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APPLIED BIO-SYSTEMS TECHNOLOGY

Research Article **Open Access**

Shrimp Pond Waste: A Source of Manure for Coconut

Kalpani Wijayasinghe and Indika Herath*

Abstract

Background: Pond waste from shrimp farming in brackish-water is a solid waste that has no identified use, rather become an environmental problem. This study aims to evaluate the potential use of shrimp pond waste as a manure for monoculture coconut plantations.

Methods: The treatments were T1- No fertilizer, T2- Inorganic fertilizer (N, P, K and Mg) and T3- Raw Shrimp Pond Waste (RSPW) with Muriate of Potash. Treatments were arranged in a Randomized Complete Block Design with 3 replicates. After treatment application the soil properties were evaluated by analysing soil pH, electrical conductivity (EC), Organic Carbon (OC), Total N, Available P, Exchangeable K and soil bulk density. Additionally, Water holding capacity (WHC) of soil as a result of addition of RSPW was also evaluated. Foliar nutrient levels of palms were also analysed for primary nutrients, six months after treatment applications.

Results: Results showed that treated soils with RSPW has been given the highest EC (0.63 dS/m) compared to all other treatments. There was no significant difference among the treatments in soil pH, OC, total N and exchangeable K. Available P is also not significantly different between T2 and T3, but significantly higher than the control. The WHC of soil increased by 31 % as a result of adding RSPW. The foliar nutrient levels were higher than critical values in T2 and T3.

Conclusions: According to the results, SPW has the potential of using as a fertilizer for coconut while long term effects need further investigations.

Keywords: Coconut, Organic Fertilizer, Shrimp Pond Waste, Soil Nutrients, Soil Properties

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INTRODUCTION

Coconut (*Cocos nucifera* L.) is a perennial tropical tree, which belongs to the family *Arecaceae*. It grows on a wide variety of soils and tolerates salinity and pH range of 5 to 8. However, coconut thrives best on well-drained soils of at least 1.5 m depth with no hardpans [1]. Fertility status of the soil is one of the main factors that influences the performance of coconut [2]. High amount of nutrients is removed through the harvest as well as other uses of different parts of the coconut palm. These nutrients should be replenished through regular fertilizing to maintain productivity of coconut palms [3]. Inorganic fertilizers, organic fertilizers or fertilizer mixtures are widely used to provide the nutrient requirement of palms.

The nutrient requirement of young coconut palms is different from that of adult coconut palms. The order of the nutrient requirement for young coconut palm is N>P>K>Mg and for adult coconut palm is K>Mg>N>P [4]. Accordingly, separate fertilizer recommendations have been developed for young palms and bearing palms. Even though growers are willing to use organic or natural sources of fertilizers/manures, lack of availability tend to limit the use of organic manure [5]. Furthermore, low levels of K in organic manure restricts the total replacement of inorganic fertilizer to supply nutrient requirement of adult coconut palms. Therefore, it is recommended to add muriate of potash or other K source together with organic manure, especially for tropical soils, which are comparatively low in K [6].

Shrimp farming in brackish-water ponds is a rapidly growing industry in many tropical nations, including Sri Lanka [7]. Shrimp aquaculture predominantly occurs in lagoon-based water systems [8]. During shrimp culture, a mixture of gasses, liquids, semi-solids and solid forms are continuously produced as waste products. When pond water is discharged, some of these materials settles out on the bottom and becomes semi-solid and solid waste [9].

Discharge of pond waste from shrimp farming has been a serious problem in most of the coastal areas in tropical countries. It is due to difficulties in acquiring new sites for disposal. This waste discharge process of shrimp farming has already caused numerous environmental issues such as deterioration of coastal water quality and hydrology, detrimental impacts on aquatic organisms, mangroves and terrestrial vegetation.

Therefore, investigating the potential use of shrimp pond waste (SPW) is a pressing need. The salt content of this material can be a problem in its application to terrestrial vegetation. The tolerance level of different plant species varies widely, while some crops such as coconut have relatively higher tolerance levels. The characteristics of SPW may vary with pond water quality, rainfall of the area and pond inputs [9].

Among the limited number of studies conducted on the issues related to discharge of SPW, a study from Indonesia has attempted to develop an organic fertilizer to be used in cultivating *Caulerpa lentiilifera* [10]. Further, Latt [9] has studied the effect of SPW on papaya, banana, rubber and jasmine plantations in Thailand. Papaya plants have shown less tolerance as they had produced more leaves but no fruits. However, banana, rubber and jasmine plantations have not reported any negative effects.

Shrimp pond waste consist of solids; residue of pond inputs such as unconsumed feed, biological wastes from the shrimp and other organisms (plankton, bacteria) and dissolved matter such as ammonia, urea, carbon dioxide and phosphorous [11]. In addition, SPW has a considerable amount of organic matter, total nitrogen and phosphorous [9]. Further, SPW also contain clay and silt particles responsible for increasing the water holding capacity. Water holding capacity is an important factor that represents the ability of soil to hold water.

It is a property widely considered in irrigation scheduling, crop selection, groundwater contamination considerations and estimation of runoff. It varies with soil texture and organic matter [12]. Accordingly, soils with smaller particles such as silt and clay have a higher volume of microspores and allows the soil to hold more water than soils with large particles like sand.

The uneven distribution patterns of rainfall over time, combined with intense insolation, results in low soil water content causing moisture stress on crops during dry spells [13]. As a rich organic clayey material SPW has a potential to enhance the water holding capacity in the soil while enhancing soil fertility. Therefore, this study aims to evaluate the potential of pond waste from shrimp farming as a manure for adult coconut plantations, in terms of supplying nutrients and conditioning the soil, to enhance the soil properties.

METHODOLOGY

Study Area

The experiment was carried out at an adult coconut plantation in the Low Country Intermediate Zone of Sri Lanka in 2018. The plantation was a monoculture of coconut palms belonging to 20 – 25 year range, with an annual inorganic fertilizer application history. This adult coconut plantation in the Intermediate Zone was selected to represent the major coconut growing areas of the country. Shrimp pond waste samples were collected from a shrimp farm in the North-western province, Sri Lanka.

Study Design & Sample Collection

There were three treatments; T1: No fertilizer (Control); T2: Inorganic fertilizer treatment (Recommended fertilizer mixture + Dolomite) and T3: 30 kg of RSPW + 1.25 kg of Muriate of Potash (MOP). The rate of shrimp pond waste application was decided based on the current recommendations of organic manure and farm yard manure for coconut palm [14].

The experiment was designed based on the Randomized Complete Block Design with three treatments. There were six palms in each plot, from which three palms were selected randomly for sampling. Treatments were applied when the soil was moist after rains. The Manure Circle (MC); the circular area around the tree, which is of 1.8 m radius from the tree was cleaned. Then treatments were applied in the MC, mixed with soil immediately and covered with a mulch from fallen coconut fronds.

Soil samples were collected from 3 points of the MC at the depth of 10 – 20 cm from individual palms, before treatment application and three months after application. Collected samples were air-dried and analysed for their soil properties.

Analysis of Soil Samples

Soil pH and Electrical Conductivity (EC) were determined using a glass electrode pH meter (Mi 180 Bench Meter, Milwaukee) [15-16]. Soil Organic Carbon (OC) was determined using Walkley and Black method [17]. Kjeldahl distillation method [18] was used to determine the Total and Available N. Available P was analysed using the Olsen method [19] and absorbance was measured at 880 nm wave length using a spectrophotometer (Shimadzu Europe - UV mini 1240). Potassium was determined by extraction with Ammonium acetate solution and analysed using a flame photometer (Sherwood Scientific, UK – Model 360). Soil bulk density was determined using the core sample method [20].

Water holding capacity of soil was determined according to the method described by Mangrich *et al*. [13], separately in a soil column using soil amended with two ratios of SPW (as 10 g and 20 g of SPW per 100 g of soil). Water holding capacity was calculated using equation 1.

$$WHC\ (\%) = \frac{mass_{wet} - mass_{dry}}{mass_{dry}} \times 100\% \quad [1]$$

Analysis of Leaf Samples

Leaf samples were collected representatively from the index leaf, the 14th leaf from the top, the 1st being the fully opened leaf with its leaflets separated, six months after treatment application. Six leaflets were taken from the mid region of the leaf and composited to form a representative sample. The oven dried leaves were ground and used for chemical analysis. The leaf N was determined in 0.1 g samples digested in Se/H_2S0_4 mixture, while 0.5 g samples digested in a $HNO_3/HCLO_4$ mixture were used for P and K. Nitrogen and P were determined colorimetrically using a Continuous Flow Analyzer and K by an atomic absorption spectrometer.

Statistical Analysis

Analysis of variance (ANOVA) was used to analyse the data using SAS Statistical software (Version 9.4).

RESULTS AND DISCUSSION

The composition of SPW analysed in three replicates are given in the Table 1 with standard deviations (SD). According to the results, SPW contained 2.78% of OC, which indicated its potential to enhance the OC in soil.

Table 1: Chemical Properties of Shrimp Pond Waste (Mean ± SD**)**

Parameter	Mean ± SD
pH	7.63 ± 0.04
EC (dS/m)	7.79 ± 0.05
OC %	2.78 ± 0.06
Total N %	0.23 ± 0.01
Available P (ppm)	622.04 ± 19.97
Exchangeable K (ppm)	627.89 ± 5.86

Electrical conductivity (EC) of SPW was 7.79 ± 0.05 dS/m. It is a measure of the amount of salts (salinity) in soil. It is also an indicator of nutrient availability. However, EC does not provide a direct measurement of specific ions or salt compounds. However, it has been correlated with the concentrations of ions like nitrates, potassium, sodium, chloride, and sulphate in soil. The pH of the pond waste is in the neutral range, while the total N and exchangeable K was low. However, available P was comparatively high, according to classification given by Dharmakeerthi *et al*. [21].

Soil Properties of Experimental Site

Soil pH of the experimental site was in the neutral range (Table 2). According to the results, EC and OC level of initial soils were also very low. The total N content was also low. However, available P and exchangeable K in this soil were very high according to classification given by Dharmakeerthi *et al*. [21].

Table 2: Chemical and Physical Parameters of the Soil in the Experimental Field

Parameter	Mean ± SD
pH	7.10 ± 0.29
EC (dS/m)	0.12 ± 0.06
OC %	0.69 ± 0.23
Total N %	0.11 ± 0.04
Available P (ppm)	347.88 ± 82.88
Exchangeable K (ppm)	274.98 ± 172.74
Bulk Density (g/cm^3)	1.43 ± 0.06

Soil Properties after Treatment Application

Properties of soils taken representatively from the MC of the palms three months after the application of treatments denote a clear difference in properties after adding SPW.

Soil pH and Electrical Conductivity (EC)

Soil pH of the treatments varied from pH 6.82 to 7.03 and the highest pH of 7.03 was recorded in T1 (control), while the lowest (6.82) value was given by T3 (RSPW), as shown in Table 3. While there was no significant difference among the three treatments, slight reduction of pH due to application of fertilizer and manure was evident. All treatments reported favourable pH levels for coconut. Coconut can be grown well in the range of pH 5 to 8 [1]. Most of the macro nutrients increase their availability in the neutral pH levels.

Soil EC ranged from 0.08 dS/m to 0.63 dS/m and the highest EC was given by T3, while minimum was given by T1 (control). When compared with the initial soil EC, SPW applied treatment had increased the EC of soil (Table 3). It may be due to the increment in the ionic concentration of SPW. However, it is well within the EC levels of coconut growing soils. For a crop like coconut, this might not cause any issue, rather being an advantage as coconut thrives in soils with high EC. Furthermore, ions like sodium are considered to be beneficial for coconut.

Soil Organic Carbon

Soil OC percentage of the treatments varied from 0.6% to 1.2% (Table 4). The T3 recorded the highest OC content of 1.2%. However, OC content among treatments was not statistically significant. Increased OC content leads to multiple benefits with respect to soil fertility [22]. The higher OC content of the SPW may, enhance the soil OC content over the time, which is considered to be of paramount importance in tropical soils.

Table 3: The pH and Electrical Conductivity of Soil under Different Fertilizer Applications (Mean ± SD)

Treatment	pH	Electrical Conductivity (dS/m)
T1	$7.03^{a} \pm 0.28$	$0.08^{c} \pm 0.02$
T2	$6.99^{a} \pm 0.20$	$0.41^{b} \pm 0.16$
T3	$6.82^{a} \pm 0.11$	$0.63^{a} \pm 0.10$

Note: Means with different superscript letters in the same column represent significant differences at P<0.05 level. T1: Control, T2: Inorganic fertilizer applied treatment, T3: Raw shrimp pond waste applied treatment.

Soil Total Nitrogen

Soil total N ranged from 0.13% to 0.18% in all treatments (Table 4). The SPW applied treatment (T3) recorded the highest total N content of 0.18%. The inorganic fertilizer treatment (T2) resulted 0.17% of total N content, while the control showed the lowest (0.13 %).

There was no statistically significant difference in total N percentage among treatments. When compared to initial soil N level, both fertilizer applied and SPW applied treatments had increased the soil N even after three months of application.

Soil Available Phosphorous

Soil available phosphorous ranged from 243.19 ppm to 944.74 ppm in all treatments (Table 4). Available phosphorous content was significantly higher in T2 and T3, compared to the control. This indicates that the SPW has been able to enhance the soil phosphorous to a similar level of inorganic fertilizer applied treatment.

Soil Exchangeable Potassium

Soil exchangeable K of treatments ranged from 99.05 ppm to 985.34 ppm (Table 4). Maximum exchangeable K was recorded by T2, while minimum was recorded by T1 (control). However, there was no significant difference among treatments. When compared with the initial soil, exchangeable K had increased in soil after addition of SPW.

Soil Bulk Density (BD)

Bulk density indicates the compaction of soil and ease of root penetration. Soil BD was significantly lower in T2 and T3, compared to control (T1). However, there was no significant difference between T2 and T3. (Table 5). Bulk density is influenced by some soil properties such as the amount of organic matter in soils, texture, constituent minerals and porosity [23].

Generally, soils with low BD have favourable physical conditions for plant growth. The T3 recorded significantly lower BD than T1 (control soil). This can be considered as an advantage of making favourable conditions to penetrate roots deep into the soil, especially for coconut, which consists of a fibrous root system.

Water Holding Capacity (WHC)

The Water holding capacity (WHC) of normal soil (without adding treatment) was 25.2% (w/w).

Table 4: Chemical Parameters of Soil under Different Fertilizer applications (Mean ± SD)

Treatment	Organic Carbon (%)	Total N %	Available P (ppm)	Exchangeable K (ppm)
T1	$0.60^{a} \pm 0.20$	$0.13^{a} \pm 0.02$	$243.19^{b} \pm 170.24$	$99.05^{a} \pm 49.85$
T2	$0.78^{a} \pm 0.22$	$0.17^{a} \pm 0.02$	$944.74^{a} \pm 268.36$	$985.34^{a} \pm 948.48$
T3	$1.18^{a} \pm 0.30$	$0.18^{a} \pm 0.04$	$895.92^{a} \pm 277.93$	$443.00^{a} \pm 81.31$

Note: Means with different superscript letters in the same column represent significant differences at P<0.05 level. T1: Control, T2: Inorganic fertilizer applied treatment, T3: Raw shrimp pond waste applied treatment.

