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Contents

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Optimal Utilization of Renewable Energy Resources Available at Ridiyagama NLDB Dairy Farm to meet its own Power and Energy demand

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Abstract– *Ridiyagama NLDB dairy farm, the largest in South Asian region, provides fifteen million litres of fresh milk annually to the nation of Sri Lanka. Dairy farms today consume more energy than any other agricultural industry facing challenges owing to ever increasing energy prizes and environmental impacts. Energy is extensively consumed in milking, cooling, water heating, lighting and ventilation processes. If one could determine and explore the best energy conservation and management opportunities available, it would not only reduce the wastage of energy in the existing processes but also enhance the environmental quality in and around this farm. Therefore, the objective of this research study would be to ascertain the required optimal power and energy demand of the farm while fulfilling it by harnessing the available renewable energy resources. Initially, screening and detailed energy audit carried out to gather required energy data and process details. Subsequently, the energy optimization and conservation opportunities such as replacement of florescent lamps by light emitting diodes, introduction of variable frequency drives for vacuum pumps and solar thermal heating etc. are introduced. To meet the optimized farm load, renewable energy hybrid system combining the renewable energy sources such as sheer wind catchers, solar thermal collectors, photovoltaic (PV) system and biogas generator with national grid are considered. Demand/supply analysis with optimal sizing of Wind/PV/Biogas/Grid combinations are then simulated. Required number of units/type/sizes, ensuring that the life cycle cost is minimized subjected to power/energy requirement of the farm is being optimally met are then figured out. Finally, the amount of excess energy that can be exported to the national grid with maximum reduction of CO_2 emission to the environment is reasonably computed and presented.*

***Keywords**: Renewable Energy Hybrid Systems, Environmental impact, Life Cycle Cost, Optimal power and energy, Energy audit, National grid*

Nomenclature

EUI – Energy Utilization Index

NLDB – National Livestock Development Board

HRES – Hybrid Renewable Energy Systems

LCC – Life Cycle Cost

IC – Internal Combustion

VFD – Variable Frequency Drive

GHI – Global Horizontal Index

CEB – Ceylon Electricity Board

1 INTRODUCTION

1.1 National Livestock Development Board (NLDB)-Ridiyagama Dairy Farm

NLDB-Ridiyagama dairy farm located in Hambanthota district is the largest in South Asian region fulfilling dairy needs of Sri Lanka. In 2014, two reputed type of cows; Jersey and Jersey-Cross were imported to the farm. Presently, 2000 acres are cultivated in this farm with pasture and fodder to feed 3000 bulls, dairy cows and calves. The farm harvests about 24,000 litres of fresh milk daily. Site plan of the dairy farm and structure details are shown in Appendix-A Figure-1 and Appendix-A Table -1 respectively.

1.2 Utilization of Energy in Ridiyagama Dairy Farm

More than 80% of the energy requirement is met by electrical energy for various processes such as milking, cooling and storing milk, lighting and ventilation etc. and the rest is from fossil fuel for crop harvesting and feeding. Monthly electricity bill is around 4 million LKR. This shows that the energy demand in dairy industry is higher than any other agricultural industry thus facing challenges owing to ever increasing energy cost [17]. Since the national energy policy framework in Sri Lanka is now enforcing awareness programs to introduce new energy saving equipment for the conservation of energy and, if NLDB-Ridiyagama farm does not adopt energy conservation programs and not introduce sustainable energy alternatives, it has to spend lot more money for its energy requirement in future. Thus, managing it efficiently and appropriately, helps to reduce wastage of energy and increase the productivity, profitability and enhance environmental quality.

1.3. Identification of the Existing Problems in Ridiyagama-Diary Farm

The energy usage affects per unit prize of milk production. If it goes up, NLDB cannot compete in the open market resulting low profit margin. Apparently, farm does not practice any energy efficient or conservation programme for optimization of its energy utilization. In cattle sheds, florescent lamps consume nearly 155 kWh/day, which can be reduced up to a reasonable level. By shifting the processes consuming electricity overlapping with system peak to off-peak period through demand side management, it can save a lot. Natural energy resources such as solar and wind power potential are amply available in this area and can be harnessed to generate in house energy requirement. While solar PV system can meet the daytime energy demand, solar thermal energy can be used as preheaters instead of existing electric heaters. Sheer wind funnels can harvest wind energy and replace existing fan driven ventilation system for cows. More than 30 tons/day of cow dung is thrown away. A digester can convert it into biogas and an IC engine can be driven by fulfilling the energy requirement of the farm.

Therefore, identification of preventable losses in dairy production processes, optimization of energy usage by introducing energy conservation methods, investigation of environmentally friendly techno-economically feasible optimally integrated HRES, computation of Energy Utilization Index (EUI) are utmost important.

Hence this research was aimed to utilize the available renewable energy resources at Ridiyagama dairy farm to meet its own power and energy demand optimally while understanding the level of feasibility and to establish Energy Utilization Index (kilo-Watthours spent per cow per year)

2 LITERATURE REVIEW

Canada and Ireland have done lots of studies regarding energy conservation and renewable energy generation opportunities in dairy industry. A case study, [4] is a classic example by Carrie Houston, Samuel Gyamfi and Jonathan Whale. In here, first they have undertook billing analysis and walking through audit to estimate the energy usage, identify equipment's and machineries in operation, energy growth rate and the amount paid for electricity. Drew chronological load curve and studied the energy consumption pattern. Thereafter, identified methods to reduce energy consumption and conservation. Subsequently, the optimal demand of the farm is established. Based on findings, they have designed a system combining renewable energy resources such as wind power and biogas plant to cater to the reduced demand of the farm. Another study carried out in Ireland [6] by J. Upton, J. Humphreys, P. W. G. Groot Koerkamp discussed about different kind of a set up. In here, they have prepared the load curve first and analysed it for cost reduction opportunities by shifting some dairy processes to system off-peak period called valley filling in demand side management without effecting the biological cycle of the farm.

3 METHODOLOGY

This should be the most appropriate practical approach that would bring the subject research study deliverables to NLDB. Following activities are planned to be carried out:

- Walk through audit followed by a detail audit and analysis of gathered data.
- Application of energy efficient and conservation opportunities.
- Techno-economical sizing of solar PV panels to cater daytime energy demand.
- Feasibility study for solar thermal as preheaters to replace existing geysers.
- Replacement of forced ventilation by natural sheer wind funnel system (INVOLEX).
- Analysis of the amount of cow dung/urine available per day to design a suitable biogas digester from which a techno-economically feasible appropriate size of a biogas plant.
- Investigation of the economic feasibility and environmental impact of integrated sustainable HRES.
- Preparation of energy utilization index (EUI- kWh/cow/year).
- Export excessive energy generated to the national grid, if there is any.

Block diagram of the proposed methodology is shown in Figure-1.

4 ENERGY AUDIT AND ANALYSIS

4.1 Historical Billing Analysis

Historical billing analysis covering 2 consecutive years, 05/2016 to 05/2018 is shown in Appendix-A Figure-2. There are 2 CEB bulk supply connections connected to this farm; contract demands of 1000kVA and 100kVA, subjected to I2 and GP2 tariffs (Appendix-A Table-2) respectively paying monthly average of 4 million LKR for electricity. It can be seen from Table 1 below, by changing the tariff system from GP2 to I2 for latter contract, annual saving of nearly 1 million LKR can be achieved without any modification or an investment.

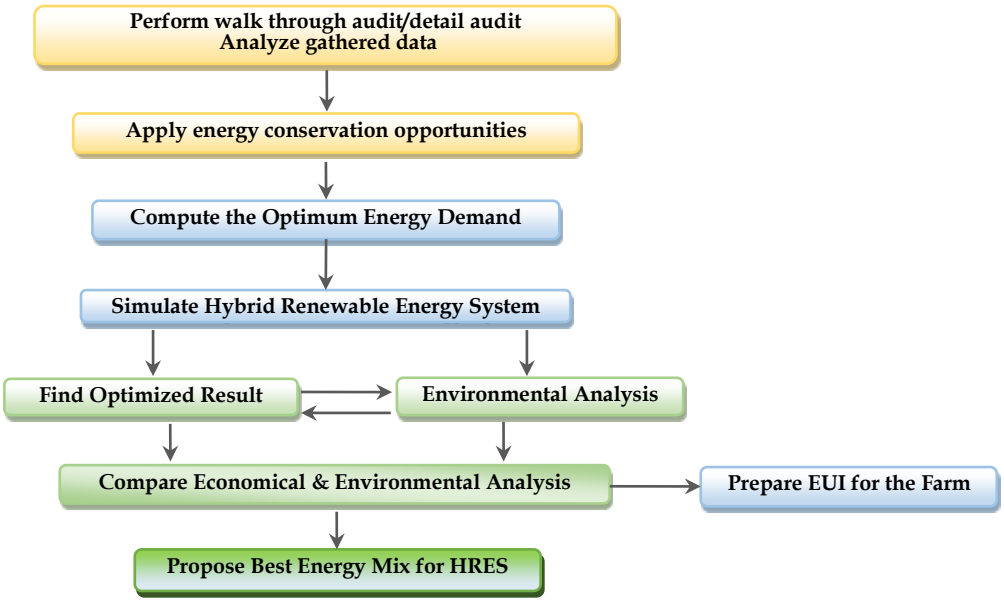


Figure 1: Block Diagram showing the Proposed Methodology

Table 1- GP2 VS I2 tariff applied for 100 kVA supply for the month of March 2018

	Units	GP2 (LKR)	GP2 Amount	I2 (LKR)	I2 Amount
Peak time	1689	26.60	44,927.40	20.50	34,624.50
Day time	5485	21.80	119,573.00	11.00	60,335.00
Off-Peak time	2739	15.40	42,180.60	6.85	18,762.15
Maximum demand (kVA)	72	1,100.00	79,200.00	1,100.00	79,200.00
Fixed charge	-	3,000.00	3,000.00	3,000.00	3,000.00
Total monthly bill (LKR)			288,881.00		195,921.65

