.254 * Quantity(-3)

The decision tree splits into two different nodes by CIF value and not by time for rice. Therefore, we see that there are two distinct regions, depending on whether the CIF value of the previous month is less than 76.189 rupees, or greater than or equal to 76.189 rupees (Fig. 8).

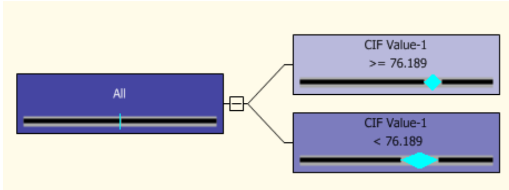

Figure 8. Decision Tree of ART model for CIF value per kg of rice

Although the decision tree splits into two different nodes by CIF value, the two models show that the current CIF value only depends on that of previous month. We need to consider only the very recent past when determining the current CIF value of rice (Table II).

Table II. ART model for CIF value per kg of rice

Region	ART model
CIF Value-1 >= 76.189	CIF Value = 34.430 + 0.461 * CIF Value(-1)
CIF Value-1 < 76.189	CIF Value = 21.423 + 0.695 * CIF Value(-1)

B-onions: The decision tree for the quantity of B-onions has only a single node. Hence, we have only one model to represent the quantity of imported B-onions (Table III). Also, the quantity depends only on that of 2 years ago and one year ago. This implies that the pattern does not fluctuate frequently and the predicted values for immediate future clearly follow the same pattern (Fig. 9).

Table III. ART model for quantity of B-onions

ART model
Quantity = -36522.062 + 0.791 * Quantity(-24) + 0.213 * Quantity(-12)

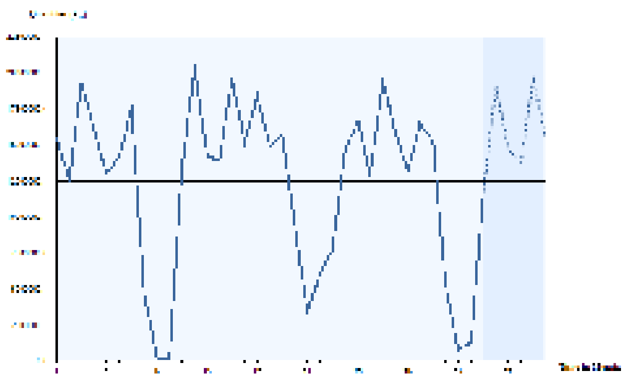

Figure 9. Graph of quantity of B-onions by time

The decision tree for the CIF value of B-onions has only a single node. It only depends on previous month and six months before (Table IV).

Table IV. ART model for CIF value per kg of B-onion

ART model
CIF Value = 24.943 -0.491 * CIF Value(-6) + 0.650 * CIF Value(-1)

Red Onions: The decision tree for the quantity of red onions has only a single node. Hence, we have only one model to represent the quantity of imported red onions for the entire period. The quantity of red onion has no history other than the quantity of previous month (Table V).

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Table V. ART model for quantity of red onions

ART model
Quantity = 530202.939 + 0.691 * Quantity(-1)

The decision tree for the CIF value of red onions has only a single node. Hence, we have only one model for the entire period. Even the current CIF value per kg for red onions depends only on that of previous two months (Table VI)

Table VI. ART model for CIF value per kg of red onions

ART model
CIF Value = 4.992 + 0.544 * CIF Value(-1) + 0.390 * CIF Value(-2)

Dhal: The decision tree produces two distinct nodes by quantity for dhal. Therefore, it follows two different ART models in the two ranges of quantity (Fig. 10).

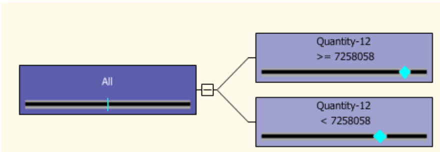

Figure 10. Decision Tree of ART model of quantity of dhal

The model is chosen by the quantity imported before a year. Therefore, the quantity of dhal doesn't change very often and relates to the quantity imported a year ago (Table VII).