Table 5: Variation in Bulk Density of Soils under Different Fertilizer Applications (Mean ± SD)

Treatment	Bulk density (g/cm^3)
T1	$1.25^{a} \pm 0.20$
T2	$0.98^{b} \pm 0.04$
T3	$1.00^{b} \pm 0.04$

Note: Means with different superscript letters in the same column represent significant differences at P<0.05 level. T1: Control, T2: Inorganic fertilizer applied treatment, T3: Raw shrimp pond waste applied treatment.

The WHC of SPW amended soil was 33.03% (w/w). WHC was significantly increased by adding SPW (Figure 1).

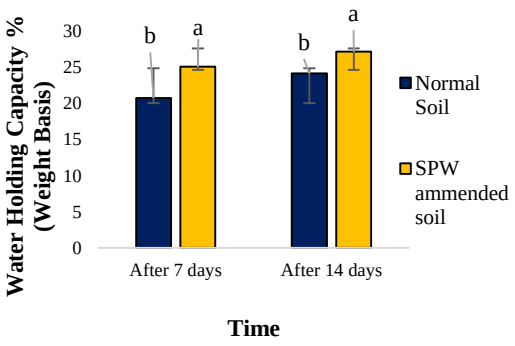

Figure 1: Variations in Water Holding Capacity of Soil Treated with Shrimp Pond Waste After 7 and 14 Days (Mean ±SD)
Note: Means with different letters represent significant differences at p<0.05 level

Foliar Nutrient Levels

The use of foliar nutrient analysis as a tool for the diagnosis of nutritional deficiencies in perennial crops, is now well recognized [24]. In this method, leaf nutrient levels are compared against the critical nutrient levels [25-26]. According to the results of the analysis, foliar nutrient levels of the conventional fertilizer applied treatment and SPW treated palms were above the critical values of the primary nutrients (Table 6). This shows that SPW has been able to provide nutrients in sufficient levels. Especially, nitrogen and phosphorus. Meanwhile, the control treatment reported values lower than critical values for all three primary nutrients.

Table 6: Leaf Nutrient Levels of Palms under Different Fertilizer Applications (Mean ± SD)

Treatment	Nitrogen %	Phosphorus %	Potassium %
T1	1.70 ± 0.02	0.09 ± 0.02	0.90 ± 0.03
T2	2.13 ± 0.02	0.21 ± 0.04	1.31 ± 0.06
T3	2.18 ± 0.04	0.18± 0.03	1.25 ± 0.04
Critical Values	**1.90**	**0.11**	**1.20**

Note: T1: Control, T2: Inorganic fertilizer applied treatment, T3: Raw shrimp pond waste applied treatment.

CONCLUSIONS

Results indicate that Shrimp Pond Waste (SPW) has been able to enhance soil phosphorous, organic carbon and bulk density, while providing sufficient levels of nutrients to the palm. Therefore, it has a potential of enhancing soil fertility and increasing the water holding capacity of soil.

However, soil EC has been increased with the addition of SPW. For a crop like coconut, this may not cause any issue as they thrive in soils with higher EC. However, it is

important to study the long term effects to see if there is a risk of salinity build- up as a result of SPW application.

CONFLICT OF INTEREST

The authors would like to declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

KW: Data collection, statistical analysis, and prepared the first draft of manuscript; IH: Designed the research, managed experiment and revised the manuscript.

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APPLIED BIO-SYSTEMS TECHNOLOGY

Research Article **Open Access**

Development and Analysis of Physico-Chemical Properties of Set Yogurt Dual Fortified with Oat Powder and Ripe Jackfruit Flesh Pulp

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Abstract

Background: Functional foods fortified with cereals and fruit pulp have shown high consumer demand mainly due to their health benefits. This study aimed at developing a dual fortified set yogurt incorporating oat (*Avena sativa*) powder, which is a rich source of nutrients and fibre, and ripe jackfruit (*Artocarpus heterophyllus*) flesh pulp, which is a rich source of nutrients and bioactive agents, as a functional food.

Methods: Oat (3.75% w/v) fortified set yogurt was prepared by incorporating ripe jackfruit pulp at 10%, 20%, 30% w/v quantities. The shelf life study of the developed yogurt was evaluated by measuring physicochemical properties such as pH, titratable acidity (TA), total soluble solids (TSS), syneresis and firmness, and by investigating the total plate count, and yeast and mould count for 21 days.

Results: Sensory analysis revealed that the 10% fruit pulp added yogurt was most accepted, which was hence chosen for further analysis. According to proximate analysis, the developed yogurt was higher in many nutrients, including protein, fat and fibre, than a market yogurt. Further, the developed yogurt can be used as a high-energy low-carbohydrate yogurt.

Conclusions: All the physicochemical parameters were within the acceptable levels up to 12-15 days and microbial safety was adequate up to 14 days. Thus, this product has potential to become a fermented milk based product with favourable sensory properties, which can be promoted as a healthy food product.

Keywords: Jackfruit, Oat, Physicochemical Properties, Proximate Analysis, Set Yogurt

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INTRODUCTION

Formulation of functional foods fortified or enriched with numerous nutrients, is given much emphasis at present. Such approaches often enhance the ability of the consumers to prevent or combat numerous non-communicable diseases such as diabetes, high blood pressure, hypercholesterolemia and cancer [1–4]. Active ingredients used in the formulation of functional foods giving such health benefits are of various types and include vitamins such as vitamin B and D [5–6], minerals such as calcium and iron [7–8], plant derived ingredients such as phenolic compounds or extracts, essential oils and dietary fibre [9], and animal derived ingredients such as omega-3 fatty acids [10]. Interestingly, formulation of fruit pulp incorporated functional foods is extensively studied, due to the high demand and health benefits associated with the fruit pulps [11].

Jackfruit (*Artocarpus heterophyllus Lam*.) is a major fruit native to India and found commonly in the tropics. Jackfruit flesh pulp is highly nutritious and possesses active ingredients that provide numerous health benefits. In addition to the starch content, which varies with the degree of maturity of the fruit and moderate fibre content, jackfruit flesh consists of a protein content of 0.57 – 0.97%. The vitamins rich in jackfruit include Vitamin C, and vitamins such as riboflavin, niacin, pyridoxine, and folic acid of the B-complex group. Minerals that improve the nutritive value of jackfruit flesh include macro elements such as calcium and magnesium and micro elements such as iron and manganese. Jackfruit is also a good source of phytochemicals that contribute much towards human health. For instance, carotenoids, a major phytochemical of jackfruit flesh, exhibits anticancer, antioxidant and anti-inflammatory properties, in addition to many other properties beneficial for health [12]. Thus, numerous functional foods, such as jam, cake, ice-cream, ready-to-serve beverages and low-fat yogurt, have been formulated incorporating ripe jackfruit flesh pulp [12–15].

Among the plentiful functional foods developed so far, functional yogurt products have secured a prominent place. It is mainly due to the high demand around the world for the fermented milk products. Yogurt fortified with minerals such as iron, calcium and zinc [16], and vitamins such as Vitamin B12 and D [17–18] have been successfully formulated and many such products have shown health benefits [17-18]. In addition, yogurts incorporated with many types of fibre or fibre sources such as psyllium husk, extruded flaxseed powder, persimmon powder and apple powder [19–21] have been successfully formulated improving the lipid profiles of the consumers [20].

Oats is a promising functional ingredient to be incorporated in yogurt as it is rich in fibre [22], nutrients such as vitamins, minerals, fat and protein [23], and bioactive agents such as antioxidants [24]. The health benefits of oats include improving of the lipid profile of hypercholesterolemic subjects, mainly due to β-glucan, and assisting in the treatment of hyperglycemia, mainly due to its low glycemic index [23]. In an attempt to transfer the health benefits of oats to the consumers via yogurt, which is a much consumer preferred food product, Malki *et al.* developed oat-flakes incorporated set-yogurt successfully [25].

Although fruits such as strawberry, blueberry, sour cherry and jackfruit have been used to make naturally flavoured yogurt [15, 26], jackfruit has not been used to flavour oat incorporated yogurt. Thus, this study aimed to develop jackfruit pulp fortified oat incorporated set yogurt as a dual fortified yogurt product, as an extension to our previous study. In addition to combining the health benefits of both jackfruit flesh and oats, incorporating the jackfruit flavour, which may enhance consumer acceptance in the yogurt product, was also targeted.

METHODOLOGY

Materials

The starter culture with *Streptococcus*

thermophillus and *Lactobacillus bulgaricus* was purchased from the Veterinary Research Institute (VRI), Gannoruwa, Sri Lanka. Oat flakes (Stassen Exports Pvt. Ltd, Colombo, Sri Lanka), full cream fresh milk with acceptable organoleptic and microbial quality (Kothmale Holdings PLC, Sri Lanka), sucrose, non-fat milk powder (Fontera Brands, Sri Lanka) and potassium sorbate (INS No.202) were purchased from a local retail shop. Also, a yogurt product with a reputed brand name was purchased from a retail shop.

Preparation of Jackfruit Flavoured Oat Incorporated (Dual Fortified) Set Yogurt

Preparation of yogurt was carried out using the procedure reported by Malki *et al.* [25] with slight modifications. Briefly, sucrose (100 g), non-fat milk powder (10 g), and oat powder sieved through a 0.18 mm sieve (3.75% w/v) were mixed with 1000 ml of full cream fresh milk. Gelatin (10 g) was dissolved in slightly warm water (60 - 65 °C) and mixed up with the other ingredients. When the mixture was heated to 80 °C, ripe jackfruit flesh pulp (10%, 20% and 30%) was mixed well according to the treatments indicated in Table 1.

Table 1: Different Jackfruit Pulp Levels used in the Study

Treatment	Jackfruit Pulp Level (w/v %)
C (Control)	-
T_1	10
T_2	20
T_3	30

The mixture was stirred well for homogenization. The yogurt mixture was pasteurized at 90 °C for 15 minutes with continuous stirring. The pasteurized yogurt mixture was cooled down to 45 °C and the yogurt starter culture was added, according to the recommendations of Veterinary Research Institute, Gannoruwa. Also, potassium sorbate (300 mg/kg) was added as the preservative. The yogurt mixture was incubated at 42 °C for 4-5 h until the pH reached 4.6. Finally, the mixture was refrigerated at 4 - 8 °C. Preliminary trials were conducted to select three different levels of jackfruit flesh pulp that can be used to incorporate in yogurt (Table 1).

Sensory Evaluation

An untrained panel of 30 members, who were selected among the university students and lecturers, carried out a sensory evaluation to select the best yogurt formulation with the highest consumer acceptance out of the four different treatments (Table 1). A 5-point hedonic scale was used to evaluate the attributes of colour, appearance, odour, sweetness, sourness, taste, overall quality and purchasing intension [25].

Physicochemical Parameters of Jackfruit Pulp and Oat Incorporated Yogurt

Yogurt was stored at refrigerated condition (4 - 8 °C). The following tests were conducted for a period of 21 days at 3-day intervals. Determination of pH was carried out by using a digital pH meter (Model: pp-206, EZODO). Total soluble solids (TSS; Brix%) was measured using a handheld refractometer (Model: ATAGO N-46, Japan). Titratable acidity was measured by titrating the yogurt samples against 0.1 N NaOH by using phenolphthalein as the indicator. Syneresis was measured for a time period of 21 days at 7-day intervals [25]. The firmness (texture) was measured using a texture analyser (ATAGO N-46, Japan).

Proximate Analysis of Jackfruit Pulp and Oat Incorporated Set Yogurt and Market Yogurt

The moisture content (MC), ash content and total solid content (TS) were determined according to the methods given by the Association of Official Analytical Chemists [27]. The crude fat content was determined by Soxhlet extraction method [27] and crude protein content was determined by Kjeldhal method [27]. The solid non-fat content (SNF) was determined according to SLS standard 824: Part 2 [28], along with the crude fibre content. The percent carbohydrate content and energy level were calculated according to

a standard formula [25]. Proximate analysis of both the developed yogurt and market yogurt was carried out.

Shelf Life Evaluation of Jackfruit Pulp and Oat Incorporated Yogurt

Shelf life evaluation of yogurt, stored at 4 – 8 °C, was carried out according to SLS 824 [28] for a time period of 21 days at 7-day intervals. Plate count agar was used for the bacterial colony count and potato dextrose agar was used for the yeast and mould count. Bacterial colony counts were taken in 24 h. The entire experiment was triplicated.

Statistical Analysis

Data of sensory evaluation was analysed by a non-parametric method (Friedman Test) while quantitative data were analysed with Analysis of Variance (ANOVA) using MINITAB (version 15) statistical software.

RESULTS AND DISCUSSION

Sensory Evaluation

The acceptance test carried out for nine attributes of yogurt samples revealed that colour, sweetness, sourness, taste, and overall quality were similar among the control and the three treatments. However, appearance, odour, texture, and purchasing intension were significantly different ($P<0.05$) among the different yogurt samples. The Treatment 1 (i.e. 10% jackfruit pulp) exhibited the best scores for most of those attributes. Treatment 1 was the best in appearance and texture with median scores of 3.81. Further, Treatment 1 was the second best in odour with a median of 3.13, while the control was the best with a median of 3.38.

The overall quality of the samples was similar with each sample showing a median of 3.50, however, Treatment 1 showed the highest sum of ranks, leading to the highest purchasing intention score (median score=4.00), while all other types of samples exhibited a median of only 3.00. Also, the sum of ranks for Treatment 1 was 93.5, while that of the control, which was the second best, was only 76.0, indicating the aptness of ripe jackfruit flesh pulp to enhance the sensory qualities of oat powder incorporated yogurt. These results reveal that dual fortified yogurt with excellent sensory attributes can be formulated by incorporating oat powder at a concentration of 3.75% (w/v) and ripe jackfruit pulp at a concentration of 10% (w/v). The mean scores of the different yogurt samples with respect to the sensory attributes are indicated in Figure 1.

Physicochemical Parameters

The physicochemical parameters of yogurt are indicative of the quality and shelf-life of the product. The physicochemical parameters of Treatment 1 (i.e. 10% jackfruit pulp), which was chosen for further analysis, showed a significant variation with time as expected (Table 2).

The pH of the yogurt sample decreased and TA of the yogurt sample increased with time, which could be ascribed to the conversion of lactose into lactic acid, due to bacterial fermentation [29]. The pH values were in acceptable range up to 12 - 15 days and TA values were acceptable up to 18 days [28]. TSS decreased with time possibly due to the consumption of soluble material by bacteria during fermentation.