4.2 Walking through Audit

Power ratings/operational hours of the equipment's gathered during walking through audit are shown in Appendix-A Table-3. Milking of the herd is twice a day, one at 3.00 AM and the other is at 3.00 PM. In one cycle, approximately 12,000 litres of milk is extracted and delivered to the refrigeration tank. It is observed that the ventilation, water pumping, and cooling consume more energy than other processes. Cooling and ventilation processes are little complicated than the others in terms of collecting data. As such, the detailed energy audit is carried out to collect actual demand of the equipment's and the durations of said processes. Every element identified by the screen survey was further audited in detail. Collected data tabulated for analyzing purposes is presented in 4.3.

4.3 Electrical Energy Consumption Breakdown by Sectors.

Energy consuming equipment's such as ventilation fans, cooling tanks, parlors and air compressors are operating in a prespecified sequence. Gathered data is shown in Table 2.

It can be seen clearly that 74% of the total energy requirement of the farm is consumed by 1.5 kW ventilation fans. Pumping water is the second highest and is about 17%. Cooling, vacuum pump, air compressor, heating and lighting consume 3%, 1%, 2%, 1% and 2% of the total energy consumption respectively and are shown in Figure 2.

Table-2 Energy consumption

Sector	kWh/Day
Lighting	155.8
Ventilation	6189.5
Motors /Pumps	1465.5
Cooling	286.3
Vacuum Pump	114.2
Air compressor	176
Heating	35.8

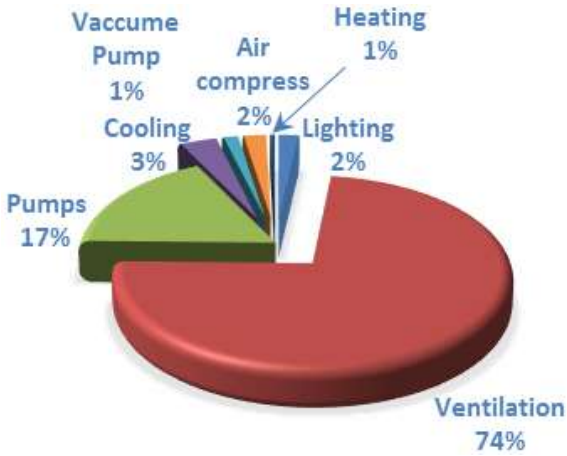


Figure 2-Energy Consumption Breakdown by Sectors

4.4 Chronological Load Curve of the Farm

Chronological demand pattern of the farm is shown in Figure 3 with two peaks occurred between 0400 to 0900 hrs. and 1500 to 2000 hrs. Peak load duration of the national grid is declared between 1830 and 2230 hrs. Therefore, the evening peak load of the farm overlaps with the system peak duration time. Owing to this, farm is liable to pay more for its electrical energy consumption during this period. (See Appendix A Table-2)

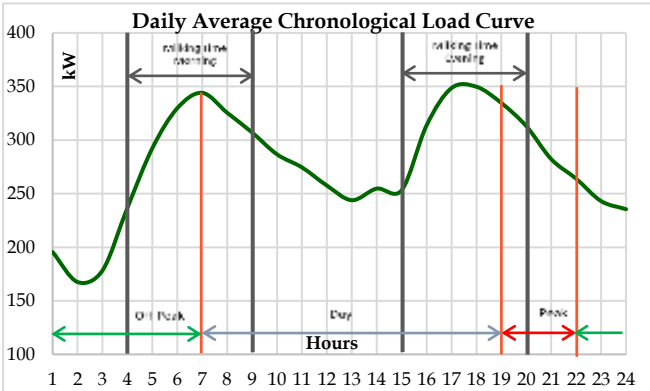


Figure 3-Average daily load pattern

5 ENRGY CONSERVATION OPPORTUNITIES

5.1 Introduction to Milking Process

Milk is extracted from each cow spending 3 to 5 minutes using pulsating cups powered by vacuum pumps, the most important pieces of equipment in the milking shed driven by

induction motors. It also aids transporting milk to the central collecting vessel and then to the milk storage tank via filters and plate coolers. Since milking process is purely biological, no changes or alteration can be done from the energy conservation point of view. Schematic diagram of the milking process is shown in Appendix-B Figure-1.

5.2 LED system instead of florescent lighting

In dairy sheds, electricity used for lighting accounts for 2% of the total electrical energy consumption. 398 double florescent lamps consume 156kWh/day for lighting. Economic analysis of the conversion of florescent lamps to LEDs is shown in Appendix B Table-1.

5.3 Solar Water Pre-Heating system instead of Existing Electric Geysers.

Eight-6kW water heaters consume 1% of total electrical energy consumption. After each milking cycle, plant and the storage tanks must be cleaned using hot water at 85°C. For this purpose, 3,200 L of water requires to be heated up from 27°C to 85°C. Since GHI is high in this area, it is worth considering solar pre-heaters instead of element heaters. It initially pre heat water from 27^0C to 80^0C. Thereafter, secondary heating from geezers required to top it up to 85^0C. RETScreen Expert clean energy management software is used to compute number of solar panels required for pre-heating. Cost spends for water heating and savings that can be achieved by introducing solar heating is shown in Appendix-B Table-2.

5.4 Vacuum Pumps driven by variable speed drives

Vacuum pumps are consuming 114.2kWh/day. Since vacuum load is time varying, wastage of energy is observed when motors are running at its full capacity, even though it is not necessary. Hence, it is proposed to introduce Variable Frequency Drive (VFD) controllers to dairy shed vacuum pumps. Controlling speed of the motor not only save significant amount of energy but also improves the controlling of vacuum pressure. As a benchmark, VFDs can save more than 35% of energy wastage. Expected annual saving that can be achieved by installing 7.5kW VFDs is shown in Appendix-B Table-3.

5.5 Sheer Wind Funnel based natural Ventilation System (VS) for Cow Sheds

Ventilation system is the key energy consumer in this farm utilizing 75% of total energy. It helps to maintain comfortable environment in cow sheds. Most cows are healthy and highly productive between 70°F to 77 °F with relative humidity <90%. For this purpose, fans are pushing air at design static pressures in conjunction with sprinklers that wet cows' back. Class 4 wind level with direction almost on South-West throughout the year is available in this area. Wind Rose and frequency distribution of wind speed are shown in Appendix-B Figure-2 and 3 respectively. Dimensions of a cow shed is 200mX30mX7m with a roof at an angle of 150^0 slope. Detail requirements for ventilation are given in Table-3.

Table 3-Detail requirements

	Body Weight	Ventilation rate $m^3/s/cow$	
		Cold whether	Warm whether
Dairy Cow	400-600kg	0.12	0.24

Volume of the cattle shed = 42000 m^3

72 numbers of 48′ diameter fans are mounted on 10′ height at 25′ apart to ventilate a dairy barn. Proposed system replaces the existing forced ventilation by natural ventilation using sheer wind funnels (INVOEX). Natural ventilation system can be designed and guided by ventilation standards for dairy barns by ASHRAE (1993) [14]. Minimum ventilation rate required for a dairy barn is 691,200m^3/h at a speed of 1-1.5m/s. Sheds are oriented in East-West direction whereas more than 75% of wind comes from South-West. Funnels receiving wind at 1 to 7m/s at 20m height can be directed to nozzles at a speed of 4 to 28m/s (Daryoush Allaei-2014) [15]. Captured wind can be directed/guided to barn through ducts. Schematic diagram of the proposed system is shown in Appendix-B Figure-4. Optimum number of wind funnels required to be installed in this farm will be explained in 6.