Table VII. ART model for quantity of dhal

Region	ART model
Quantity-12 >= 7258058	Quantity = 16417268.904 + 0.345 * Quantity(-12) -0.963 * Quantity(-5) -0.584 * Quantity(-6)
Quantity-12 < 7258058	Quantity = 9679317.785 -0.093 * Quantity(-6) -0.259 * Quantity(-5)

The decision tree for the CIF value of dhal has only a single node. Hence, we have only one model to represent the CIF value of dhal (Table VIII). Also, it only depends on that of the very recent past which means that CIF value of dhal fluctuates frequently.

Table VIII. ART model for CIF value per kg of dhal

AR T model
CIF Value = 4.992 + 0.544 * CIF Value(-1) + 0.390 * CIF Value(-2)

Potatoes: The decision tree produces two distinct nodes by quantity for potatoes. Therefore, it follows two different ART models in the two ranges of quantity (Fig. 11).

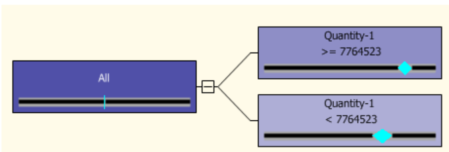

Figure 11. Decision Tree of ART model of quantity of potatoes

The current quantity of potatoes imported only depends on recent past which is last two months (Table IX). The models are chosen based on the quantity imported previous month.

Table IX. ART model for quantity of potatoes

Region	ART model
Quantity-1 >= 7764523	Quantity = 16936094.580 -0.406 * Quantity(-2) -0.423 * Quantity(-1)
Quantity-1 < 7764523	Quantity = 9954527.020 -0.599 * Quantity(-2)

The decision tree produces two distinct nodes by CIF value for potatoes. This shows that there are two distinct periods in the year during which CIF value of potatoes is significantly different. If the CIF value eight months ago is less than about 25 rupees, then the model is different from when it is more than 25 rupees (see Fig. 12).

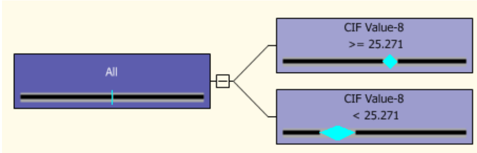

Figure 12. Decision Tree of ART model for CIF value per kg of potatoes

The CIF value of potatoes does not change frequently and correlated only to the CIF value about a year ago (Table X).

Table X. ART model for CIF value per kg of potatoes

Region	ART model
CIF Value-8 >= 25.271	CIF Value = 3.239 -0.152 * CIF Value(-8) + 1.009 * CIF Value(-12)
CIF Value-8 < 25.271	CIF Value = -7.232 + 1.319 * CIF Value(-12)

Maldive fish: The decision tree for quantity of maldive fish produces two distinct nodes, one for before November 2007 and another thereafter (Fig. 13).

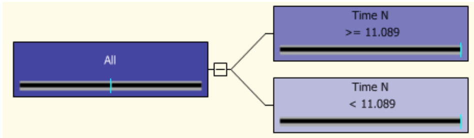

Figure 13. Decision Tree of quantities of Maldives fish

The quantity of maldive fish has remained the same on average during both periods of time (Table XI).

Table XI. ART model for quantities of maldive fish

Region	ART model
Time >= 11.089	Quantity = 370678.600
Time <11.089	Quantity = 370678.600

The decision tree for CIF value of maldive fish produces two distinct nodes, depending on the CIF value of the previous month being more or less than 207 rupees (Fig. 14).

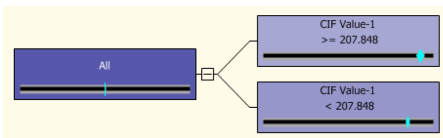

Figure 14. Decision Tree for CIF value per kg of maldive fish

The CIF value of maldive fish follows two different patterns in regions explained above. The current value is correlated only to the CIF value of the previous month and eight months ago (Table XII).