The variation of syneresis, which indicates the extent of whey separation, with time was determined as a quality parameter. Although syneresis of regular yogurt gradually increases with time most probably due to the rearrangement of the casein network [30], syneresis of Treatment 1 significantly decreased with storage time (Table 3). Treatment 1 contained a higher fibre and TS level that can hold water, due to the incorporation of jackfruit pulp and oat powder. In addition, the interactions of increased fibre and total solids with whey protein and changing casein network would have caused the decrement of syneresis with time, of Treatment 1. In fact, the incorporation of β-glucan, which is the major fibre component of oats and incorporation of fruit material such as apple pomace have reduced

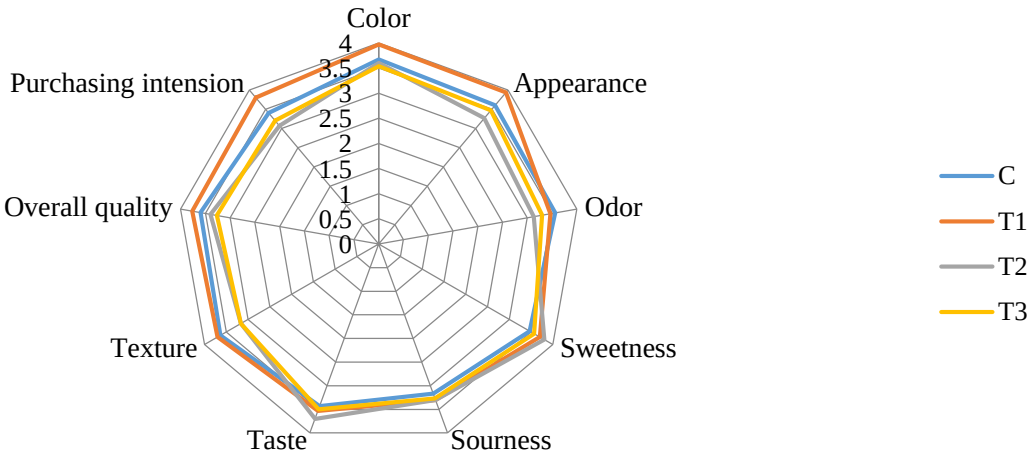

Figure 1: Mean Scores of Different Yogurt Samples for Sensory Attributes
Note: C: Control (no jackfruit pulp), T1: Jackfruit pulp 10%, T2: Jackfruit pulp 20%, T3: Jackfruit pulp 30%

Table 2: Variation of Physicochemical Properties of Jackfruit Pulp (10% w/v) and Oat (3.75% w/v) Incorporated Set Yogurt with Time

Time Period (Days)	pH	TA (%)	TSS (%)
Initial	$4.6^{a} \pm 0.01$	$0.8^{e} \pm 0.00$	$28.1^{a} \pm 0.33$
3	$4.6^{b} \pm 0.00$	$0.8^{e} \pm 0.03$	$26.5^{ab} \pm 0.33$
6	$4.5^{c} \pm 0.01$	$0.9^{ed} \pm 0.00$	$25.5^{bc} \pm 0.33$
9	$4.5^{d} \pm 0.01$	$1.0^{cd} \pm 0.06$	$24.3^{d} \pm 0.29$
12	$4.5^{e} \pm 0.01$	$1.0^{c} \pm 0.03$	$23.5^{de} \pm 0.33$
15	$4.5^{f} \pm 0.00$	$1.1^{cb} \pm 0.03$	$22.5^{e} \pm 0.33$
18	$4.4^{g} \pm 0.00$	$1.1^{b} \pm 0.03$	$21.1^{f} \pm 0.33$
21	$4.3^{h} \pm 0.00$	$1.3^{a} \pm 0.03$	$20.5^{f} \pm 0.33$

Note: Values with different superscript letters in each column denote significant differences at 0.05 significance level. TA: Titratable Acidity, TSS: Total Soluble Solids.

syneresis of yogurt [31-32]. Favourably, the firmness of Treatment 1, which is the jackfruit pulp (10% w/v) and oat (3.75% w/v) incorporated yogurt, remained constant up to day 21 (Table 3).

Proximate Analysis

Proximate analysis results of the selected jackfruit pulp (10% w/v) and oat (3.75% w/v) incorporated yogurt (T1) were compared with that of a representative market yogurt, in order to evaluate the content of basic food components. Table 4 gives the proximate composition of the yogurt developed in this study and 'market yogurt'.

Table 3: Variation of Syneresis and Texture (firmness) of Jackfruit Pulp (10% w/v) and Oat (3.75% w/v) Incorporated Yogurt with Time

Time (Days)	Syneresis (%)	Texture or Firmness (N)
Initial	$6.9^{a} \pm 0.07$	$0.12^{a} \pm 0.01$
7	$4.9^{b} \pm 0.24$	$0.66^{a} \pm 0.28$
14	$3.3^{c} \pm 0.06$	$0.15^{a} \pm 0.09$
21	$2.2^{d} \pm 0.16$	$0.06^{a} \pm 0.01$

Note: Values with different superscript letters in each column denote significant differences at 0.05 significance level.

Table 4: Variation of Proximate Parameters of Jackfruit Pulp (10% w/v) and Oat (3.75% w/v) Incorporated Yogurt and Market Yogurt

Proximate Component	Market Yogurt	Jackfruit Pulp and Oat Incorporated Yogurt
MC%	$70.7^{a} \pm 0.47$	$70.8^{a} \pm 0.12$
TS%	$31.0^{b} \pm 0.30$	$35.8^{a} \pm 0.71$
Ash%	$0.1^{b} \pm 0.03$	$0.5^{a} \pm 0.03$
Protein%	$2.9^{b} \pm 0.01$	$5.9^{a} \pm 0.06$
Fat%	$3.0^{b} \pm 0.06$	$4.0^{a} \pm 0.12$
SNF%	$31.3^{b} \pm 0.18$	$40.4^{a} \pm 0.48$
Fibre%	$0.0^{b} \pm 0.00$	$1.0^{a} \pm 0.03$
Carbohydrate%	$23.3^{a} \pm 0.49$	$18.0^{b} \pm 0.19$

Note: Values with different superscript letters in each column denote significant differences at 0.05 significance level.

Although the moisture content of T1 was higher than that of the market yogurt, the increase was only 0.1%, which indicates that the moisture content of T1 is at an acceptable level. As expected, T1 showed a higher mean value for TS (35.8%), than the market yogurt which showed a value of 31.0%. It is due to the incorporation of jackfruit and oats. Also, the high mineral content of jackfruit pulp and oats, which is beneficial for human health, resulted in a significantly higher ash content of T1 (0.5%) than the market yogurt (0.1%).

The protein content of T1 (5.9%) was significantly higher than that of the market yogurt (2.93%), due to the addition of jackfruit and oats rich in proteins [12, 23] in the T1 formulation. Also, the fat content of T1 (4.0%) was significantly higher than that of the market yogurt (3.0%) as, incorporation of oats in T1 is a good source of fat [12]. Further, the fat content of T1 is above the minimum level of fat content required for yogurt [28]. This is a favourable and essential factor as fat contributes to building the microstructure of yogurt.

The two yogurt samples showed significantly different solid-non-fat (SNF) contents. The SNF value of T1 (40.4%) was significantly higher than that of the market yogurt (31.3%), due to the incorporation of oats, especially rich in fibre, and jackfruit pulp in T1. SNF of regular yogurt mainly contains carbohydrate, lactose, protein and mineral matter [33] and the SNF value should be at least 8% [28]. This value may be raised in order to achieve the appropriate texture and viscosity of the final product [34]. The high score for texture exhibited by T1 according to the sensory evaluation may be because of the high SNF value of T1. In addition, the fibre content contributing to SNF content of T1 may give functional properties to the developed yogurt as described previously. In fact, the fibre content of T1 was significantly higher than that of the market yogurt.

Although T1 consisted of higher percentages of protein, fat, fibre and ash, the market yogurt consisted of a significantly higher percentage of carbohydrates than T1, indicating the suitability of T1 for low carbohydrate diets. Nevertheless, T1 and market yogurt showed comparable energy values approximating to 130 kCal/100g, indicating the appropriateness of T1 for obtaining energy through consumption.

Microbial Safety Evaluation of Jackfruit Pulp (10% w/v) and Oat (3.75% w/v) Incorporated Yogurt

Microbial spoilage which leads to the development of unfavourable sensory attributes, undesirable physicochemical changes and toxins, and growth of pathogens, may result in food products unfit for consumption. Thus, the microbial safety of the developed yogurt product was assessed using the total plate count and yeast and

mould count. The bacterial count showed a steep increase up to the seventh day, after which it showed a slow increase up to the 14th day (Table 5). The bacterial count reduced after the 14th day as indicated by the plate count on the 21th day, due to the spoilage of the yogurt sample, mainly due to the increment of acidity which retards the bacterial growth in yogurt [33].

The yeast and mould count increased with time. The development of high acidity and low oxygen conditions during the fermentation process may offer favourable conditions for the growth of yeasts and moulds of which contamination takes place mainly due to the processing environment [35]. This result indicates that ripe jackfruit pulp (10% w/v) and oat powder (3.75% w/v) incorporated yogurt is more suitable for consumption within 14 days from the day of production at the preservative (potassium sorbate) level of 300 ppm. However, the preservative level could be increased up to 1000 ppm according to the Codex Standard [36] for increasing the shelf life of yogurt.

Table 5: Variation of Total Plate Count and Yeast and Mould Count of Jackfruit Pulp (10% w/v) and Oat (3.75 % w/v) Incorporated Yogurt

Storage Period (days)	Total Plate Count (CFU/g)	Yeast and Mould Count (CFU/g)
Initial	7.9×10^4	-
7	3.5×10^5	2.35×10^2
14	5.2×10^5	2.82×10^3
21	6.2×10^4	3.12×10^3

CONCLUSION

A consumer preferable functional yogurt, dual fortified with oat powder and ripe jackfruit pulp, was developed using 3.75% w/v oat powder and 10% w/v jackfruit pulp contents. It was, also, observed that properly packaged jackfruit flavoured oat incorporated yogurt can be stored at 4 -8 °C up to 14 days with a minimum level of preservative (300 ppm of potassium sorbate). The nutrient content, especially protein and fat along with fibre, of this developed yogurt was higher than that of a representative regular yogurt from the market. This product may be constituted as a fermented diary based food product with favourable sensory properties and acceptable shelf life, offering much health benefits to the consumers.

CONFLICT OF INTEREST

The authors would like to declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

UR: Investigation and data curation. GP: Designed the research, supervised the study, performed statistical analysis and wrote the manuscript. AW: Designed the research and supervised the study.

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APPLIED BIO-SYSTEMS TECHNOLOGY

Research Article **Open Access**

Human Health Importance Zoonotic Gastrointestinal Helminths and Ectoparasites among Stray Dogs in Galle District, Sri Lanka

Sameera Rathnayaka[1], Nayana Gunathilaka[2*] and Lahiru Udayanga[3]

Abstract

Background: A notably high stray and semi domesticated dog population exist in close proximity to humans in Sri Lanka. However, the prevalence of gastrointestinal and ecto-parasites among these stray dog population has been limitedly studied. Therefore, the present investigation focused on zoonotic potential among stray dog community in Sri Lanka.

Methods: A total of 110 stray dogs randomly captured from the Galle District of Sri Lanka during May to July 2018 was considered for the study. Freshly voided fecal samples were obtained. Ectoparasites were collected using a lose comb and stored in an alcohol solution. Presence of major gastrointestinal and ectoparasitic species were investigated using standard microscopic methods. The Chi-square test of independence was used for statistical analysis.

Results: The highest egg count as Eggs per Gram (EPG) were detected from *A. caninum* (264.65 $\pm$ 86.02 EPG), followed by *T. canis* (58.38 $\pm$ 7.22 EPG) and *E. vermicularis* (22.70 $\pm$ 5.70 EPG). Approximately one third of the stray dog population (29.1%; n= 32) indicated ectoparasitic infestations, dominated by *Rhipicephalus sanguineus* (40.9%; n=45), *Ctenocephalides canis* (23.6%; n=26) and *Ixodes scapularis* (19.1%; n=21). The results of the Chi-square test of independence denoted that there was a significant difference on the prevalence of helminthic parasites, among male and female stray dog populations (χ^2= 15.19, *df* = 7, *P* = 0.03).

Conclusions: The present study revealed the potential risk on human health by intestinal helminthic and ectoparasites among stray dog populations. Hence, better understanding of such diseases and their control is essential.

Keywords: Dog, Ectoparasites, Gastointentinal, Helminthic, Infection, Prevalence

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INTRODUCTION

Human-animal link is a beneficial dynamic relationship that is influenced by behaviours, which may useful for health and well-being of both animals and humans. This bond is advantageous in emotional, psychological, and physical interactions of people, animals, and the environment [1]. According to some research findings, presence of a friendly dog, moderates blood pressure reactivity to a social stressor in children [2], young adults [1-4]. Although there are some beneficial effects to humans from animals, animal pets are also considered as important sources of zoonotic infections. There are several reported health hazards associated with owning a pet animal. Among them, animal bites and allergies have been identified as the commonest and predominant health hazards. In addition, a diverse range of infections such as parasitic, bacterial, fungal and viral diseases are possible to be transmitted into humans from domestic pets [5-6].

Some studies have emphasized that the potential health risk by enteric parasites to the humans, which were harboured from pet dogs and cats, remains as a significant problem in the world [7]. Immuno-compromised individuals are highly vulnerable for acquiring parasitic infections from their pets [8]. In addition, there are some risk groups such as young children, elderly, pregnant women, veterinarians or animal nurses, who remain at a greater risk, due to either their immune system, behaviour or occupation [9].

The larval stages of several animal parasites can infect humans and produce severe diseases. Visceral and ocular larval migrans caused by common dog roundworm and *Toxocara canis* are two well-recognized clinical syndromes [10]. However, with the adoption of good hygiene and a thorough knowledge of the transmission of these parasites, people who are at risk should be able to continue enjoying the significant benefits of pet ownership. Although this aspect is well recognized and studied in developed countries, canine parasitic zoonoses pose a lowly prioritized public health problem in developing countries such as Sri Lanka, where conditions are conducive for transmission.

As a developing country, Sri Lanka's populations of stray and semi domesticated dogs exist in close proximity to increasing densities of human populations in urban environments. However, records on the prevalence of gastrointestinal and ectoparasites among stray dog population has been limitedly documented in Sri Lanka. Therefore, the objective of the present study was to investigate the occurrence of gastrointestinal and ectoparasitic species of human health importance, within a randomly selected stray dog population in Galle District of Sri Lanka.

METHODOLOGY

Study Area

The present study was conducted in the Galle District, Southern Province of Sri Lanka (6° 3' 12.6684'' N; 80° 13' 15.5208'' E). It covers an area of 1,652 km^2 of which 35 km^2 is covered by water bodies. This District contains a total of 1,058,771 human population [11]. "Dog Care Clinic E.V" is a Non-Governmental Organization (NGO) in Sri Lanka, which conducts animal welfare activities as a free service. This free service screens randomly captured stay dogs and treat for disease conditions, if necessary. The treated stay animals are usually returned to their original population, after proper treatment and follow-up. Stray dogs captured from four areas namely; Dalawella, Harumalgoda West, Heenatigala South and Thalpe South) in Habaraduwa District Secretariat Division, Galle District were selected for the study (Figure 1).

Collection of Samples and Examination for Ecto and Endo Parasites

A total of 110 randomly captured stray dogs, which were taken to the animal welfare clinic (for sterilization), during May to July 2018 were selected for the study.