5.6 Off-Peak Water Pumping System

River Walawe fulfils the water requirement of farm consists of 2-15kW pumps, operate right throughout the day controlled by float switches installed in storage tanks. Daily water usage is about 800,000 to 1,000,000 liters. Required energy for water pumping system is approximately about 157.5 kWh/day costing 716,870 LKR annually. Since pumps are operated by float switches, they do operate even during the system peak hours. To avoid this, time-based water pumping system is proposed with an annual saving of 405,590 LKR.

5.7 Refrigeration of Milk

Cooling process consumes about 3% of the total dairy farm energy consumption. Milk is harvested around 35^{0}C to 37^{0}C needed to be lowered quickly around 4^{0}C. Refrigeration system consists of a bulk tank, a motor-driven compressor unit, an evaporator and a condenser unit. While inspecting the refrigeration process, places found with lots of energy wastage. Refrigerant pipes are not well insulated, condenser shells are covered with dust particles hence, cooling process found to be not efficient. A well-planned schedule maintenance program can eliminate this issue. Another big issue is the circulation of output heat inside the cooling room. An exhaust duct is proposed to remove heated air.

6 OPTIMAL HYBRIDS RENEWABLE NERGY SYSTEM (HRES)

6.1 Introduction

The remarkable ability of HRES is to foster the deployment of renewable energy and better alternatives for CO_2 emission reduction for electricity production. In here, the system has to be designed techno economically, considering the optimal power and energy demand of the farm as well as the power and energy output pattern of the different solar PV, wind and biogas combinations. Hence, multiple possible combinations of HRES owing to different sizes of PV arrays, DC-AC converters, wind funnels and biogas systems are to be considered and simulated.

6.2 Optimized Electricity Demand of the Farm

The optimized demand pattern of the farm after introducing LEDs, VFDs, Solar hot water system and off-peak water pumping system is taken and treated as the farm load when designing the HRES. The optimized load curve is shown in Figure 4. Two peaks occur between 0600 and 0900 hrs. and 1600 and 2000 hrs. during milking time. Peak demand is about 334.9kW occurring at 1800 hrs. in the evening. Daily consumption is about 6321 kWh/day with a load factor of 78.6%.

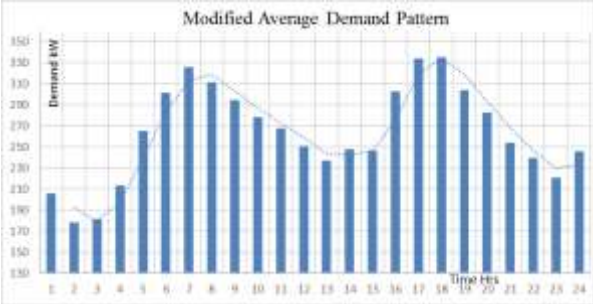
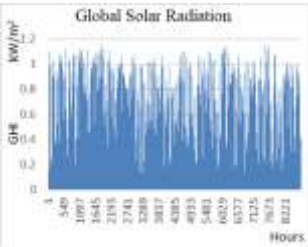
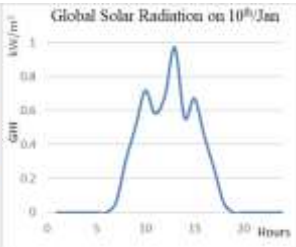


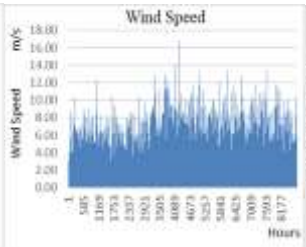
Figure 4-Modified average demand pattern of the farm

6.3 Solar & Wind Energy Potential in the Farm

Global Horizontal Index pattern shown in Figure 5 is taken from NASA surface meteorology and solar energy database. Hourly average solar energy density values on 10th Jan 2018 are shown in Figure 6 for illustration purpose. HOMER Graham algorithm is used to determine hourly values of solar radiation. The wind pattern of Mattala international airport, taken from metrological department is shown in figure 7. Since NLDB farm is very close to Mattala, roughness factor is assumed to be the same as at the airport. Hourly wind pattern at Mattala area is shown in Figure 8 on 10th/Jan. 2018 for illustration.







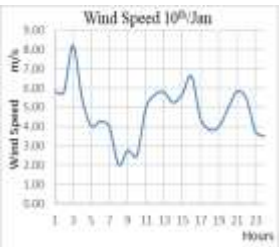


Figure 5-Annual GHI pattern

Figure 6- Solar radiation on 10th/ Jan

Figure 7-Hourly wind speed

Figure 8 Wind speed on 10th/Jan

6.4 Modelling of System Components

Generalized model of the hybrid renewable energy system proposed for NLDB farm in this research study is shown in Figure 9. The modelling of PV, wind and biogas systems are described in this section.

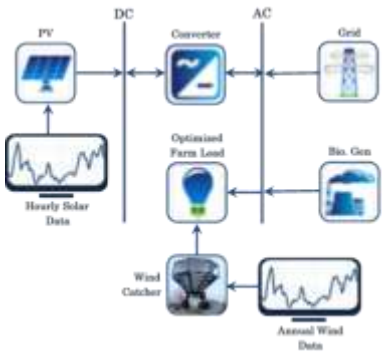


Figure 9-Generalized model of the hybrid renewable energy system

6.5 Photovoltaic System

The electrical power output from PV panels $P_{PV(t)}$ at time t is given by:

$P_{PV(t)} = I_t * \eta_{PV} * A_{PV}$ *I_t=Solar intensity; A_{PV} = Total area of the photovoltaic panel*

$\eta_{PV} = \eta_r * \eta_{PC}\left[1 - N_T\left[\left\{T_{ambient} + \left(\frac{NOCT-20}{800}\right)R_t\right\}T_{reference}\right]\right]$ *η_{PV} = Efficiency of the solar module*

Canadian CS6U-340M-PV module is selected in this study for simulation and the technical parameters are given in Appendix-C Table-1. Symbols have their usual meaning.

6.6 Wind System

In this study, wind exploited by sheer wind catcher (INVOLEX) is simulated for natural ventilation requirement in cow sheds. Captured wind replaces the existing ventilation fans. Fluctuation of the wind changes the number of fans in operation. In here, positive wind power is treated as negative-load and negative wind power is treated as positive-load with varying wind pattern while modelling. Symbols have their usual meaning.

$P_{Wind(t)} = {}^{1}/_{2} * \rho * A * C_p * V^3$ *C_p = Boltzmann constant; V= Wind velocity*

Where; $220\ kW_{during\ daytime} \leq P_{Wind\ (t)} \leq 110\ kW_{during\ night\text{-}time}$ *4≤ Number of wind funnels ≤24*

6.7 Biogas System

More than 3,000 cattle's in this farm produces about 20 tons of manure and 20,000 litres of urine daily. Lower Heating Value (LHV) and efficiency curves of the biogas generators are taken from the IRENA report of biogas [18] for modelling purposes. One kilogram of cow manure produces 40 litres of biogas and 1000 litres of biogas can generate 1kWh.

$$P_{Biogas(t)} = \frac{LHV * \eta_{Biogas} * V_{fuel} * Time_{Biogas-On}}{365 * 9}$$

$160kW \leq P_{Biogas(t)} \leq 20kW$ $2000\ hrs. \geq Time_{Biogas\text{-}On} \geq 1400\ hrs.$

6.8 Objective Function

The economic factors considered when optimizing the HRES includes capital cost, operation and maintenance costs of solar PV, biogas plant, wind funnel and revenue earned by exporting excess energy to the national grid if available. Optimization of the objective function is achieved by minimizing the system cost while maximizing the overall system income subjected to the constraints given with the equations described in 6.5 to 6.7.

$Objective\ Function = Minimize\ NPV\ of \sum_{i=1}^{25}(Cost_i - Income_i)$ *for i=1 to 25 years*

In the objective function, Life Cycle Cost (LCC) of the HRES is minimized to get the optimum size of PV, biogas plant and number of wind funnels.