Table XII. ART model for CIF value per kg of maldive fish

Region	ART model
CIF Value-1 >= 92.589	CIF Value = 115.180 -0.416 * CIF Value(-8) + 0.267 * CIF Value(-1)
CIF Value-1 < 92.589	CIF Value = 62.957 + 0.251 * CIF Value(-8)

Dried Sprats: The decision tree for the quantity of dried sprats has only a single node. The average quantity of dried

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sprats is about 3378307 and it only depends on the corresponding figure for three months earlier (Table XIII).

Table XIII. ART model for quantity of dried sprats

ART model
Quantity = 3378307.738 -0.604 * Quantity(-3)

The decision tree produces two distinct nodes by time for CIF value per kg for dried sprats. Before October 2008, the CIF value is significantly different from other time (Fig. 15).

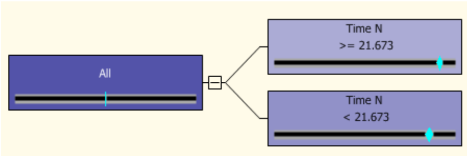

Figure 15. Decision Tree of ART model CIF value per kg of dried sprats

There has been noteworthy increase in the CIF value per kg of the dried sprats in September 2008. Also, it does not change frequently and only has a history of one month (Table XIV).

Table XIV. ART model for CIF value per kg of dried sprats

Region	ART model
Time > = 21.673	CIF Value = 63.676 + 0.552 * CIF Value(-1)
Time < 21.673	CIF Value = 54.691 + 0.566 * CIF Value(-1)

Fresh apples: The decision tree for the quantity of fresh apples has only a single node. The average quantity of apples is about 2173433 and it only depends on the corresponding figure for two months earlier.

Table XV. ART model for quantities of fresh apples

ART model
Quantity = 2173433.103 -0.393 * Quantity(-2)

The decision tree for the CIF value of fresh apples has two distinct nodes. If the CIF value of the previous month is less than 35 rupees, it defines one region; otherwise, the other region (Fig. 16).

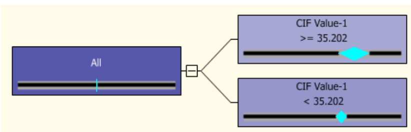

Figure 16. Decision Tree of ART model CIF value per kg of fresh apples

This shows that in one period apples are cheap compared to other times of the year. Anyway, the current CIF value is only related to that of the last month in both periods (Table XVI).

Table XVI. ART model for CIF value per kg of fresh apples

Region	ART model
CIF Value-1 >= 35.202	CIF Value = 11.950 + 0.728 * CIF Value(-1)
CIF Value-1 < 35.202	CIF Value = 7.002 + 0.812 * CIF Value(-1)

Fresh grapes: There has been a significant change in quantity of fresh grapes depending on whether the quantity six months ago is less than 290982 kg or not (Fig. 17).

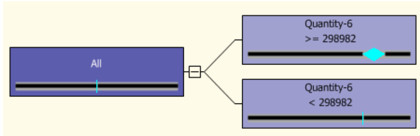

Figure 17. Decision Tree of ART model of quantity of fresh grapes

The quantity of fresh grapes imported has been governed by two models for the two regions produced in the decision tree. It is constant for one region and only varies upon the value six months ago for the other region (Table XVII).

Table XVII. ART model for quantities of fresh grapes

Region	ART model
Quantity-6 >= 298982	Quantity = 397682.569 -0.149 * Quantity(-6)
Quantity-6 < 298982	Quantity = 303908.724

There have been two regions for the CIF value of fresh grapes too. The regions are defined as CIF value of the previous month is less than 93 rupees or not (Fig. 16).

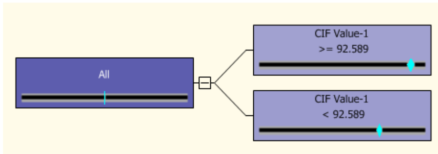

Figure 18. Decision Tree of ART model of CIF value per kg of fresh grapes

The ART model for the region of more than 93 rupees includes the CIF values 8 months ago and one month ago. But, in the other region, it only depends on the value of eight months ago. The CIF value does not frequently change when the value is low. When it is high, the value tends to change frequently as it has a bearing only on the value of previous month (Table XVIII).