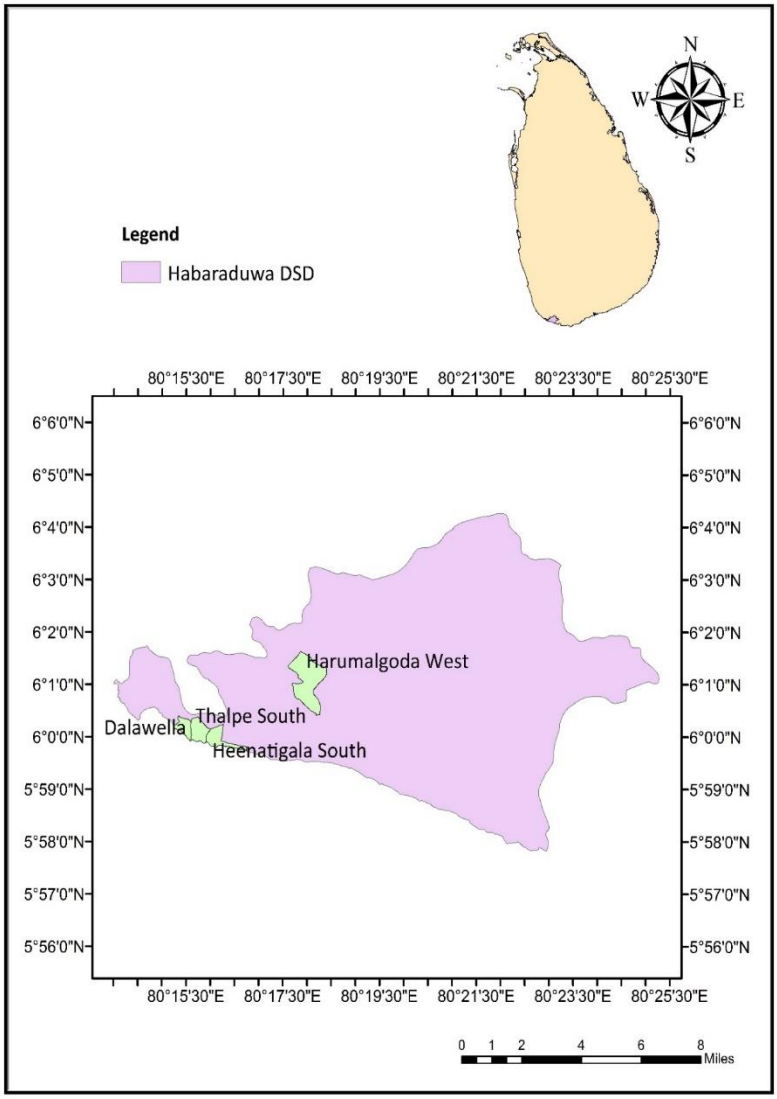

Figure 1: Spatial Location of the Habaraduwa District Secretariat Division

Collection of Stool Samples to Screen Gastrointestinal Parasites

Freshly voided fecal samples (30 g) were collected in to separate vials containing 10% formaldehyde and transported to the laboratory at the Department of Parasitology, Faculty of Medicine, University of Kelaniya, Ragama.

Screening for Ecto-Parasites

Each animal was rubbed with an ether soaked cotton wool. The dogs were combed on to a white paper. The collected ecto-parasites were preserved in 70% alcohol for morphological identification. All collected specimens were transported to the laboratory at the Department of Parasitology, Faculty of Medicine, University of Kelaniya, Ragama, Sri Lanka.

Processing of Samples at the Laboratory

Ecto-Parasite Specimens

Collected ecto-parasites (Fleas, ticks and lice) were macerated overnight with 10% potassium hydroxide (KOH) solution followed by dehydration with a series of alcohol solution. The specimens were mounted in Berlese medium and observed at 40X magnification under a binocular dissecting microscope.

Stool Samples for Gastrointestinal Parasites

The stool samples were processed by Kato-Katz thick smears using the modified Kato-

Katz technique [12]. Fifty mg of the sediments delivered by Kato-Katz template was taken onto a degreased glass slide.

It was covered with a cellophane strip soaked overnight in 50% solution of glycerol-malachite green. Slides were examined for helminthic eggs under a light microscope, immediately after preparation. Parasite eggs were identified based on the morphological characteristics. Density of infection, as expressed by Eggs per Gram (EPG) of faeces, was calculated by multiplying each slide count by 20 [13]. Each sample was duplicated to maintain the accuracy.

Data Interpretation

The prevalence, intensity, mean intensity and mean abundance were calculated for different gastrointestinal parasites as mentioned below [14].

Prevalence (P)

The number of infected animals with one or more individuals of a particular parasite species, divided by the number of hosts examined.

Intensity

The number of individuals of a particular parasite species in a single infected host (expressed as a numerical range).

Mean Intensity

The average intensity, expressed as the total number of parasites of a particular species found in a sample, divided by the number of infected hosts.

Mean Abundance (A)

The total number of individuals of a particular parasite species in a sample of a particular host species, divided by the total number of hosts of that species examined, including both infected and uninfected hosts.

Statistical Analysis

The chi-square test of independence was used to evaluate the significance in the GI parasitic prevalence, in terms of gender and spatial locality. Significance of the effect of the spatial location and gender on the intensity of GI parasitic infections among stray dogs, was statistically evaluated by using the General Linear Model followed by the Tukey's pair-wise comparison in IBM SPSS Statistics (version 23 copyright IBM Corporation). The 95% confidence levels (CI) of the EPG in the study populations were generated by using the one sample t test.

In addition, the Bray Curtis similarity based Cluster analysis followed by Analysis of Similarities (ANOSIM) was used to evaluate the overall clustering status of dog communities from different study areas, based on the intensity of GI parasites. In addition, Distance-Based Redundancy Analysis (dbRDA) was also performed to recognize the underlying segregation patterns of the study populations based on the intensity of GI parasite assemblages using the Plymouth Routines in Multivariate Ecological Research version 6 (PRIMER 6).

RESULTS AND DISCUSSION

Prevalence of Ecto-Parasites

A total of 110 dogs, consisting of 50 (45.5%) males and 60 (55.5%) females were examined in the current study. Of them, 65 dogs (59.1%) had ectoparasitic infestations, dominated by *Rhipicephalus sanguineus, Ctenocephalides canis*, and *Ixodes scapularis* (Figure 2). *R. sanguineus* was the most prevalent, with a prevalence of 40.9% (n=45), followed by *C. canis* (23.6%; n=26). Meanwhile, *I. scapularis* denoted the lowest prevalence rate of 19.1% (n=21). It was interesting to note that nearly one third of the surveyed population (29.1%; n= 32) had more than one ectoparasitic infestations (Figure 2).

Prevalence of Gastrointestinal Helminthic Parasites

Examination of stool smears revealed the occurrence of seven nematodes, namely *Ancylostoma caninum, Trichuris vulpis, Toxocara canis, Enterobius vermicularis, Eucoleus aerophilus, Uncineria stenocephala* and

Physaloptera rara, along with one parasite belonging to the phylum Platyhelminthes (*Paragonimus kellicotti*) within the studied dog population.

Out of the total surveyed, 33.6% (n=37) had GI helminthic infections of eight parasitic species. *A. caninum* was the most prevalent parasite, accounting for 27.3% (n=30) infections, while *E. vermicularis*, *E. aerophilus*, *P. rara* and *P. kellicotti* indicated the lowest prevalence rates (0.91%) in the total investigated dog population (Figure 4). Even among the infected dogs detected for GI helminthic parasites, *A. caninum* infection was the most predominant recording 81.1% (n=30) of the total infections. Interestingly, 13.5% of them had co-infections mostly with *A. caninum* and *T. canis (Figure 3).*

When the prevalence of eggs within infected dogs is considered, *A. caninum* advocated the highest prevalence of 264.6 ± 86.0 EPG, followed by *T. canis* (58.4 ± 7.2 EPG) and *E. vermicularis* (22.7 ± 5.7 EPG). The lowest egg count of 0.7 ± 0.3 EPG was denoted by *E. aerophilus* (Table 1).

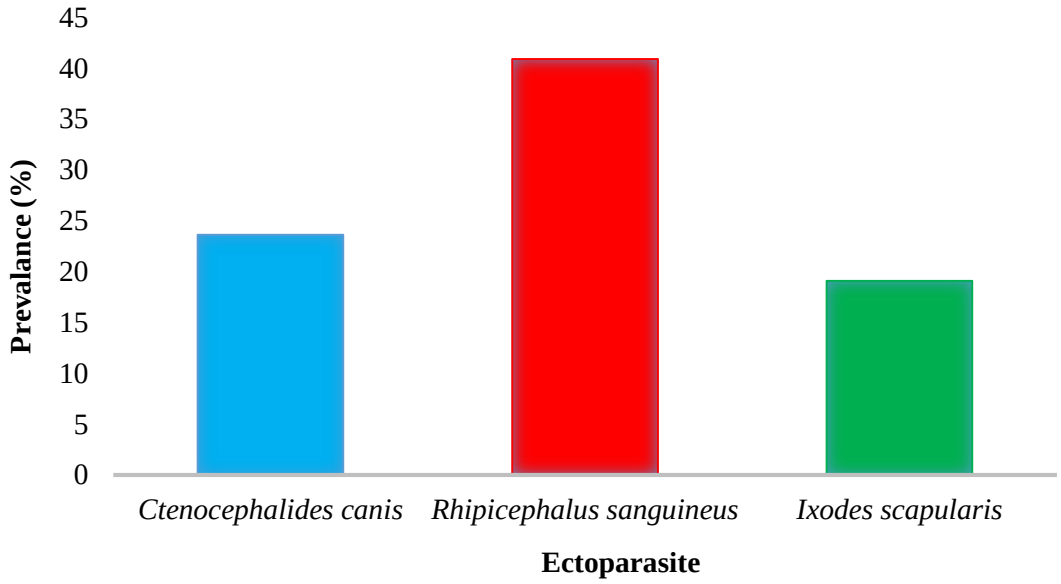

Figure 2: Prevalence Rates of Ectoparasitic Infestations in the Studied Dog Community

Table 1. Intensity of Gastrointestinal Helminths as Eggs per Gram in Stool

Phylum	Species	Mean	Standard Error	95% CI
	Ancylostoma caninum	264.65	86.02	(90.20 - 439.10)
	Trichuris vulpis	17.51	5.64	(4.14 - 33.10)
	Toxocara canis	58.38	7.22	(17.10 - 108.52)
Nematoda	*Enterobius vermicularis*	22.70	5.70	(9.45 - 68.7)
	Eucoleus aerophilus	0.65	0.31	(0 - 1.96)
	Uncineria stenocephala	2.59	1.74	(0.53 - 6.72)
	Physaloptera rara	3.89	1.89	(0.40 - 10.57)
Platyhelminthes	*Paragonimus kellicotti*	2.59	1.54	(0.67 - 5.86)

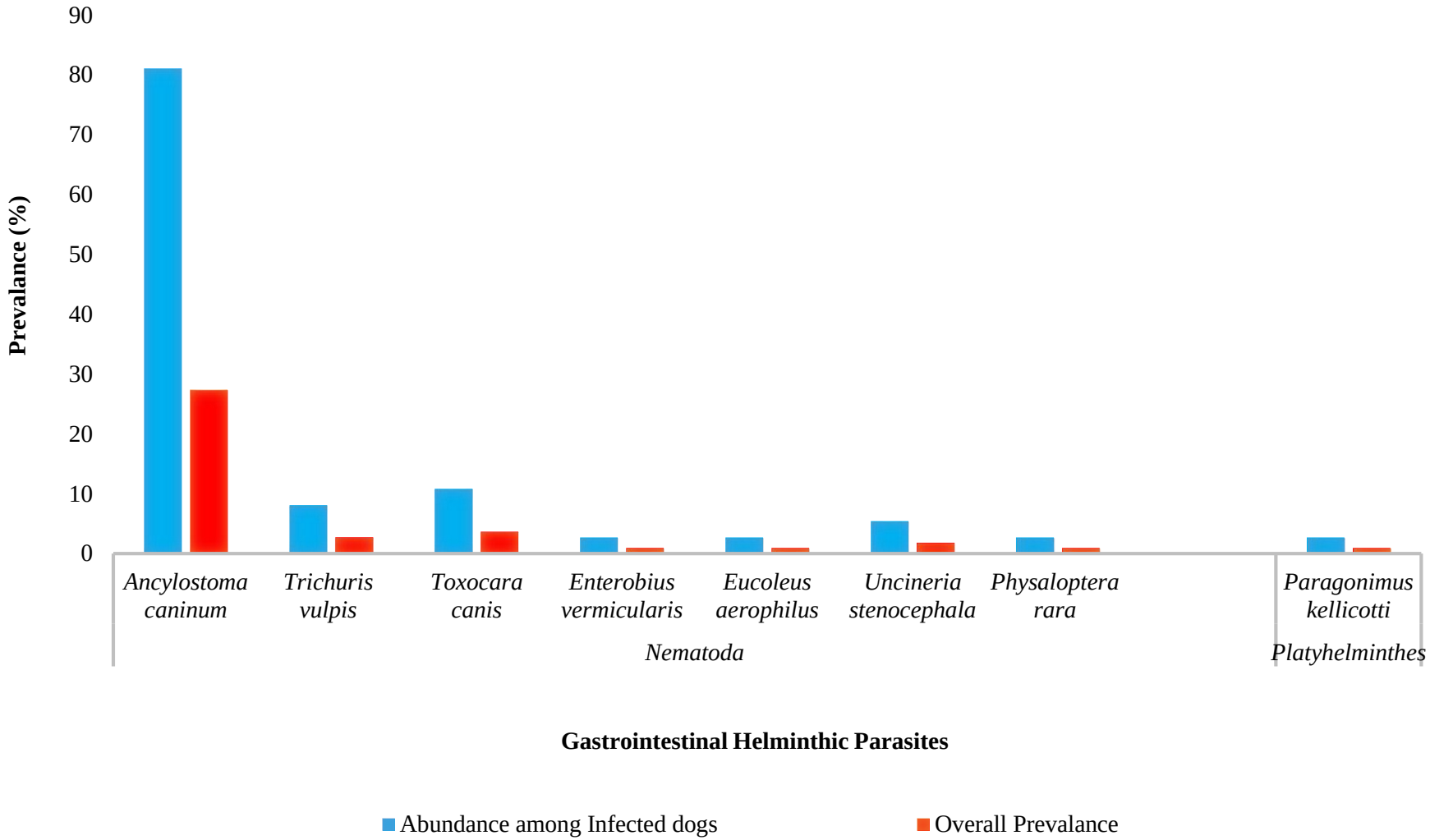

Figure 3: Prevalence Rates of Gastrointestinal Helminthic Infections among Stray Dogs

Gender Precise Prevalence of Gastrointestinal Helminthic Parasites

Among 60 female dogs, 26 dogs had GI helminthic parasites indicating an overall prevalence of 43.3%, while males showed an infection rate of 22.0% (n=11/60). A higher prevalence rate of *A. caninum, T. canis* and *U. stenocephala* were observed among female dogs (56.8%, 8.1% and 8.1%, respectively) than the in males (24.3%, 5.4% and 5.4%, respectively). Interestingly, few parasites such as *E. vermicularis*, *E. aerophilus*, *P. rara* and *P. kellicottiall* were identified only from male stray dogs (Table 2). According to the results of the Chi-square test of independence, the prevalence of infections among stray dogs denoted a significant difference among males and females (χ^2= 15.19, *df* =7, *P*=0.03). However, it was noted that the intensity of the infections (EPG) were not significantly different among the male and female dogs based on the GLM (*P>0.05*).