$LCC = C_{capital.} + C_{O\&M} + C_{fuel} + C_{elec.-import} - C_{elec.-export}$ *O&M =Operation and Maintenance*

Solar PV area, size of biogas plant and number wind funnels are stochastic variables of the capital cost function.

$$C_{capital} = \frac{P_{module}A_{PV}}{A_{module}}\left(C_{module} + C_{invter}\left(\sum_{i=15}^{25}\frac{1}{(1+r)^i} + 1\right)\right) + C_{wind\ funnel} * Number_{wind\ funnel} + C_{Biogas} * P_{Biogas}$$

Nett Present Value of O&M cost are considered for the lifetime of 25 years.

$$C_{O\&M} = \left(\sum_{i=1}^{25}\frac{1}{(1+r)^i}\right)\left[\left(\frac{C_{O\&M\ of\ PV} * P_{Module} * A_{PV}}{A_{module}}\right) + C_{O\&M\ of\ WT} * Number_{wind\ funnel} + C_{O\&M} * P_{Biogas}\right]$$

Biogas plant is restricted to be operated only during the evening peak from 1400 hrs. to 2200 hrs. overlapping with the national grid evening peak.

$$C_{fuel} = \left(\sum_{i=1}^{25}\frac{1}{(1+r)^i}\right)\left[\frac{P_{Biogas(t)} * 365 * 9 * C_{Biogas-Fuel}}{LHV * \eta_{Biogas}}\right]$$

In the objective function, income is generated by selling net power production throughout the year to the national grid. Energy sold to the grid is treated as positive and imported from the grid is treated as negative in monitory terms.

$$Net\ Power\ Production_{\ t} = P_{PV(t)} + P_{Biogas(t)} - \left(P_{Demand(t)} - P_{wind(t)}\right) \qquad \textit{If, Net Power Production} > 0$$

$$C_{electricity-export} = \left(\sum_{i=1}^{25}\frac{1}{(1+r)^i}\right)\left[\sum_{t=1}^{8760} C_{export(t)} * Net\ PowerProduction\right] \quad \textit{If, Net Power Production} < 0$$

$$C_{electricity-import} = \left(\sum_{i=1}^{25}\frac{1}{(1+r)^i}\right)\left[\sum_{t=1}^{8760} C_{import(t)} * Net\ Power\ Production\right]$$

6.9 Optimization Procedure

Initially, the net energy production (NEP) by all possible combinations of PVs (area≤6000m^2 to match the transformer capacity), 4≤wind funnels≤24, 20kW≤biogas-generator≤160kW with hourly average values of wind and solar against optimum demand of the farm are established. Excess energy, if available is exported to the grid only during daytime. Wind is restricted to match the ventilation demand. If NEP is in excess, energy is sold to the national grid and vice versa. The NPV value of NEP is then computed for 25-year evaluation period. Thereafter, the NPV of capital costs, O&M costs and fuel costs are added to the NPV of annual net electricity cost. Finally, this is plotted to find out the minimum value of LCCs. Four combinations namely PV/Wind/Biogas, PV/Biogas, PV/Wind and Wind only systems are considered and analysed. Flow chart illustrating the steps carried out during the optimization procedure is shown in Appendix-D Figure-1.

7 RESULTS AND DISCUSSION

Four combinations of HRES stated in 6.9 are locally analysed to see their impact on the environment while the indexes such as LCC, rate of return and simple payback period (SPP) for each set are further examined to see their economic feasibility.

7.1 Case 1 - PV, Biogas & Sheer Wind Funnel System

In here, 820 technically feasible sets are analysed applying industrial tariff and net metering. It was found that the minimum LCC corresponds to 830kW PV plant (4750m^2), 16 wind tunnels and 160 kVA biogas generator costing around 259.33 million LKR. The individual renewable energy generation, energy demand, grid energy purchased and sales for an illustration purposes on a day are shown in Figure 10 and 11 respectively.

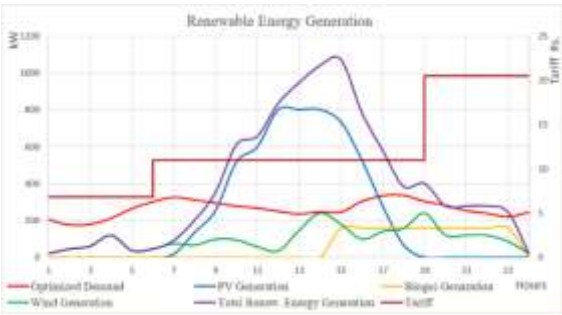


Figure 10-Renewable energy generation

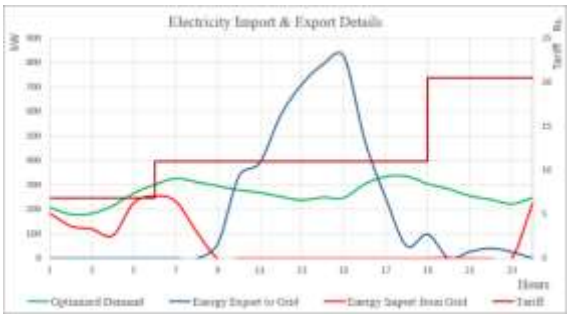


Figure 11-Energy import/export to the grid

7.2 Case 2 - PV & Biogas System

In this case, 240 feasible sets of PV and biogas generation opportunities are considered. It was found that the minimum LCC corresponds to 830kW PV plant (4750m^2) and 60 kVA biogas generator costing around 272.54 million LKR. The net energy production, renewable energy generation, energy demand, grid purchased and grid sales on an average day is shown in Figure 12 and 13 respectively.

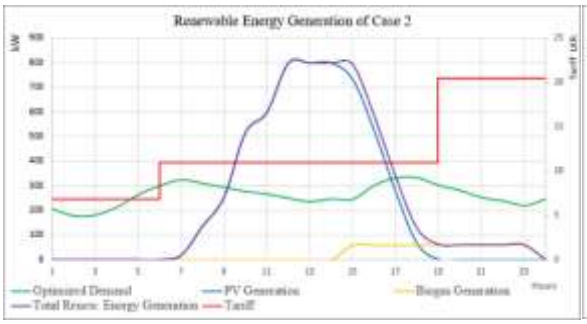


Figure 12- Renewable energy generation

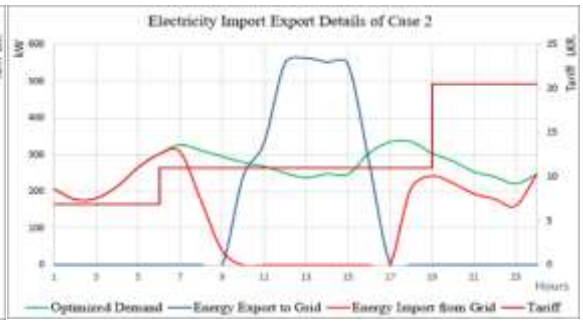
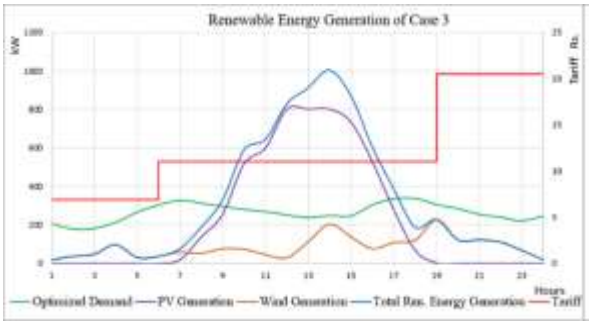


Figure 13- Energy import/export to the grid

7.3 Case 3 - PV & Sheer Wind Funnel System

One hundred and eighty sets of PV plants and wind energy harvesting opportunities are considered here. It was found that the minimum LCC corresponds to 830kW PV plant

(4750m²) and the required number of wind tunnels to be 12 for ventilation costing around 264.9 million LKR. The net energy production, renewable energy generation, energy demand, grid purchased and on an average day is shown in Figure 14 and 15 respectively.



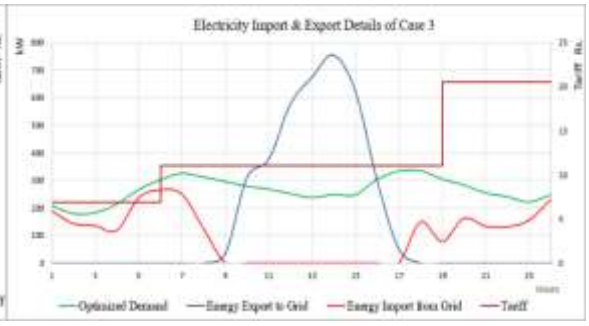
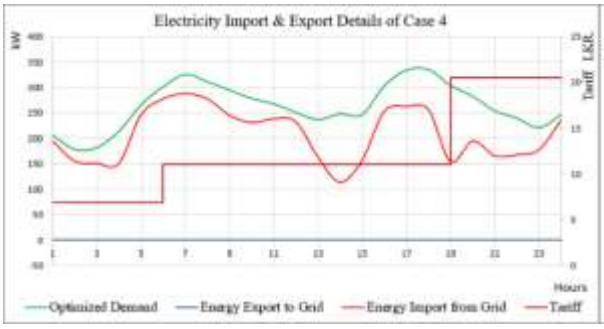


Figure 14-Renewable energy generation **Figure 15- Energy import/export to the grid**

7.4 Case 4 – Wind Energy System Only

Number of wind funnels varied here from 4 to 24 with prespecified constraints. In this case, 6 sets of wind energy harvesting opportunities are considered. It was found that 8 wind funnels are sufficient to provide wind energy for ventilation purposes costing 252.3 million LKR. The net energy production, renewable energy generation, energy demand, grid purchased and grid sale on an average day is shown in Figure 16 and 17. respectively.