Table XVIII. ART model for CIF value per kg of fresh grapes

Region	ART model
CIF Value-1 >= 92.589	CIF Value = 115.180 -0.416 * CIF Value(-8) + 0.267 * CIF Value(-1)
CIF Value-1 < 92.589	CIF Value = 62.957 + 0.251 * CIF Value(-8)

Fresh oranges: The current value of the quantity of fresh oranges imported differs by the quantity imported six months ago. This shows that the demand for oranges is not the same throughout the year. There is a period in which the demand is higher than 314278 kg (Fig. 19).

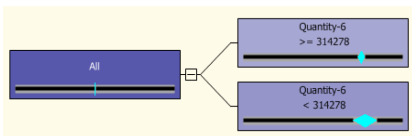

Figure 19. Decision Tree of ART model of quantity of fresh oranges

The quantity imported follows two different models for the two regions produced in the decision tree. In the region where demand is higher, the model depends only on the quantity imported 6 months and 1 year ago. In the other region, it only depends on the value 6 months ago (Table XIX).

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Table XIX. ART model for quantity of fresh oranges

Region	ART model
Quantity -6 > = 314278	Quantity = 509754.389 -0.096 * Quantity(-12) -0.524 * Quantity(-6)
Quantity -6 < 314278	Quantity = 556760.512 -0.669 * Quantity(-6)

There have been two regions for the CIF value of fresh oranges too. The regions are defined as CIF value six months ago is less than 45 rupees or not (Fig. 20).

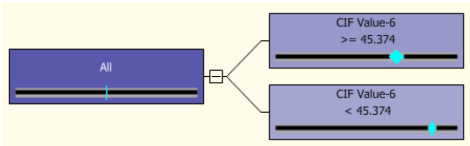

Figure 20. Decision Tree of ART model of CIF value per kg of fresh oranges

Depending on the region, the model for CIF value of oranges has two different forms. If CIF value six months ago is less than 45 rupees, the average CIF value is about 59 rupees and it only depends on the previous month's CIF value. Otherwise, it is about 27 rupees and has a history of six months and one month (Table XX).

Table XX. ART model for CIF value per kg of oranges

Region	ART model
CIF Value-6 >= 45.374	CIF Value = 27.604 + 0.555 * CIF Value(-1) -0.177 * CIF Value(-6)
CIF Value-6 < 45.374	CIF Value = 59.403 -0.113 * CIF Value(-1)

IV. CONCLUSION

This section discusses a study carried out with a data set related to the importation of certain primary food items to Sri Lanka which possesses an agricultural economy.

The food items studied here are rice, Bombay onions (B-onions), red onions, dhal, potatoes, dried sprats, maldive fish, fresh apples, fresh grapes, and fresh oranges. The period considered was from 1st January 2007 to 30th November 2009.

Sri Lanka have been able to reduce the quantity of imported rice significantly which is justified by the increase in production [13]. The largest imported quantity for the food items considered is Bombay onions. The importation of onions (both Bombay onions and red onions) is continuously happening without any change in its pattern. There are times in which the Bombay onions are not imported at all. The same situation occurs often with the import of red onions and potatoes which are considered in this study. Sri Lanka has not imported red onions in the period July to September 2009. The quantity of potatoes defines two ranges clearly. There are times where average quantity is 16936094 kg and other times for which the average is only 9954527 kg.

The CIF value per kg for maldive fish has increased from 181 rupees in 2007 to 509 rupees in 2009. Among other main food items, CIF value per kg for dhal has increased drastically from 2007 to 2009. In 2009, the CIF values per kg of fresh apples and fresh oranges also have increased.

The authors believe that the results presented in this study provide significant insights and knowledge on importation of food items considered here. It can be utilized for better policy decision making in agriculture which paves the way to cultivate some of the food items. The patterns can be used for decision making in importation too, so that Sri Lanka make arrangements to import when price is low in the world market and study seasonality in production and demand of the items considered in this study.

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