Spatial Distribution of Gastrointestinal Helminthic Parasites

The prevalence rates indicated significant spatial variations in the spatial distribution of gastrointestinal helminthic parasites between the studied GNDs (χ^2= 12.11, *df* = 3, *P*=0.007). All the GI parasites identified during the study were reported from Dalawella GND at significantly higher prevalence rates.

On the other hand, the stray dogs screened in Heenatigala South and Harumalgoda West GND areas had *A. caninum* and *T. canis* infections (Figure 4). In case of the intensity of parasitic infections, the EPG counts of parasites advocated significant spatial variations as indicated by the GLM (*P*=0.017). Heenatigala South GND denoted the highest parasitic load of all recorded parasite intensities, except for *E. vermicularis* and *T. vulpis*. However, the highest parasite intensity of *E. vermicularis* and *T. vulpis* were observed among the stray dogs screened from Dalawella area.

As depicted in the dendrogram of the cluster analysis, the gastrointestinal parasitic assemblages formed two major clusters sharing a 60% similarity, in terms of the EPG (Figure 5). Thalpe South GND formed one major cluster, while the remaining three GND areas, namely, Dalawella, Heenatigala South and Harumalgoda West formed the second cluster, which was proven to be significant through the Analysis of Similarities (ANOSIM) at 95% level of confidence (Global R=0.97). The dbRDA plot also confirmed the above clustering status. The relatively lower intensities of all parasites (except for *T. Vulpis*) could be the contributing factor for the formation of a single cluster by Thalpe South GND, as depicted by the radiating axils in the dbRDA plot (Figure 6).

Table 2: Gender Precise Prevalence of Gastrointestinal Helminthic Parasites among Stray Dogs

Phylum	Species	Prevalence (%)	
		Male	Female
Nematoda	*Ancylostoma caninum*	24.3	56.8
	Trichuris vulpis	2.7	2.7
	Toxocara canis	5.4	8.1
	Enterobius vermicularis	2.7	0.0
	Eucoleus aerophilus	2.7	0.0
	Uncineria stenocephala	5.4	8.1
	Physaloptera rara	2.7	0.0
Platyhelminthes	*Paragonimus kellicotti*	2.7	0.0

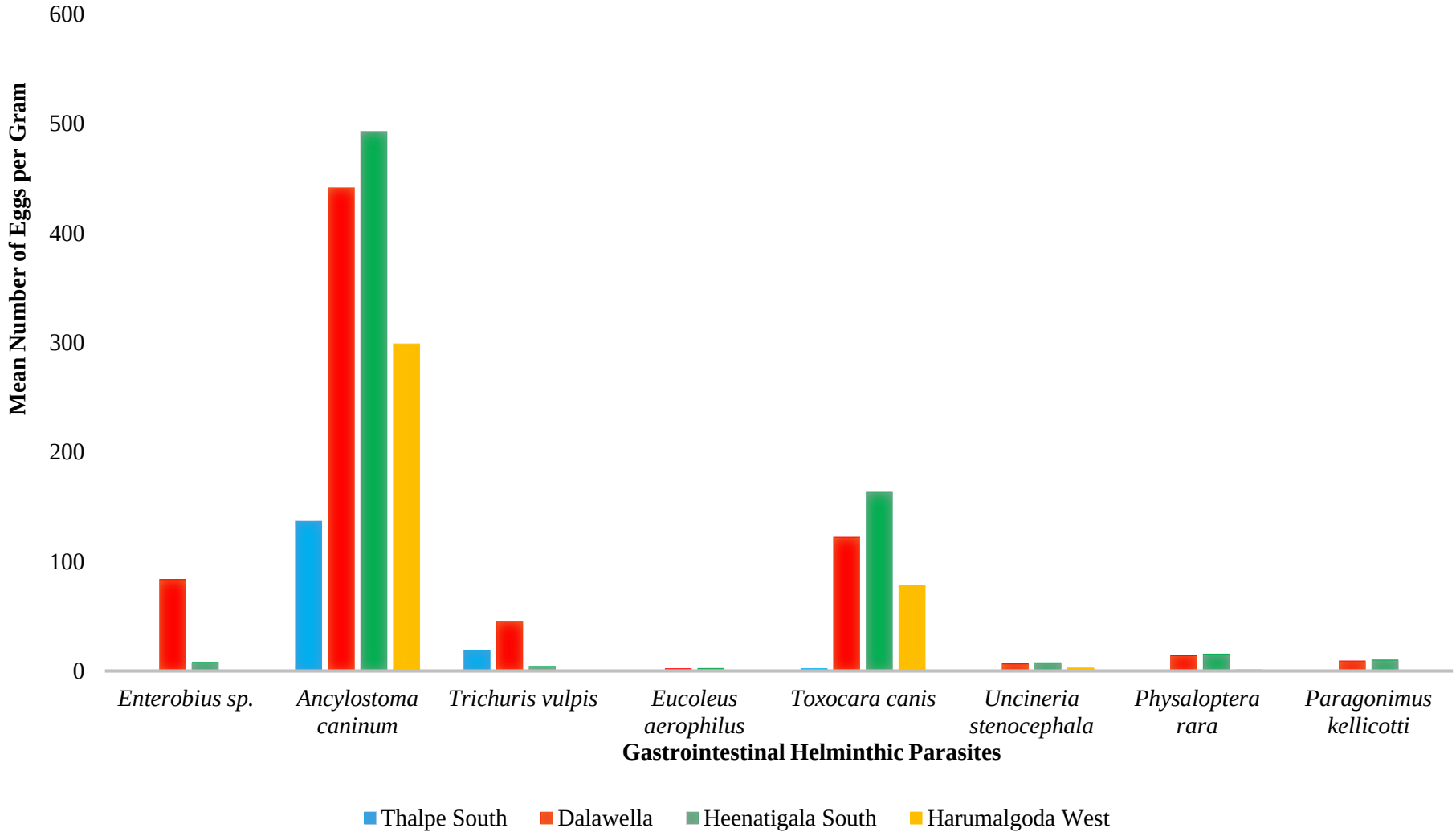

Figure 4: Parasitic Load of Gastrointestinal Helminths in Terms of in Eggs Per Gram Among Stray Dogs

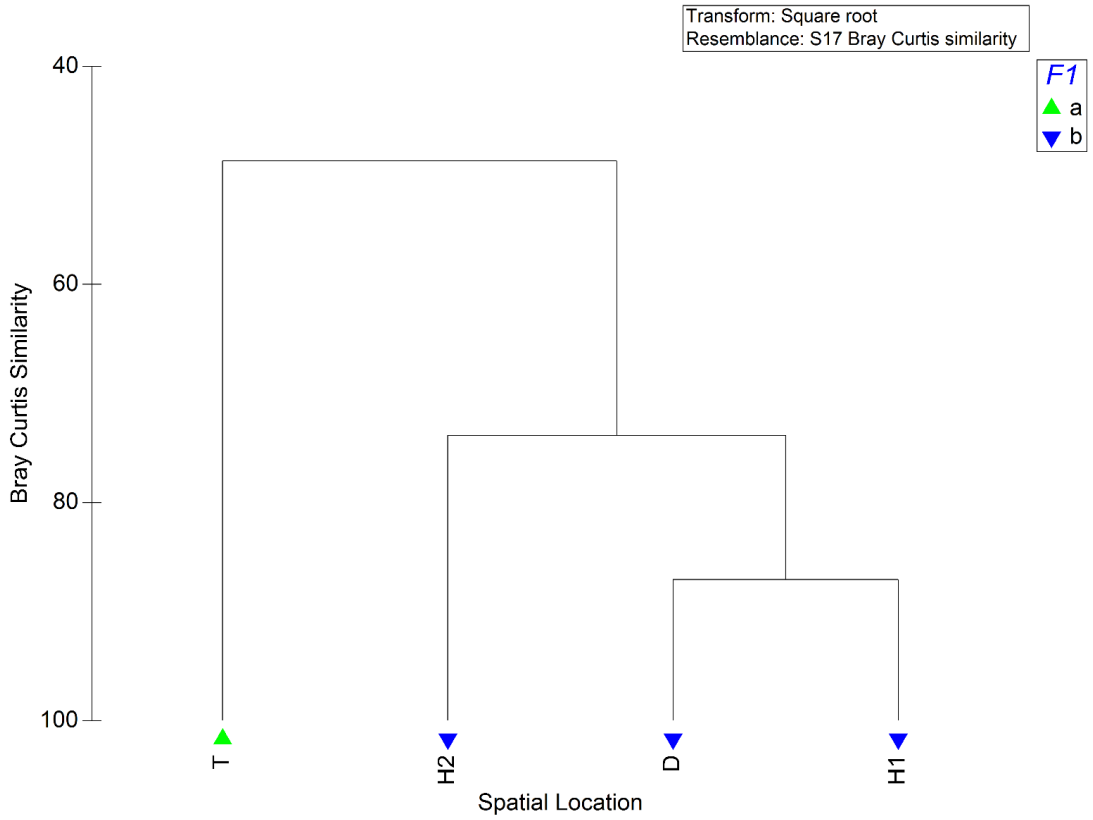

Figure 5: Dendrogram of the Cluster Analysis of Studied Dog Communities in the 4 GND Areas in terms of Eggs per Gram (EPG) of Gastrointestinal Helminthic Parasites

Note: D: Dalawella, H1: Heenatigala South, H2: Harumalgoda West and T: Thalpe South

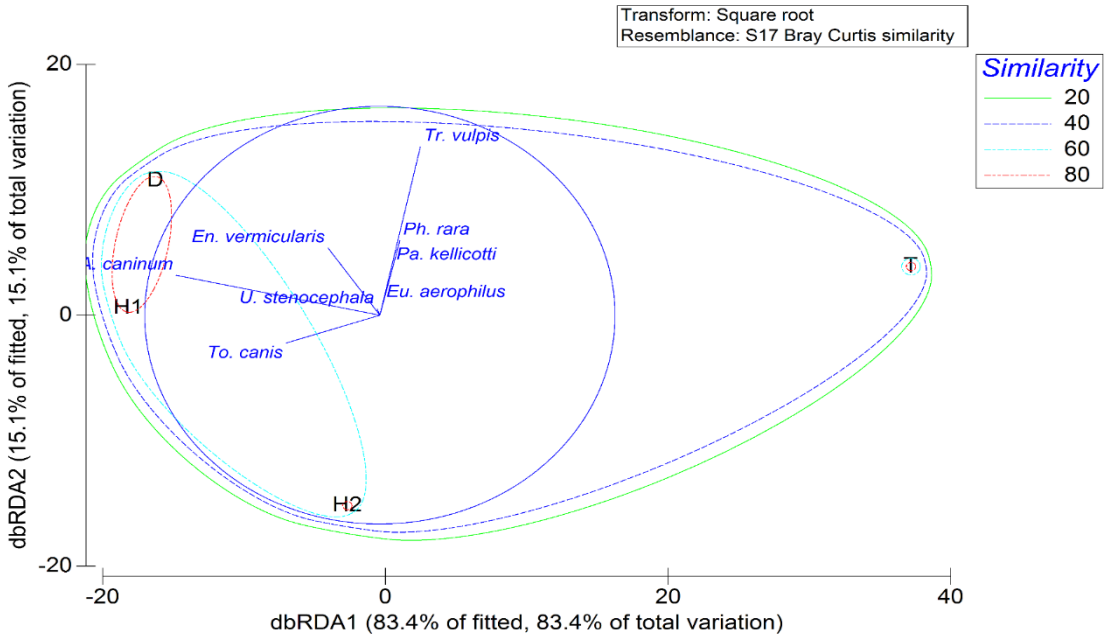

Figure 6: dbRDA Plot of Studied GND Areas in terms of Eggs Per Gram (EPG) of Gastrointestinal Helminthic Parasites in Stray Dogs

Note: D: Dalawella, H1: Heenatigala South, H2: Harumalgoda West and T: Thalpe South

Different pathogens have been identified to cause health impacts to humans through more than 250 zoonoses [15-16]. The reservoirs for these zoonoses are domestic livestock, carnivores and rodents [16]. Among these, dogs contribute majorly as definitive or reservoir hosts for many zoonotic parasites, especially in low economic and developing countries [17-18]. In Sri Lanka, dog population is estimated at three million in 2008 and has reduced up to 2.2 million as a result of the successful Catch-Neuter-Vaccinate-Release (CNVR) programme [19]. It is reported that about 500,000 of these are stray dogs. This amount increases day by day and local Government Authorities receive a considerable number of complaints from the general public [20].

There is a potential to transmit zoonotic infections to humans by swallowing or inhaling pathogens from dogs as the animal reservoir hosts, eating the hosts or via bites. Parasites of human health importance may also be transmitted from dogs to humans by vectors, such as fleas, ticks and mosquitoes [21]. Parasitic helminths are among the most commonly encountered disease causing agents in dogs all over the world [22]. A study conducted in Brazil has also evidenced that the helminth and ectoparasite species were highly prevalent among stray dogs [16].

According to literature, typical helminthic parasites of dogs are *Echinococcus granulosus*, *Dipylidium caninum*, *Toxocara canis*, *Dirofilaria immitis* and *Ancylostoma caninum* [16]. Studies conducted in Sri Lanka has identified some GI parasites with zoonotic potential namely; *T. canis*, *Strongyloides* sp, *E. coli*, *Trichuris* sp, hookworm, *G. duodenalis*, *S. lupi*, *Toxascaris* sp, and *Taenia* sp [23]. Meanwhile, some earlier records have highlighted the occurrence of *Toxoplasma gondii*, *Echinococcus granuloses*, *Ancylostoma caninum*, *A. braziliense*, *Diphylobothrium latum, T. canis* [24-26], *Isospora* sp, *Cyclospora* sp and *Capillaria aerophyla* among dogs [27]. The present study revealed the presence of *A. caninum*, *T. canis*, *E. vermicularis*, *T. vulpis*, *P. rara*, *P. kellicotti*, *U. stenocephala* and *E. aerophilus*. However, *E. vermicularis* has not been reported in dogs. In this case the dogs could have eaten any other animal with oxyurids.

It is well known that the close and frequent contact between dogs and people increases the risk for the transmission of zoonotic diseases. The high prevalence rates of *T. canis* may cause visceral and ocular larva migrans to humans, which lead to blindness and *A. caninum* associated with hookworm related cutaneous larva migrans [16, 28-30]. In addition, the present study recorded the presence of other hook worm species namely; *U. stenocephala,* which may also cause cutaneous larva migrans [16]. Cutaneous larva migrans is caused by the penetration of third stage L3 larvae of the hook worm into the human skin. This has been reported mainly in tropical areas, where climate and other abiotic factors favour for the development of nematode life cycle [28]. Therefore, Sri Lanka, being a tropical country with all favorable conditions to facilitate the nematode life cycle, high prevalence of hookworms among stray dog population may indicate the potential risk for human health. In addition, some studies have indicated that *E. aerophilus* has a potential to cause lung diseases in humans [31].