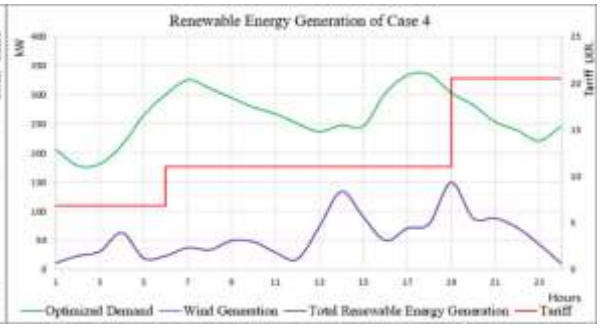


Figure 16- Renewable energy generation **Figure 17-Energy import/export to the grid**

7.5 Summary of the Hybrid Renewable Energy Systems

Table 4 depicts the summary of minimum LCC for each case. As can be seen, the minimum LCC occurred in case 4. The cost involved here is the initial capital of 24 million LKR, required for the construction of wind funnels and its accessories. However, as a result, NLDB has to pay nearly 24 million LKR for electricity in subsequent years. Therefore, the four cases are further evaluated with their rate of return figures as shown Figure 18 and table 5 to get a clear picture and an insight feeling for the best fit solution.

Table 4-Summary of the Hybrid Renewable Energy Systems

	Rate of Return MLKR/Yr	NPV of Savings MLKR
Case 1	38.35	348.28
Case 2	24.29	220.56
Case 3	27.80	252.49
Case 4	4.66	42.3

Table 5 Rate of return and NPV savings

	Case 1	Case 2	Case 3	Case 4
Combinations	830kW-PV 16 Wind/160 Biogas	830kW-PV 160 Biogas	830kW-PV 12 Wind Funnels	8 Wind Funnels
Capital Cost	300.2	219.23	240.23	24.0
NPV of Elec. Cost	-79.13	37.5	16.6	226.85
NPV of O & M Cost	12.37	6.1	7.1	1.4
Fuel Cost	25.89	9.71	-	-
LCC	259.33	272.54	264.9	252.30
Rank	**02**	**04**	**03**	**01**

Figures are in Million LKR

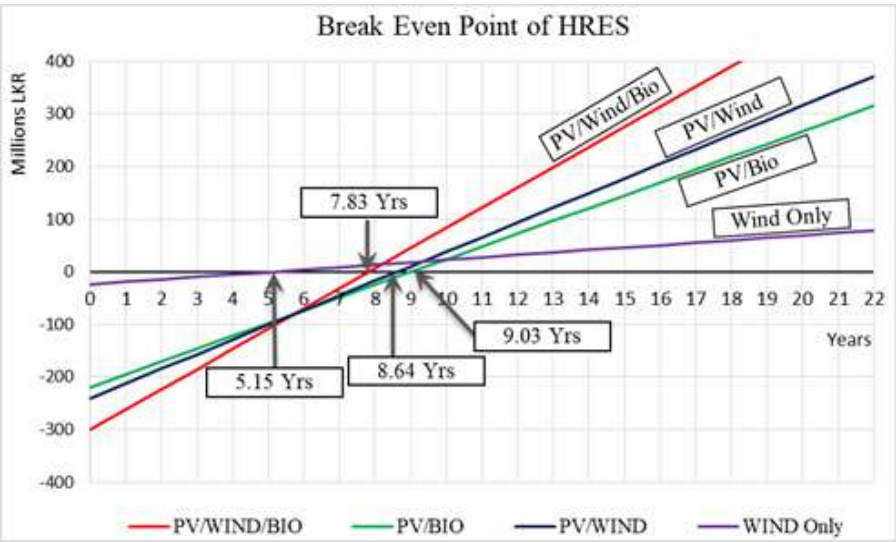


Figure 18-Rate of returns of HRES

At the beginning of each case, capital cost is taken as negative and saving is taken as positive return from the investment. Figure 8 shows the slopes and pay back points for 4 cases. Even though the savings on electricity at its minimum level in wind only system (24 million LKR), the PV/WIND/BIO hybrid system gives highest return on investment even at a high capital cost of 300.2 million LKR. The gradient of case-1 shows 38.35 million LKR/year and more aggressive than other 3 cases.

7.6 Environmental impact and CO_2 emission reduction assessment

Four cases are further studied to see the environmental impact. Electricity generation technologies emit greenhouse gases at some point in their life cycle and hence have a

carbon footprint in general. Figure 19 shows the reduction of carbon emission for the four cases. Reduction is very high in case 1. In case 3, carbon emission reduction is less than case 1, even though there is no carbon emission. However, case 3 helps carbon emission in indirect manner as it imports electricity from the grid nearly equal to the same amount that generated by biogas in case 1. It should be noted that, biogas digesters in case-1 helps to keep clean and Non-toxic environment inside the farm. In view of the above, HRES case-1 can be considered to be the more environmentally friendly option than case 3.

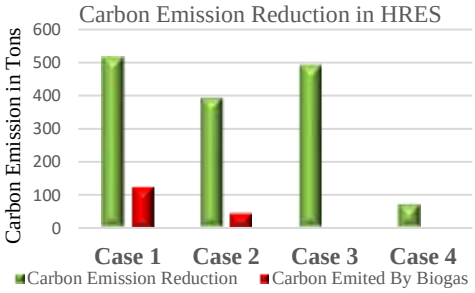


Figure 19- Carbon Emission Reduction

8 CONCLUSIONS

Power and energy data correspond to each and every process of NLDB farm are collected and analysed in walking through audit and detail audit to determine the appropriate energy conservation methods. As a result, the LED bulbs are introduced in place of existing fluorescent lamps, VFD drives are introduced for vacuum pumps and solar water heating system as pre-heating system in addition to the off-peak pumping proposed to optimize the electricity demand. Well-established energy utilization index (EUI) was considered as the benchmark for energy requirement for a cow per year. The existing EUI is 1863 kWh/cow-year and after optimizing the electricity demand in the farm and introducing hybrid renewable energy (HRE) system, the EUI drops dramatically to about 1121 kWh/cow-year. Four HRE combinations simulated against the optimized power and energy requirement of the NLDB farm to investigate the technical feasibility. They are:

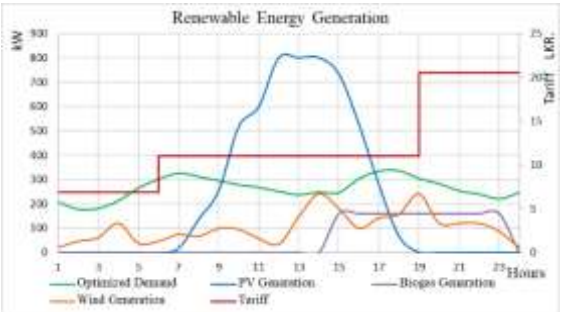
Case 1: - Combination of PV/Biogas/Wind

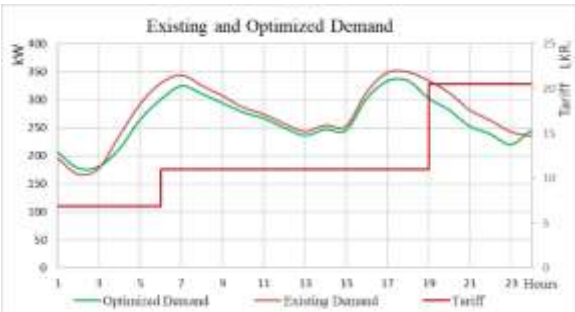
Case 2: - Combination of PV/Biogas

Case 3: - Combination of PV/Wind

Case 4: - Wind only

In the economic feasibility study, wind only system became the lowest NPV of LCC and the second lowest was PV/BIO/Wind system. The LCC of Wind only system is found to be 252.3 million LKR while the LCC of the PV/BIO/Wind system is about 259.33 million LKR. The capital cost of case 1 is 300.2 million LKR and that of case 4 is 24 million LKR. In terms of net saving of energy in life cycle, the case 1- is more aggressive. The gradient of saving of this combination is very high compared to case 4. The reduction of carbon emission was another concern in HRES while doing the environmental impact analysis. It





was found that the reduction of carbon emission is around 1908.7 tons/year in case 1 and is higher than other three cases. Moreover, cow dung generates methane, other toxic odour and fumes to the environment without control in Case 4. The biogas digester in case 1, controls the unwanted odour generation thus minimizing the impact to the environment. Finally, it can be concluded that, Case 1-PV/Bio/Wind system is the most techno-economically and environmentally friendly hybrid renewable energy system suitable for the NLDB farm. The size of the PV plant would be 830kW with a 160kW biogas generator set and 16 numbers of wind tunnels. The net present value of LCC is 259.33 million LKR and the annual energy saving is about 38.35 million LKR. The diagrams shown below clearly illustrate the optimized demand, net energy purchase and export, renewable energy generation and the proposed tariff for Case-1 hybrid renewable energy system (HRES).

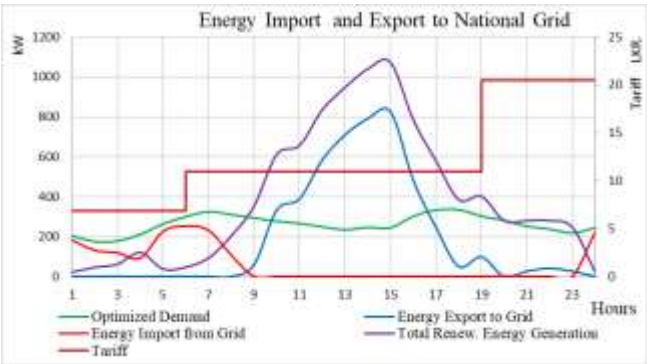


Figure 20-Optimized demand, net energy purchase and export, renewable energy generation and the proposed tariff for Case-1 hybrid renewable energy system (HRES).

Appendix-A

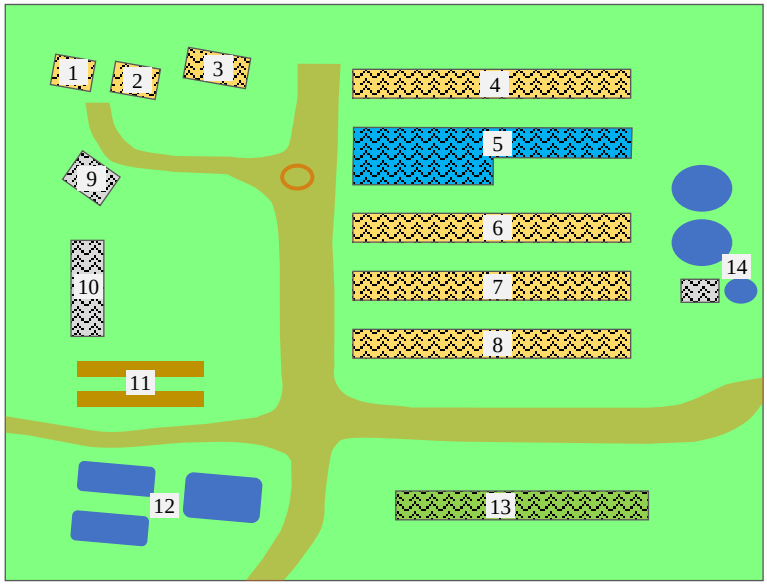


Figure A1-Site plan of the NLDB dairy farm

Table A1-Structure details

Floor	Activity Type
1	Main Office
2	Trainee Quarters
3	Doctor Quarters
4	Cow Shed 4
5	Milking Unit
6	Cow Shed 1
7	Cow Shed 2
8	Cow Shed 3
9	Workshop
10	Feeding Unit
11	Cow Dung Trap
12	Filter Tanks
13	Calves Shed
14	Water Tank and Filter

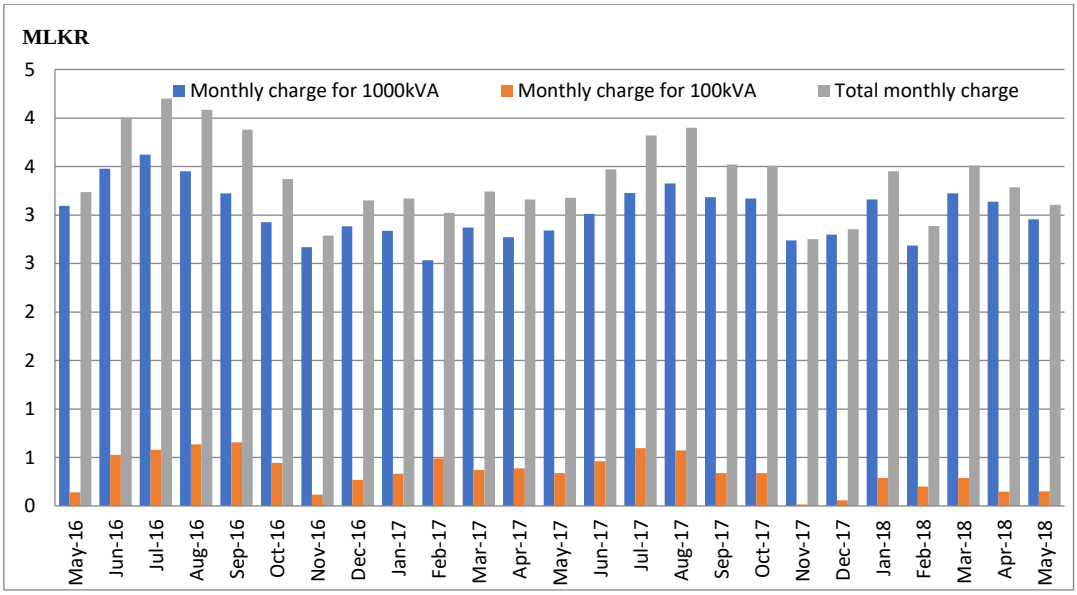


Figure A2-Billing analysis covering 2 consecutive years- 05/2016 to 05/2018

Table A2-Tariff systems offerred by Ceylon Electricity Board

Charging Mechanism	Industrial Rate I2 (LKR/kWh)	General Purpose Rate GP2 (LKR/kWh)
Peak (1830-2230)hrs	20.50	26.60
Day (0530-1830)hrs	11.00	21.80
off-Peak (22.30-530)	6.85	15.40
kVA Maximum Demand Charge	1100	1100
Fixed Charge	3000	3000

Table A3-Equipment ratings, operational hours and quantity

Equipment Type	Operational hours/day	Rating kW	Qty.
Ventilation Fans	18	1.5	350
Fluorescent Lamp	12	0.036	398
Agitation Motor	2	0.38	8
Pivot Motor	8	0.75	5
Heaters	2	6	8
Compressor	8	10	8
Agitation Motor	2	0.38	8
Molasses Pump	0.5	5.6	1

Equipment Type	Operational hours/day	Rating kW	Qty.
Water Pumps-1	24	5.6	1
Water Pumps-2	24	15	2
Water Pumps-3	10	30	4
Pressure Pump	12	15	2
Filter Pump	24	5.6	3
Blower Pump	0.3	7.5	2
Milk Pump	3	0.75	4
Vacuum Pump	8	5.6	6

Appendix-B

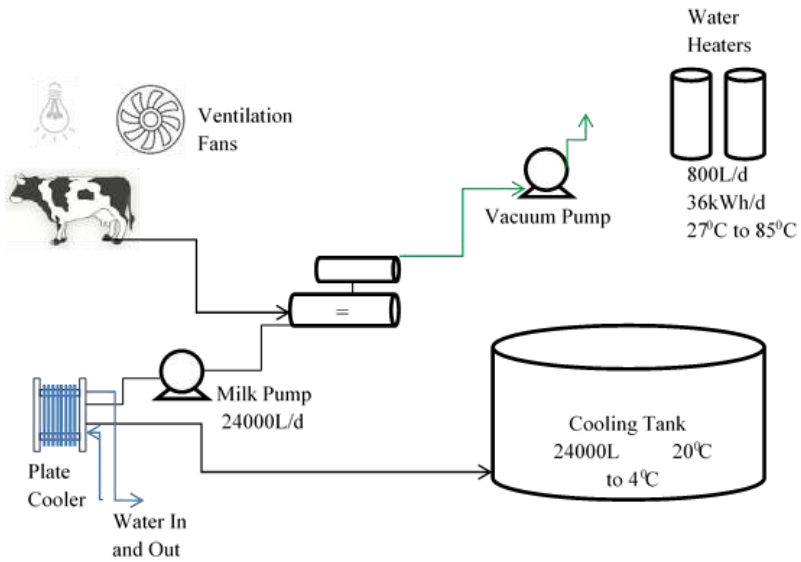


Figure B1-Milking process

Table B1-Economic analysis of fluorescent to LED lighting conversion

Replace Florescent lamps by LED lamps	Florescent	Proposed LED
Numbers of Lamps	398	398
Wattage	80W	42W
Lifespan(hours)	30,000	50,000
Lumens (Brightness)	2000	3600
Operation hours (h)	4380	4380
Annul Consumption(kWh)	139,459	73,216
Annul Energy Saving(kWh)	n/a	73,077
Average Unit Energy Cost (LKR.)	15.5	15.5
Annual Electricity Cost Saving (LKR.)	n/a	1,132,693.5
Cost to replace Florescent to LED (LKR.)	n/a	3,980,000.00
Pay Back Period	n/a	42 Months