Overall, the highest prevalence rates were observed with *A. caninum* (80%) followed by *T. canis* and *T. vulpis*. Presence of *A. caninum* with highest percentage of prevalence, is in agreement with previous studies conducted among stray dogs in Sri Lanka (around 80%) [27] and India (72 – 89%) [32]. However, a study conducted in Brazil has reported a prevalence rate of 95% [16]. Some studies have highlighted that the presence of one parasitic species may enhance the occurrence of another species, since dogs with high parasitaemia generally persist with low immunity levels [33]. It is reported that a strong positive association has been identified between *Ancylostoma* sp. and *T. vulpis* [33-34]. Therefore, co- occurrence of *T. vulpis* as the

third highest parasite with compared to *A. caninum* in the present study, agrees with the above finding.

Trichuris vulpis is distributed all over the world. However, it is mostly predominant under warm and humid climatic conditions. Even though, *T. vulpis* infection is rare, humans may acquire this infection when they accidentally ingest embryonated eggs, through contaminated soil, food or fomites [35]. The present study highlighted a prevalence rate of 9% for *T. vulpis*, which remained similar to the findings from Spain, Southern Brazil that have reported prevalence rates of 10% and 9.3%, respectively [36-37]. However, this rate was clearly lower than a previous study conducted in Sri Lanka, (36.7%) among a stray dog population in Hantana area, Kandy District, Central province [27]. The zoonotic potential of *T. vulpis* is questionable [38]. Although dog whipworms are generally not considered as an intestinal nematode of zoonotic importance, there are some records on *T. vulpis* causing visceral larva migrans syndrome and intestinal infections in humans [39-42].

The occurrence of *T. canis* was higher among females (8.1%) than males (5.4%) in the present study. This also lies in agreement with the previous studies, which have reported prevalence rates ranging from 8.7% to 5.5% [16, 37, 43]. A previous study conducted in Sri Lanka has also reported the presence of *T. canis* as the most dangerous zoonotic disease, since it may cause both visceral larvae migrans and ocular larvae migrans in humans [27].

Among the ectoparasites, *Rhipicephalus sanguineus* remained predominant, followed by *Ctenocephalides canis* and *Ixodes scapularis.* Ticks and tick-borne diseases have drawn a wider attention due to its increasing trend in global burden [44]. Different tick species have been detected from dogs. Species belonging to the family Ixodidae are important vectors of various parasites, in terms of both veterinary and public health aspects [45]. *Rhipicephalus sanguineus* is the most diverse tick species that has been recorded, especially in tropical countries [46]. This tick species can act as a vector for a wide range of pathogens, comprising the genera *Babesia*, *Hepatozoon*, *Ehrlichia*, *Rickettsia* and *Mycoplasma* [16, 45]. In addition, the prevalence of *I. scapularis* has a potential medical importance as *Ixodes* ticks in Europe (*I. ricinus* and *I. persulcatus*) has reported the ability of transmitting tick-borne encephalitis (TBE) virus, a flavivirus that can cause fatal brain infection among humans [47-49]. In addition, *I. scapularis* is a major vector of pathogens in North America that cause diseases in humans including Lyme disease, human babesiosis and granulocytic anaplasmosis [44-50].

Ctenocephalides canis is an intermediate for the transmission of *Dipylidium caninum* to humans [51-52]. In the life cycle of *D. caninum*, dogs and wild carnivores are the final host, while the human is considered as an occasional host. *Ctenocephalides canis* is regarded as the most abundant ectoparasite among dogs worldwide [45]. The present study identified *C. canis* at a prevalence rate of 23.6%, which stands contract to some other previous studies that have reported prevalence levels of 45.7% in Brazil [16] and Nigeria [53]. Therefore, the presence of *C. canis* may indicate a transmission potential of *Dipylidium caninum* to humans as an occasional host.

Globalization and urbanization are contributing factors that tend to increase the risk of zoonoses for humans in the coastal region of the island. There is a considerable influx of tourists in the coastal region from December to March annually. The availability of stray dogs in these areas may be a new or first ever experience to many of the tourists travel in these areas who have arrived from developed countries. Hence, this implicate some potential impacts on tourist and local communities via intestinal

parasites and ectoparasitic infections, even though there are no published evidences to quote. It is also important to the note that the abundance of stray dogs and feces bestowed on public and private properties are a recurrent irritant and an important public health issue, due the occurrence of parasites with Zoonotic potential [23].

The present study revealed that the intestinal helminthosis is common among stray dog populations in the Galle District of Sri Lanka, some of which may have zoonotic potential. In addition, presence of ectoparasites, which can act as vectors for diseases, can cause serious impacts on human health. Therefore, screening of stray and domestic dongs is vital in order to minimize the potential risk for human health. On the other hand, raising awareness on animal welfare and potential risks associated with zoonotic parasites among general public is of paramount importance. Furthermore, health authorities should focus on implementing or strengthening current CNVR and animal welfare programmes catering to the current need.

CONCLUSION

The present study revealed that the intestinal helminthosis is common among stray dog populations in the Galle District of Sri Lanka, some of which may have zoonotic potential. In addition, presence of ectoparasitses which can act as vectors for diseases can cause serious impacts on human health. Therefore, it is recommended that public education on the proper care of dogs, including veterinary care, and potential risk of these parasites on human health.

CONFLICT OF INTEREST

The authors would like to declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

SR: Data collection, samples identification and reviewed the manuscript. NG: Designed the research and wrote the manuscript. LU: Performed the statistical analysis and wrote the manuscript. All authors read and approved the manuscript.

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APPLIED BIO-SYSTEMS TECHNOLOGY

Research Article **Open Access**

What Drives Deforestation? A Case of Deforestation Drivers in Sri Lanka

Manuri Gamage, Shashika Guruge*, Menuka Udugama, Mohamed Iffam and Ishara Anjalee

Abstract

Background: Sri Lanka has a striking variety of forest types brought about by spatial variations that can be simply classified as tropical rain forests. Forests account for removal of 17–25% of annual greenhouse gas emissions at the global level. State of deforestation in Sri Lanka is controversial in both scope and quantity. Therefore, understanding the drivers of deforestation is fundamental to the development of policies and measures that can incorporate to amend the current status of deforestation activities, toward more favourable environment-friendly outcome. Aim of this study is to assess the determinants of deforestation to better understand the patterns and intensity of deforestation in Sri Lanka, during the past three decades.

Methods: Data were acquired through two secondary sources; Food Agriculture Organization of the United Nation (FAO) and Department of Census and Statistics for the period from 1990 to 2016. A structural model was used to approximate the causes of deforestation and burnt forest area.

Results: Results reveals that the forest area has been decreased from 1990 to 2010 and remains nearly at a steady level, which shows the success of national wide reforestation and afforestation programmes. Interestingly, income, agricultural gross domestic products, crop production, crop production area, poverty, population, literacy rate, agricultural labour force and agricultural land area showed significant impacts (at 95% confidence level) on the forest cover change, while none of the factors denote any significant impact towards burnt tropical forest cover.

Conclusions: Study reveals the factors that are significantly affect the forest cover change. Interestingly none of the factors had any significant impact towards burnt tropical forest cover and yet to be studied in future. Study provides clues of the success of some reforestation programmes which need to be studied further.

Keywords: Deforestation, Drivers of Deforestation, Structural Model, Tropical Forests

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INTRODUCTION

Forests are a central part of terrestrial ecosystems with multiple definitions made to fit specific purposes, based on views, concepts, and priorities [1]. Forest classification system includes forest vegetation group and non-forest vegetation group that provide multiple benefits on life of the earth, including protecting of watersheds, providing habitats for animals, reducing Green House Gas (GHG) emission, preventing soil erosion, and mitigating climate changes. World's forests amount has been continuously declining as a result of increase of human population and the increase of demand for food and land.

Forest resources are the home of multiple ecological services fundamentally important to human wellbeing. Further it regulates the climate and water resources, while providing habitats for plants and animals. Forests are under constant threat of degradation or destruction due to increasing human interactions. Deforestation or the forest degradation crisis accounts for significant, yet disputed portion of human induced greenhouse gas emissions. Therefore, the studies related to forest cover change are a central component in developing strategies for management of natural resources. Further the community is seeking to design mechanisms to reduce forest-related carbon emissions through promoting the enhancement of carbon stocks via reforestation.

Deforestation is an incidence of removal of trees and the conversion from forest vegetation into non-forest vegetation and other land uses. Deforestation has many definitions and most of them have been compiled and classified by Lund [2] either as a change in land cover or a change in land use. By supporting all those literature, Lund [2] has defined deforestation as "the act or process of changing forest land to non-forest land". Further, more often deforestation has been defined as the transformation from forested land to non-forested land during a certain time [3]. Deforestation is responsible for 17–25% of annual greenhouse gas emissions that is a principal factor in global warming [4-5]. International bodies have been developing numerous policies for strengthening carbon sequestration by forests, through reducing deforestation to encourage the developing countries to identify drivers of land use change, including deforestation.

Climate change is a pressing global issue and it negatively affects many developing countries. As a response to this pressing challenge, many countries have been introducing major programmes to reduce deforestation and forest degradation. However, these programmes are hindered by limited understanding of the extent of deforestation and forest degradation and their underlying causes [6]. As countries that are moving towards the implementation phase of their national REDD+ (Reducing Emissions from Deforestation and forest Degradation) programmes, it is crucial to better understand what drives deforestation. This will assist in identifying policy responses which remains challenging because, while the number of scientific assessments of deforestation drivers is increasing, they often reach diverging conclusions [7].

Over the last few decades there have been a considerable number of deforestation studies conducted in the world, with compared to Sri Lanka. According to the literature, countries in Latin America have recognized, the access to markets and agricultural and forest activities as the main causes of deforestation, that may subject to the forest types too [8]. Further above study has identified that deforestation measurements focused at different scales and on different forest types would help governments to improve their reports for international initiatives and more importantly, for developing local policies for the sustainable management of forests in Latin America.

In another study, Trigueiro *et al.* has used a Geographically Weighted Regression (GWR) approach to assess the spatial variability of deforestation drivers in Brazil [9]. The results show that, to effectively reduce deforestation, public policies should integrate strategies focusing not only at national and biome levels, but also at the regional level. In Myanmar, a number of spatially explicit potential drivers of deforestation such as infrastructure, elevation, slope, deforested land, and population, have been identified [10].

Although the effects of deforestation are well known, the understanding of its drivers across regions and countries is crucial. Further there are many studies, which consider that certain driving factors influence deforestation equally in all regions. Yet, deforestation has a strong spatial structure that can lead drivers to vary their influence on deforestation in different regions [9]. Van Khuc *et al*. has used Geographic Information System (GIS) tools, structural regression models (structural model), and a regression tree method to quantify the extent, as well as the approximate causes of deforestation and forest degradation in Vietnam [6]. Results have concluded initial forest cover, per capita income, agricultural production, governance, population growth, food, and poverty as drivers of deforestation and forest degradation.

One of the South Asian studies has analysed the land cover and investigated the spatial patterns of deforestation and forest fragmentation in South Asian region since the 1930's. The study covered eight countries of the region including; India, Bangladesh, Bhutan, Nepal, Pakistan, Afghanistan, Sri Lanka and Maldives [11]. In South Asia, agricultural lands are predominant (43%) of the total geographical area followed by barren lands (20.0%) and forests (14.7%). The long-term change analysis has indicated a loss of 29.6% of the forest cover. Forest fragmentation had denoted significant spatial-temporal variations. The large core forests in South Asia have denoted significant decrement over last eight decades [11].

Xu *et al.* quantifying the dynamics of forest and agricultural lands and the spatially explicit drivers of their changes, provides a solid foundation for land use and land cover change modelling and projection in South and Southeast Asia [12]. Laurance, highlights the pattern and pace of tropical forest destruction in the Americas, Asia, and Africa [13]. He recognizes Asian forests as the most immediate less surviving forests, than the other two regions, along with higher relative rates of deforestation and logging. This study has further identified human population pressure, weak government institutions and poor policies, increasing trade liberalization, and industrial logging as the four main emerging key drivers of forest destruction [13].

Sri Lanka has a striking variety of forest types brought about by spatial variations in rainfall, altitude and soil [14-15]. The Sri Lankan forests have been categorized broadly as tropical wet lowland evergreen forests; wet sub-montane forests; wet montane forests; tropical dry mixed evergreen forests in the dry lowlands, with riverine vegetation along river banks; tropical moist evergreen forests in the intermediate zone; thorny scrublands in the arid areas; and mangrove forests in the coastal areas, lagoons and at the river mouths [14-15]. Just due to the complexity of classification, the forests were simply classified as “tropical” and “other forests”, in the current study. The tropical rain forests are evergreen, luxuriant and rich in tree species as well as in other plant and animal life and a major source of the world's hardwoods, which are used in fine furniture and other high-grade uses too. Only a small proportion of the world's tropical forests are under management in any meaningful sense and often confined to the collection of revenue from logging operations or the protection of national parks by government forest services.

State of deforestation in Sri Lanka is controversial in both scope and quantity. Therefore, understanding the drivers of deforestation is fundamental to the development of policies and measures that can incorporate to amend current status of deforestation activities, toward more favourable climatic and biodiversity-friendly outcomes. Aim of this study was to assess the determinants of deforestation to better understand the patterns and intensity of deforestation in Sri Lanka, during the past three decades.

METHODOLOGY

This study followed a framework, which is built on three levels of drivers that are associated with deforestation [16]. The first level consists of agents of deforestation, and second stage with decision parameters and agent characteristics, while the last level considers a broad set of socio-demographic characters, such as economic, political, cultural, demographic, and technological factors. Following the literature review, four broader categories were selected as the causes of deforestation. Those categories include agricultural and food production (AFP), socio-economic factors (SEF), human resource factors (HRF), land use changes (LUC). Therefore, a general model of deforestation was formed as follows;

$$DF|BFT|BFO = f(AFP, SEF, HRF, LUC) \quad (1)$$

DF : Deforestation
BFT : Burnt forest tropical
BFO : Burnt forest others

As presented above, deforestation can be shaped by many wide-ranging factors that are complex with interactions to be disentangled. A new integrated model was derived to build up the structural model of drivers of deforestation [12-17] as follows;

AFP : f (AGGDP, CRPD)
SEF : f (IN, POV, POP)
HRF : f (LIT, LAB)
LUC : f (AGLA, CROPLA)

$$DF|BFT|BFO = f(AGGDP, CRPD, IN, POV, POP, LIT, LAB, AGLA, CROPLA) \quad (2)$$

AGGDP : Agricultural Gross Domestic Products
CRPD : Quantity of crop production
IN : Income
POV : Poverty
POP : Population
LIT : Literacy rate
LAB : Labour force in agriculture
AGLA : Agricultural land area
CROPLA : Crop production area

Burnt forest tropical and burnt forest others were included in the above model. Income, poverty and population were included to epitomize the socio-economic factors. Change in AGGDP and change of quantity of crop production were used to describe the agricultural and food factors. Meanwhile, change of labour force in agriculture and change of literacy rate were included in to exemplify the human resource factors. In addition, the change in agriculture land share from total land share (%) and change of crop production area (ha) were included to represent land use changes.