Table B2- Energy savings by solar water heating system

Daily Energy consumption (Q_s)	m xC_p x ΔT = 3.2 x 1.16 x 58 = 215.3 kWh/day
Annual energy consumption	78,584.5 kWh
Average energy cost	LKR. 15/kWh
Annual energy cost for water heating	LKR. 1,178,767.5

Required solar energy/day (Qs) = m.Cp.ΔT = 3.2 x 1.16 x (80-27) = 196.7 kWh
Average Solar Radiation (SR) = 5.5 kWh/m²/day
Collector Yield (CY) = SR. η_{sys} .η_k =2.09 kWh/m²
Collector array (CA) = Qs/CY = 196.7/2.09 = 94.11m²
No of panels required = 94.11/2 = 47
Energy required to heat up by 5 ^{0}C= m. Cp. ΔT = 3.2 x 1.16 x 5 = 18.56 kWh/day
Energy losses in the night = λ x T x t= 0.03 x 80 x 12= 28.8 kWh/day
Total electrical energy required for hot water = 18.56 + 28.8 = 47.36kWh/day
Total annual energy required = 47.36 x 365 = 17,286.4 kWh
Annual energy saving solar hot water system = 78,584.5–17,286.4 = 61,298.1 kWh
Annual cost saving by installing solar hot water system = 61,298.1 x 15 = LKR. 919,471.5

Table B3- Energy savings by VFD controlling system

Rated Capacity of Vacuum pumps	5.6 kW
Numbers of vacuum pumps available	6 Nos.
Annual energy consumption of vacuum pumps	73,584 kWh
% of energy saving by introducing VFD system	35%
Average annual energy saving by introducing VFD system	25,754 kWh
Average unit energy cost at farm	15.5 LKR/kWh
Average annual energy saving	LKR. 399,187.00
Capital required to install new VFD system	LKR. 720,000.00
Pay Back Period	1Year 10 Months

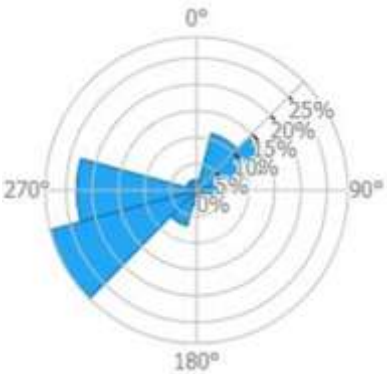


Figure B2-Wind Rose

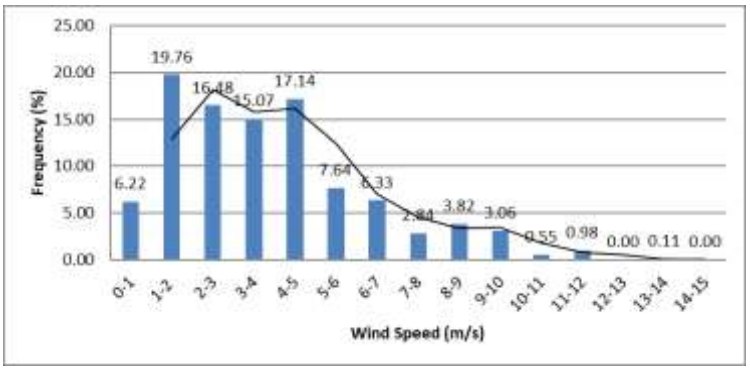


Figure B3-Frequancy distribution of wind pattern

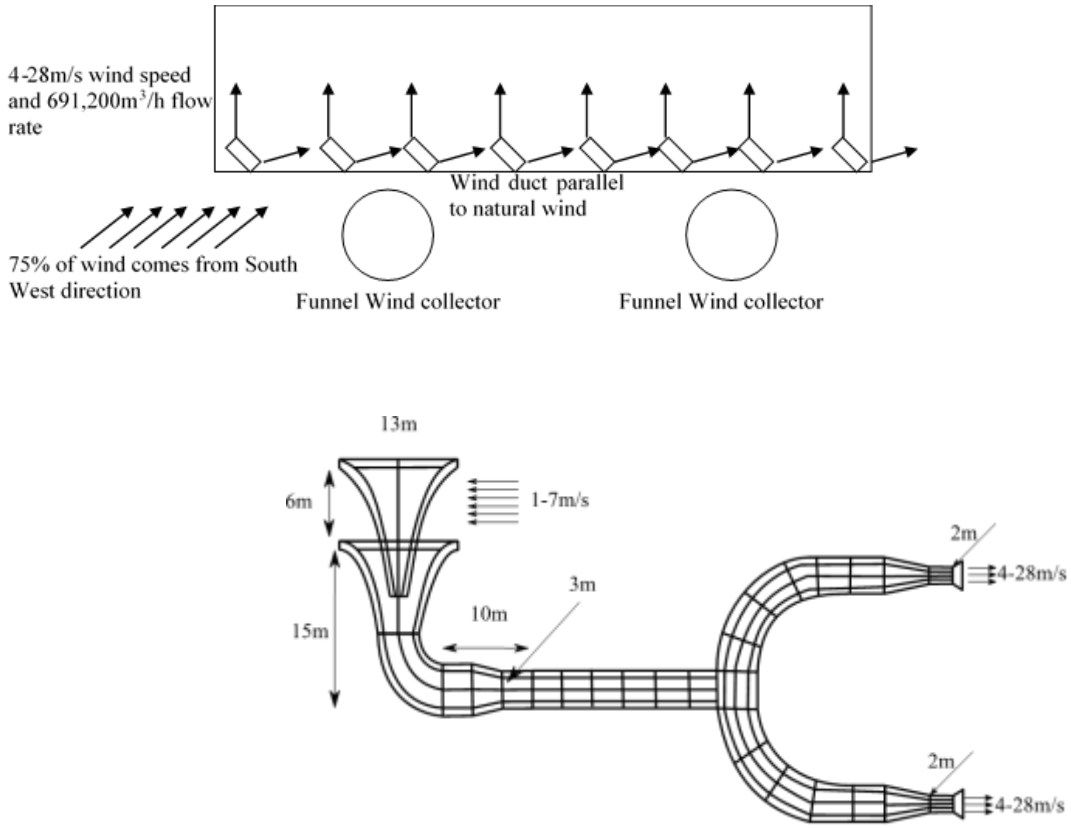


Figure B4-Shemetic diagram of sheer wind funnel based natural ventilation system

Appendix-C

Table C1

Rated power	340W
Open circuit voltage	47.2V
T_{ref}-cell temperature at the reference condition	25 ^{0}C
N_T-photovoltaic efficiency temperature coefficient	43 ^{0}C
NOCT-nominal cell operating temp.	-3.7 x 10^{-3} $^0C^{-1}$
Dimensions	1956*992*40mm
Weight	26.5Kg
Module efficiency	17.52%

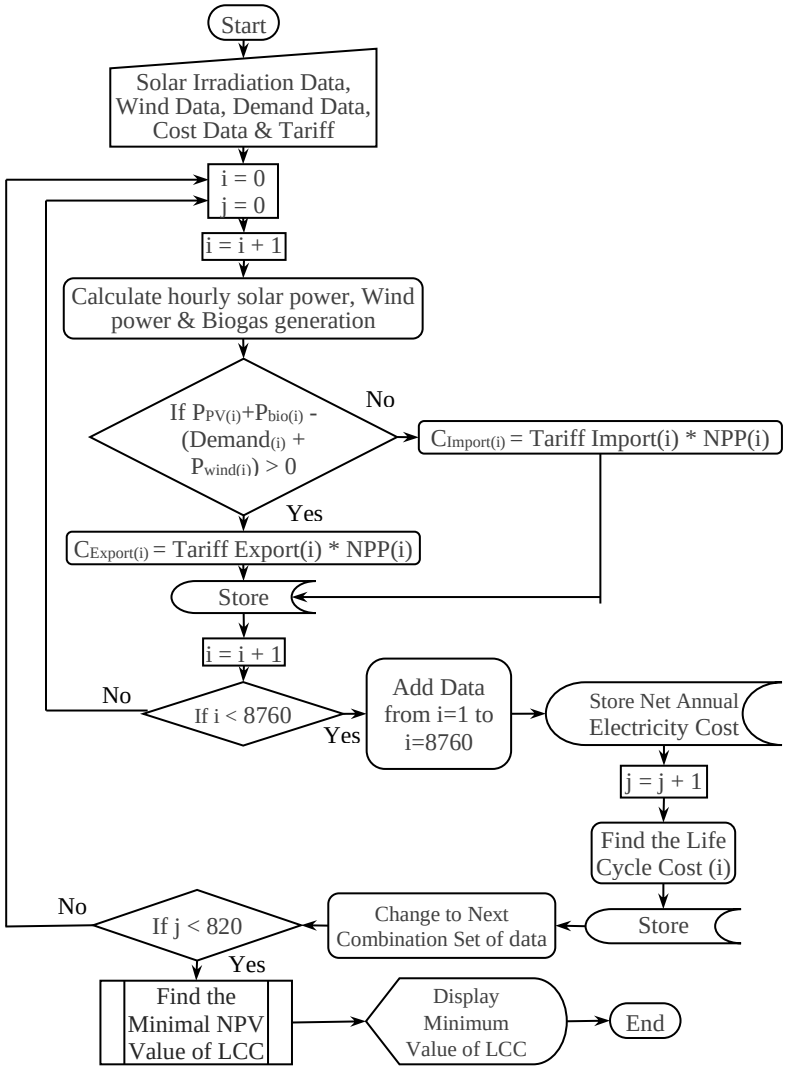


Figure C1-Hybrid Renewable Energy System optimization approach

9 ACKNOWLEDGEMENT

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Global warming: Combating temperature stress with modifications in growth media in Green Leaf Lettuce (*Lactuca sativa*)