Data Collection and Analysis

Data were acquired from two secondary sources; Food Agriculture Organization of the United Nation (FAO) and Department of Census and Statistics for the period from 1990 to 2016. All the potential variables were included and tested to find the best model. Collinearity was tested using Variance Inflation Factors (VIF) and the final model was derived using a stepwise method, which retains only the statistically significant variables. Finally, STATA (version 14) was employed to re-examine the reliability and validity of the final model, using the Shapiro-Wilk test for normality ($P>0.1$). Then the structural model was used to derive the explanatory relationships between the deforestation and their drivers.

RESULTS AND DISCUSSION

Table 1 shows the descriptive statistics of all potential variables that were used to select the best model.

Figure 1 shows the changes in forest cover, while figure 2 shows the burnt forest area of both tropical and other forests.

Table 1: Descriptive Statistics for Potential Variables in the Integrated System

Variables		Mean	Std. Dev.	Min	Max
FCOVER	Total forest cover change (ha)	138.95	40.93	89.34	174.75
PFCOVER	Percentage of total forest cover change (ha)	0.01	0.01	0.00	0.01
FTBURNT	Burnt forest area (T) (ha)	20100.36	5588.34	14961.52	29601.43
PFTBURNT	Percentage of burnt forest area (T)(ha)	0.90	0.29	0.66	1.41
FOBURNT	Burnt forest area (O)(ha)	10328.05	5060.54	3828.96	17924.00
PFOBURNT	Percentage of burnt forest area (O) (ha)	0.47	0.24	0.17	0.84
Socio Economic Factors					
INCOME	Change of Per capita income (Billion PPP dollar)	45.06	35.20	18.53	102.00
PINCOME	Percentage of per capita income change(Billion PPP dollar)	46.42	9.84	37.02	61.11
POVERTY	Change of Annual poverty rate (%)	-9.12	5.64	-19.00	-5.40
PPOVERTY	Percentage of Annual poverty rate change (%)	-14.64	11.69	-35.19	-6.70
POP	Change of Population (Unit 1000)	760.45	148.90	534.69	917.14
PPOP	Percentage of Population (Unit 1000) change	4.05	0.86	2.93	5.29
Agricultural and Food					
AGGDP	Change in AGGDP (Rs/$)	0.94	1.05	-0.37	2.02
PAGGDP	Percentage of AGGDP (Rs/$) change	29.28	30.95	-11.37	67.14
CROPPROD	Change of Quantity of crop production (Tonnes)	220518.2	985031.1	-950755.0	1747071.0
PCROPPROD	Percentage of Quantity of crop production change (Tonnes)	4.40	15.20	-12.15	28.74
Human Resource Factors					
LITRATE	Change of Literacy rate (%)	0.77	0.55	0.28	1.68
PLITRATE	Percentage of Literacy rate change (%)	0.86	0.62	0.31	1.88
LABOUR	Change of labour force in agriculture (%)	-4.19	3.50	-7.43	1.68
PLABOUR	Percentage of labour force in agriculture change (%)	-10.78	8.95	-18.07	4.25
Land Use Changes					
AGRILAND	Change in agriculture land share from total land share (%)	1.46	1.33	-0.21	2.82
PAGRILAND	Percentage of change in agriculture land share from total land share (%)	3.68	3.35	-0.56	6.83
CROPPRODAR	Change of Crop production area (ha)	-12144.8	172236.0	-250623.0	207575.0
PCROPPRODAREA	Percentage of crop production area (ha) change	-0.40	10.29	-14.03	13.15

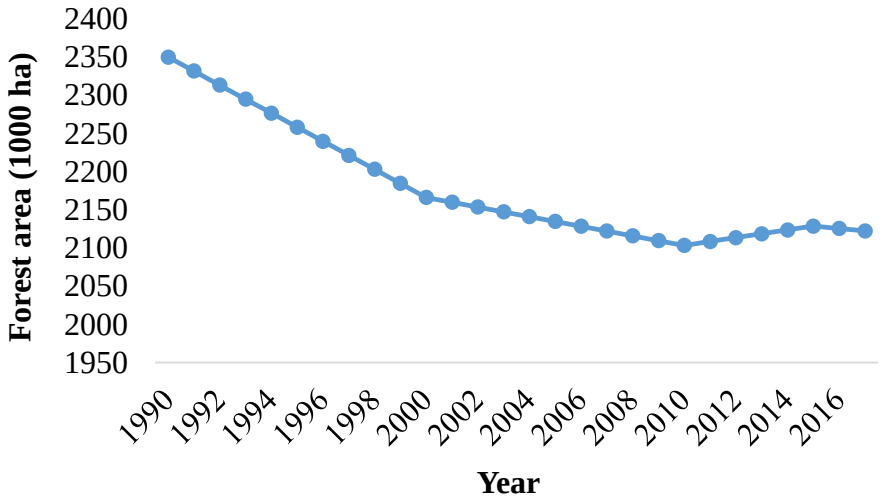

Figure 1: Temporal Variation of the Forest Area in Sri Lanka

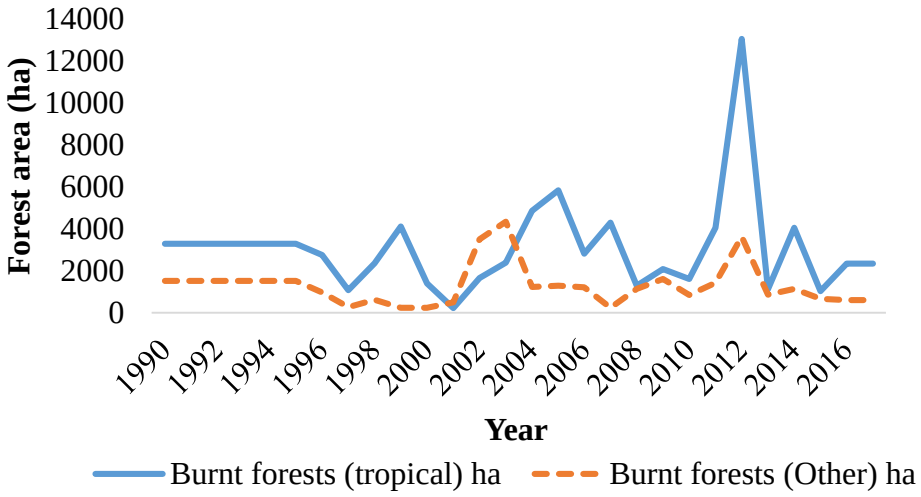

Figure 2: Temporal Variation of the Burn Forest Area in Sri Lanka

Forest cover in Sri Lanka has been declining from 1990 to 2010 and then remains at a stable phase with very minor changes. Tropical forests have been burnt drastically with respect to the other forests. As shown in the Table 2, the total forest cover changes in the period 2010 to 2017 had been smaller, than the 1990 to 2005 period. This is due to the succession of previously deforested areas during the second period. The total burnt forest area was approximately 39346.94 ha in 2016. Tendency of forest burning has been increased, causing a huge impact on tropical forests.

According to the results of the structural regression model used to identify the approximate drivers of deforestation, all the variables have remained significant (P<0.05). Therefore, all the variables significantly affect the forest cover change. The respective R^2 values of all the variables are also >70%, depicting a good fitness level. According to the Table 3, per capita income and crop production denote negative relationships with the forest cover change,

Table 2: The Extent of Deforestation in Sri Lanka during 1990 to 2017

Year	Unit	Total Forest Cover Change	Deforestation		
			Burnt Forest Area (Tropical)	Burnt Forest Area (Others)	Total Burn Forest Area
1990-1995	ha	165.91	19753.97	9063.96	28817.93
	%	0.01	0.84	0.39	
1995-2000	ha	165.14	14961.52	3828.96	18790.48
	%	0.01	0.66	0.17	
2000-2005	ha	174.75	18260.88	11077.82	29513.44
	%	0.01	0.84	0.51	
2005-2010	ha	89.34	17924.00	17924.00	35937.34
	%	0.00	0.84	0.84	
2010-2017	ha	99.62	29601.43	9745.50	39446.56
	%	0.00	0.85	0.46	

Table 3: Estimated Results of the Structural Model of Forest Cover Change

Variables	Forest Cover Change	Socio Economic	Crop Production Quantity	Labour Force	Crop Production Area
INCOME	-0.12				
	(-3.49)				
LABOUR	8.96				
	(3.16)				
AGGDP	0.06				
	(0.92)				
CROPPRODAREA	-2.33				
	(-2.38)				
POVERTY		$-9.74*10^{-4}$			
		(-1.66)			
POP		$8.74*10^{-4}$			
		(8.23)			
CROPPROD			44.28		
			(13.78)		
LITRATE				-0.75	
				(-14.95)	
AGRILAND					-0.46
					(-11.05)
P-value	0.00	0.00	0.00	0.00	0.00
Observations	28	28	28	28	28
R-squared	0.83	0.75	0.88	0.90	0.82
Adj. R squared	0.79	0.73	0.87	0.89	0.82

Table 4: Estimated Results of the Structural Model of Burnt Forest Area (Tropical)

Variables	Burnt Forest Area	Socio Economic	Crop Production Quantity	Labour Force	Crop Production Area
INCOME	0.66				
	(0.56)				
LABOUR	-620.37				
	(-0.62)				
AGGDP	-2.56				
	(-0.11)				
CROPPRODAREA	-95.96				
	(0.62)				
POVERTY		$-9.74*10^{-4}$			
		(-1.66)			
POP		$8.74*10^{-4}$			
		(8.23)			
CROPPROD			44.28		
			(13.78)		
LITRATE				-0.75	
				(-14.95)	
AGRILAND					-0.46
					(-11.05)

suggesting that the increase in per capita income and crop production area will subsequently decrease the forest cover change.

Change of labour force in agriculture and change in agricultural GDP shows a positive relationship with the forest cover change. Table 4 shows the relationship of independent variables with the burnt forest area (tropical) and burnt forest area (other). It includes coefficients of variables and t values. All the variables had p-values less than 0.05 with relatively very smaller R^2 values. Thus, although the variables significantly influence the deforestation, their impact towards both burnt tropical and other forest areas are minimum.

CONCLUSION

This study attempted to assess the deforestation drivers in Sri Lanka. Study reveals that overall forest area in Sri Lanka has decreased from 1990 to 2010 and remains nearly at a steady level. This shows the success of some nation-wide reforestation programmes. Interestingly, income, agricultural GDP, crop production, crop production area, poverty, population, literacy rate, agricultural labour force and agricultural land area were found to significantly affect the forest cover change, while none of the factors denote any significant impact towards burnt tropical forest cover. Country's tropical forest cover is still in danger due to some other reasons that were not revealed through this study and yet to be studied in future.

CONFLICT OF INTEREST

The authors would like to declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

MG: Designed and implemented the study; SG: Designed and implemented the study and wrote the manuscript; MI: Data collection and analysis; MU and IA wrote and reviewed the manuscript.

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APPLIED BIO-SYSTEMS TECHNOLOGY

Research Article **Open Access**

Socio Economic Drivers of Vegetable Farming in Kalpitiya

Virajith Kuruppu*, Nadeera De Silva, Jagath Edirisinghe, Lahiru Udayanga, Radhika Gimhani and Indika Herath

Abstract

Background: Different agricultural practices along with many food utilization patterns could be observed around the globe. Among those, vegetables have become a vital nutritious meal and a dietary habit in most Asian countries, including Sri Lanka. In recent years more and more farmers have shifted towards vegetable farming from other agricultural activities. Farmers cultivate a wide array of vegetables even without assessing the suitability of those crops, creating sustainability issues in the long run. Investigating reasons for such practices is vital to recognize possible root causes of these crop choices. Hence, the current study was conducted to identify key socio-economic determinants of farmers, which affect the choice of vegetable crops.

Methods: Study adopted exploratory research methods. A sample of 130 vegetable farmers in Kalpitiya Divisional Secretariat were selected randomly for the study. A pre-tested structured questionnaire and focus group discussions were deployed to gather data. Multinomial Logistic Regression (MLR) was employed to elicit the relationship between the choice of crop and selected socio-economic variables.

Results: Farmers tend to select Pumpkin aiming a higher selling price per unit over Beet ($P<0.05$) and Cabbage ($P<0.01$). However, farmers tend to select Beet ($P<0.05$) and Cabbage ($P<0.01$) aiming a higher yield prospect over Pumpkin. Interestingly, female farmers ($P<0.01$) tend to select Pumpkin over Beet due to easiness in harvesting. Farm gate prices and the average yield are the main deciding factors to select a particular vegetable crop by a farmer. Also, short harvesting cycles in these crops mitigate market and production risk to a certain degree.

Conclusions: Creating better market linkages with sufficient information could be a possible solution to introduce alternative agricultural activities among farmers in order to create sustainable farming practices within the agrarian community in Kalpitiya.

Keywords: Kalpitiya, Production Choice, Socio-Economic Drivers, Vegetable Cultivation

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INTRODUCTION

Agriculture is a predominant socio-economic practice in almost every South Asian country including Sri Lanka. It contributes immensely to the Gross Domestic Product (GDP). Thus, the foundation of many agribusinesses in developing countries lie with the primary production of the agriculture sector. Rice is considered as the staple food commodity in Sri Lanka. In addition, vegetables, fruits, cereals, pulses, root and tuber crop cultivation is done in the country. Amongst those, vegetables are a popular agro commodity and local community consume vegetables in raw, cooked or partially processed forms. Over the years, vegetables have become a vital side dish in the main meal, in the routine dietary habit in Sri Lanka [1]. A wide array of vegetable varieties are being cultivated around different geographical areas in the island. Farmers cultivate around 80 different varieties of fruits and vegetables domestically and produces approximately around 3,000 million kg of vegetables annually [2]. Thus, vegetable subsector is an important component in the Sri Lankan agricultural sector [3-4].

Kalpitiya Divisional Secretariat (DSD) located in the Puttlam District is a key area for vegetable production. It is considered as one of the highly productive agricultural areas in the country. Kalpitiya contributes to a high percentage of vegetables (40% of the local vegetable demand) and fruit production of the country while creating a high number of job opportunities for the residents [5]. Approximately 62% of the agricultural extent in Kalpitiya is employed by intense agricultural fields with shallow-rooted crops and the remaining (38%) accounts for coconut cultivation lands [5]. Crop cultivation in the area is done throughout the year without implementing any seasonal cultivation practices. The dominant crop species in the Kalpitiya area are chilli, onion, okra and beetroot. Even though the Department of Agriculture has indicated suitable varieties for cultivation, farmers in the area mainly tend to cultivate imported varieties with a relatively higher demand.

In recent years more and more farmers have shifted towards vegetable farming from other agricultural activities. Their patterns of cultivation, including crop selection and timing, have also changed due to the dynamic nature of the sector [6]. One such reason for this is the short harvesting cycles in many vegetable crops. This yields, faster cash inflow cycles and also mitigates climatic risk in agriculture, compared to many other perennial agricultural crops. Further, according to Perera *et al.* [7], the international trade in fruits and vegetables has increased rapidly during the last two decades. This could be another reason why many farmers tend to shift towards the vegetable subsector. Apart from those reasons there may be various socio-economic factors at micro level, which influence this behaviour [8]. At the same time, it is important to investigate, whether this increasing tendency of farmers shifting to vegetable subsector is sustainable in the long run, since it could create market instability, through imbalance supply and demand in domestic markets. Therefore, proper investigation is required to identify micro level factors, which determine the farmers' choice of crop. This aids to understand the nature and patterns of the farmer choice, along with alternative strategies, to maintain the sustainability of the vegetable subsector in Sri Lanka.

In addition, understanding the nature of vegetable production in the country is important for the generation of long-term strategies in the agriculture sector. It addresses specific issues in the vegetable supply chain around the country. This may overcome possible price volatilities and adverse structural changes in the agricultural markets in the country. Otherwise, over supply and shortage may disturbs the natural market behaviour creating various lapses. Investigating micro economic factors of farmers is an ideal way to initiate such work. In light of this, the main objective of the study is to identify key socio-economic

determinants of farmers which affect the choice of vegetable crop.

METHODOLOGY

Conceptual Framework

The context of vegetable farming in Sri Lanka is complex. Therefore, the current study adopted exploratory research methods. Both qualitative and quantitative approaches were used in the study. Study inquired the factors, which affect farmers' choice of crops. Accordingly, figure 1 illustrates the conceptual framework of the study. It is assumed that the farmer's choice of crop is dependent on selected socio-economic variables. These variables represent micro level aspects of the farmer. Set of macro-economic factors are also moderating the relationship between dependent and independent variables.

Gender, age (years), education of the farmer, extent (acre), average yield (kg $acre^{-1}$), unit selling price (LKR kg^{-1}), average fertilizer usage (kg $acre^{-1}$), number of family and hired labour for the selected crop and organic fertilizer usage are the selected independent variables, which influenced the choice of crop. Broad macro-economic factors such as government policy frameworks, developments in market and other infrastructure, technological advancement and research and development are considered as the mediating variables [9-11].

Study Area

Study was conducted in Kalpitiya Divisional Secretariat (DSD) which is located in the Puttalam District, North-Western Province in Sri Lanka. Kalpitiya DSD belongs to the DL_3 (North Western Dry Zone) agro-ecological zone, which has unique features due to sandy soil and semi-arid environment [12].

Data Collection

A sample of 130 vegetable farmers were selected randomly for the study. Grama Niladhari (GN) divisions, which had the highest number of vegetable farmers were selected with the aid of Agrarian Services Centre (ASC) in the area. Both primary and secondary data were used to interpret the results. Primary data collection was done using a pre-tested structured questionnaire survey, along with focus group discussions. Secondary data were gathered from various secondary sources. Questionnaire covered socio-economic status of the respondents, crop production practices, status, patterns and behaviours.

Statistical Analysis

Both descriptive and inferential statistics were used to analyse data. Multinomial Logistic Regression (MLR) was employed to elicit the relationship between dependent and independent variables. Dependent variable, which is choice of crops is a discrete and non-ordered categorical variable and hence the MLR was used.

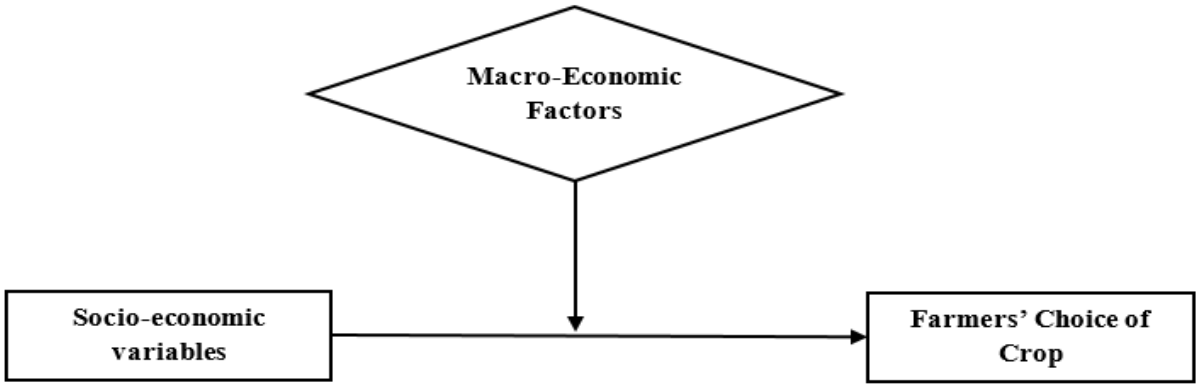

Figure 1: Conceptual Framework of the Study

MLR model considers, more than two discrete and non-ordered categorical variables as the dependent variable.

Equation 1 illustrates the probability of a dependent variable to be in the n^{th} category in the MLR model. Baseline category is denoted by *j*. MLR with a dependent variable that has a single category must have "*J-1*" logistic regression models [13-15].

$$\pi_j = \frac{\exp \sum_{k=1}^{K} \beta_{jk}\, x_k}{1 + \sum_{j=1}^{J-1} \left(\sum_{k=1}^{K} \beta_{jk}\, x_k \right)} \quad (1)$$

The MLR, which has 3 categories takes the sum of probabilities of each category, which is equal to "1"

$$P(D = 1|x) + P(D = 2|x) + P(D = 3|x) = 1 \quad (2)$$

Hence, only two odds ratios are calculated and each category is compared with these ratios. The model is linearized by taking the natural logarithms of these odds ratios to obtain logistic models.

RESULTS AND DISCUSSION

Majority (91%) of farmers, who participated for the study were males. Age of the sample was ranging from 19 years to 79 years with an average age of 42 years. Age distribution indicated a relatively higher presence of younger farmers in the vegetable cultivation. In general, younger farmers were more interested on vegetable cultivation in the area, due to speed of cash recovery between cultivation cycles. A crop cycle ranged between 45 to 60 days on the average.

Adjacent famers cultivated different vegetable varieties in order to avoid competition between them. From the total sample, half of the farmers represented grade six to grade 10 education categories, while only few (18%) had an education level below grade five (Table 1). This indicates majority of the sample was having a reasonable education.

The average vegetable land extent was 6879.65 m^2 (1.7 acre) and more than 95% of farmers held land less than 20234.30 m^2 (5 acre) of land. Hence, vegetable cultivation was practiced in small land plots within the area. Average farm gate prices of Pumpkin, Beet and Cabbage were 74.43 LKR kg^{-1}, 45.82 LKR kg^{-1}, and 33.00 LKR kg^{-1} respectively (Table 1). Farm gate prices ranged between 10 LKR kg^{-1} to 180 LKR kg^{-1} for all three vegetable varieties. Farmers obtained an average yield of 0.92 kg m^{-2} (3734 kg $acre^{-1}$) for pumpkin, 1.54 kg m^{-2} (6233 kg $acre^{-1}$) for Beet and 2.78 kg m^{-2} (11242 kg $acre^{-1}$) for Cabbage.

They also applied 0.10 kg m^{-2} (354 kg $acre^{-1}$) of solid form of inorganic fertilizer, separately for both Pumpkin and Beet and 0.08 kg m^{-2} (349 kg $acre^{-1}$) for Cabbage. Interestingly, majority (80%) mixed various types of organic matter (poultry manure, cow dung, paddy husk and other crop and animal residue) with inorganics. Average monthly household income of only 28% of farmers were below LKR 100,000. This implies earnings of the farmer families were at a satisfactory level, compared to other crop cultivators around the country.

Farmers tend to select Pumpkin aiming at a higher selling price per unit over Beet ($P<0.05$) and Cabbage ($P<0.01$) when everything else was held constant (table 2). This was mainly due to the varietal selection and frequent cultivation of *batana* variety in the area. Hence, they obtain better farm gate prices for *batana* pumpkin variety compared to normal variety (Table 2). However, there was a considerable yield difference between these two varieties. In general, farmers obtained a relatively lower yield from *batana* variety. On the other hand, this is one of the highly demanded vegetable commodities in the local consumer markets.

Farmers tend to select Beet ($P<0.05$) and Cabbage ($P<0.01$) aiming higher yield prospects over Pumpkin when other factors are not changing. Both Beet and Cabbage are originally cultivated in the upcountry region

Table 1: Socio-Economic Characteristics of the Sample

Demographic Character	N = 130	Percentage
Gender		
Male	119	91
Female	11	9
Education level		
Grade 5 or below	18	14
Grade 6 – 10	65	50
Up to O/L	35	27
Up to A/L	12	9
Higher education	-	-
Average monthly household income*		
< 50,000	13	10
51,000 -100,000	22	18
101,000-150,000	19	15
151,000-200,000	15	12
201,000-250,000	19	15
251,000-300,000	8	6
301,000-350,000	4	3
351,000-400,000	5	4
401,000-450,000	2	2
451,000-500,000	5	4
501,000-550,000	2	2
551,000-600,000	3	2
601,000-650,000	2	2
651,000-700,000	-	-
>700,001	5	4

	Crop		
	Pumpkin	**Beet**	**Cabbage**
Average Land extent (acre)	1.50	1.74	1.62
Average Yield (kg acre^{-1})	3734	6233	11242
Average Farm gate price (LKR kg^{-1})	74.43	45.82	33.00
Average Inorganic fertilizer usage (kg acre^{-1})	354	354	349

*Note: * Only 124 farmers were disclosed the average monthly household income*

of Sri Lanka.

In recent years, low-country farmers also initiated cultivation of some of those vegetable varieties. This resulted competition between primary vegetable production groups in the country. This transformation is prominently evident in the Kalpitiya area. In the early years, Kalpitiya area was popular for the cultivation of cash crops like other field crops (OFC). However, at present more farmers have adopted vegetable cultivation. This has been further boosted with the establishment of the Norochchole Dedicated Economic Centre (DEC), which is specialized for vegetable marketing. Estimated daily vegetable trade of the centre is 100,000 kg. Interestingly, female farmers ($P<0.01$) tend to select Pumpkin over Beet. This may be due to easiness in harvesting.

Adherent topography (sandy soil and arid climatic condition) is also boosting the cultivation of vegetables in Kalpitiya. At present the area is flourished with roughly around 2500 hectares of vegetable lands [16].

Table 2: Results of the MLR Analysis

Crop[a]	Parameter	Coefficient	SE	P value
Beet	Intercept	35.09	3511.23	0.99
	Gender (Male)	-17.66***	1.34	$<1*10^{-3}$
	Age	-0.01	0.03	0.84
	Extent	0.27	0.44	0.53
	Average Yield	$<1*10^{-3}$**	$<1*10^{-3}$	0.03
	Selling Price per unit	-0.04**	0.02	0.01
	Average Fertilizer Usage	0.00	$1*10^{-3}$	0.83
	Organic Fertilizer Usage	1.00	0.80	0.21
	No. Family Labor	0.06	0.25	0.81
	No. Hired Labor	0.04	0.04	0.34
	[Education=1]	-16.46	3511.23	0.10
	[Education=2]	-16.50	3511.23	0.10
	[Education=3]	-16.49	3511.23	0.10
	[Education=4]	0[b]	-	-
Cabbage	Intercept	35.91	3511.23	0.10
	Gender	-20.22	$<1*10^{-3}$	-
	Age	-0.03	0.04	0.49
	Extent	0.39	0.50	0.43
	Average Yield	$1*10^{-3}$***	0.00	$<1*10^{-3}$
	Selling Price per unit	-0.12***	0.03	$<1*10^{-3}$
	Average Fertilizer Usage	$<1*10^{-3}$	$1*10^{-3}$	0.77
	Organic Fertilizer Usage	-0.58	1.14	0.61
	No. Family Labor	-0.37	0.39	0.34
	No. Hired Labor	0.06	0.05	0.31
	[Education=1]	-32.14	4271.77	0.99
	[Education=2]	-14.42	3511.23	0.10
	[Education=3]	-14.51	3511.23	0.10
	[Education=4]	0[b]	-	-

a. The reference category is: Pumpkin.
b. This parameter is set to zero because it is redundant.
***Significant at 1% level, **Significant at 5% level, * Significant at 10% level.

Agriculture itself has created nearly 30,000 jobs in the area. Inter-monsoon starting from October to December and North-East monsoon starting from December to February are the two major rainy seasons. Farmers tend to cultivate more on these seasons. The presence of fresh water reserves in the soil at easily accessible depths is another factor, which encourages cultivation in the area. This favours crops, which have short life span such as vegetables. Sequential vegetable cropping pattern (three to four crops are planted one after another) was visible in the area [16]. Crop diversity within the farm and natural fallowing was at a minimum level. Maintaining an optimum level of water supply for plants is vital, in order to provide moisture as well as to reduce heat. Therefore, most farmers use irrigation systems like, sprinklers and drips. Extraction of too much of groundwater may result salt water intrusions in the area. Hence, establishment of agro-wells should be done with care.

In overall, development of farming activities in Kalpitiya area have been intensified over the years according to the respondents. Interestingly, more and more farmers have gradually opted for vegetable cultivation. This practice was prominent

among younger farmers. Usage of high amounts of agrochemicals is one of the major issues identified in the vegetable cultivation. Poor soil fertility and high nutrient leaching potential in the area, have induced farmers to apply high amounts of agrichemicals. Excess chemicals, which leach into groundwater could lead to long term health issues among the community. This could be reduced by applying sufficient organic manure in to the soil layers. Water efficiency could be improved by applying mulches and planting cover crops [17].

Farmers rarely exhibit such practices in their cultivation. In addition, Kalpitiya area is highly vulnerable to climatic changes. Even minor changes in climate could have a significant impact on the cultivation. Hence, farmers should be properly aware on alternative crop cultivations like fruit crops and plantation crops to mitigate climatic risk in agriculture to a certain extent. At the same time promotion of protected house cultivation among the community is another suitable option [18]. Also, information flow of the supply chain is less efficient. Most of the time, both producers as well as consumers make incorrect selling and purchasing decisions based on false signals.

CONCLUSION

According to the findings, it is evident that both farm gate prices and the average yield were the main driving factors influencing the selection of a particular vegetable crop by a farmer. Farmers obtained better returns and faster cash recovery from the vegetable cultivation. Also, short harvesting cycles in these crops tend to mitigate market and production risk to a certain degree. In addition, Norochchole Dedicated Economic Centre (DEC), which is located in the Kalpitiya peninsular also promote the vegetable marketing in the area. However, farmers were inclined to cultivate only few selected vegetable varieties rather than focusing on many varieties. For the short run this might create price competition and lower producer prices. In the long run this might create major issues in sustainability in vegetable cultivation in Sri Lanka. Hence, this has to be managed by introducing alternative cultivations like fruit crops and plantation crops among these farmers and establishing market chains accordingly.

AUTHORS' CONTRIBUTIONS

VK: Designed the study, data analysis and wrote the manuscript; NDS: Data collection and reviewed the manuscript; JE: Designed the study and reviewed the manuscript, LU: Improved the manuscript; RG and IH reviewed the manuscript.

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