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Abstract – *The study was carried out at Open University of Sri Lanka to evaluate the response of growth and yield of lettuce (Green leaf coral) as an adaptation measure for temperature stress due to global warming. Experiment consists two temperature conditions as temperature stress T1 (*35^0C – 36^0C*) and ambient temperature T2 (* 32^0C – 33^0C*) with five type of growth media such as; coir dust (M1), coir dust: sand(1:1) (M2), coir dust : sand (1:2) (M3), coir dust : sand : cow manure (1:1:1) (M4) and top soil (M5). A completely randomized design (CRD) with three replicates was used. Growth and yield parameters such as; plant height, average length of leaf, average width of leaf, average leaf area, average root length, number of leaves, fresh and dry bio masses of plant were measured. Apart from that moisture percentage and porosity of growth media were also measured. The data were statistically analyzed according the General Linear Model (GLM) procedure and the mean separation was done using the Least Significant Difference (LSD) at P= 0.05 level. SAS Statistical software (university version) was used for the statistical analysis. According to the analysed data, treatment with growth media of coir dust: sand (1:2) (M3) in both temperature stress and ambient temperature shown significantly higher percentage of porosity which might be due to higher proportion of sand than other treatments. Media was the only factor affected on porosity. Growth parameters were significantly influenced by temperature, growth media and their interaction effect. At temperature stress, coir dust: sand: cow manure (1:1:1) (M4) media was the only treatment which was positively contributed to the growth and yield parameters. In ambient temperature, coir dust : sand : cow manure (1:1:1) and coir dust: sand(1:1) growth media contributed to the higher yield.*

***Keywords**: Media, Temperature, Growth, Yield, Moisture, Porosity*

Nomenclature

^{0}C - Celsius
GLM - General Linear Model
LSD - Least Significant Difference
SAS - Statistical Analysis System

1 INTRODUCTION

1.1 Background and justification

Lettuce (*Lactuca sativa*) belongs to the family of Compositae and one of the most consumed vegetable across the world. Lettuce has several medicinal properties and contains secondary metabolites such as phenolic, ascorbate, tocopherol, lignin and vitamins (A, B1, B6, C and K) and acts as an anti-inflammatory agent protecting neuronal cells. On the other hand, lettuce contain source of iron and potassium dilatory fiber, folic acid and manganese. Furthermore, lettuce supply omega -3 fatty acids that is essential for the normal growth and development of humans (Le Guedard, 2008).

In the present context, hydroponics and aeroponics techniques are the most popularized methods that are used for lettuce cultivation. In Sri Lanka, lettuce cultivation can be seen mainly in the open field as well as under greenhouse condition. Furthermore, hydroponics and aeroponics techniques are used for cultivation of lettuce by most of commercially cultivated farms in Sri Lanka. However, majority of small holdings farmers used their land or various types of growth media to cultivate lettuce. When selecting growth media for lettuce cultivation, one has to consider many properties such as drain ability, water retention capacity and porosity. Most of the times crop can be failed due to selection of unsuitable media because of poor characteristics of media such as poor drain ability, poor water holding capacity, poor aeration, high rate of nutrient leaching and higher compaction.

Makhadmeh et al., (2017) reported that the substrate has an influence on lettuce production and furthermore, he mentioned that growing medium as the most important factor for successful production. Therefore, a good substrate must be chosen as it is a decisive factor. Baevre (1982) also mentioned that the growth medium is a very important component in successful vegetable production. Nelson, (1991); Argo and Biernbaum, (1997) reported that the growth media serve as reservoir for nutrients and provide an anchorage or support for the plant. In addition, they must be capable of holding adequate water and supplying it to the plant, and providing for the exchange of gasses between the rhizosphere and the atmosphere.

Sezen et al., (2006) reported that the challenges with soil-based production systems such as limited space, declining productivity, soil contamination with weed seeds, pathogens and heavy metals have increased interest in the development of soilless substrate. Furthermore, Kämpf, (2005) concluded that the good substrate should provide optimal growth conditions for a plant to develop and good substrate possesses few characteristics such as water economy, good aeration, retention capacity of water and nutrients, high structural stability and resistance to decomposition. Adediran (2005) reported that the use of soil in commercial horticultural practices may limit production due to the bulk, high labor input and storage space requirements. The growing of seedlings is better done with container or pot systems involving soilless media. The system allows close, consistent and effective control of plant growth on a large scale. Verdonck and Gabriels (1992) mentioned that the success of a horticultural substrate is mainly based on the behavior of the plants grown in them; high-quality substrates with the proper physical and chemical properties can result in high yields and excellent plant quality. Furthermore, they reported that the soilless culture avoids problems associated with decreasing fertility of natural soils, due to disease limitations and the increase in salinity.

According to the Intergovernmental Panel Climate Change (IPCC) (2007), the expected changes in temperature over the next 30-50 years are predicted to be in the range of 2-3 °C. Furthermore, Mheel et al., (2007) reported that the heat waves or extreme temperature events are projected to become more intense, more frequent, and last longer than what is currently been observed in recent years.

Gunawardena and De Silva *(*2014) mentioned that the decreased rainfall and increased in temperature will increase the evapotranspiration and soil moisture deficits. Luz *et al.*, (2009) reported that when exposed to stress conditions, as in high temperatures, lettuce tends to reduce its cycle, compromising the production and making the leaves more rigid, and also to stimulate the tassel induction, an undesirable characteristic, since it makes the vegetable unfeasible for commercialization. The challenge for lettuce cultivation is to develop adaptability to higher temperature because it is an originally mild climate species (Queiroz et al., 2014). Temperature effects are increased by water deficits (Hatfield, 2015). Therefore, media with proper moisture holding ability is vital to mitigate the effect of temperature stress on lettuce at considerable level. Lee and Cheong (1996) reported that the lettuce grew well in the hot climate of Singapore when root-zone temperatures were kept below 25°C. Media can be influenced on root temperature control due to capability of moisture retention.

The aim of this study was to evaluate the effect of temperature stress on growth and yield of green leaf lettuce (*Lactuca sativa*)when grown in different substrates as growth medium. Therefore, at the end of this research it is possible to identify the best growth media for lettuce to combat temperature stress.

2 METHODOLOGY

This study intends to identify the suitable growth media to adapt to the consequences of higher temperature stress due to global warming by evaluating the effect on growth and yield parameters of green lettuce variety. In this study plants were maintained with adequate water without any water stress.

2.1 Growing conditions

The study was conducted at The Open University of Sri Lanka from March 2018 to March in 2019. Experiment was repeated thrice to replicate the poly tunnel effects. Two factors were used in the study; one factor was temperature with two levels as temperature stress (T1) and ambient temperature (T2) and the other factor was different types of growth media as, coir dust (M1), coir dust: sand(1:1) (M2), coir dust :sand (1:2) (M3), Coir dust :sand: cow manure (1:1:1) (M4) and top soil (M5). There were ten treatments and treatments were arranged in completely randomized block design with three replicates (Table 1 and 2). Most of the farmers in Sri Lanka, used top soil as the growth media for lettuce due to economic feasibility. Therefore, media were selected according to the availability and economic feasibility and cow manure has selected as a one component of the M4 media to evaluate the effect of cow manure due to its high nutrient content, moisture holding capacity and ability of improving soil structure. One set of plants was kept in temperature stress condition at the poly tunnel and temperature range was maintained at 35°C- 36°C through an automated regulatory system. The other set of plants was kept in ambient temperature (32°C - 33°C) condition at plant house with free air circulation as normal environment (Figure 4). Gunawardena and De Silva *(*2014)

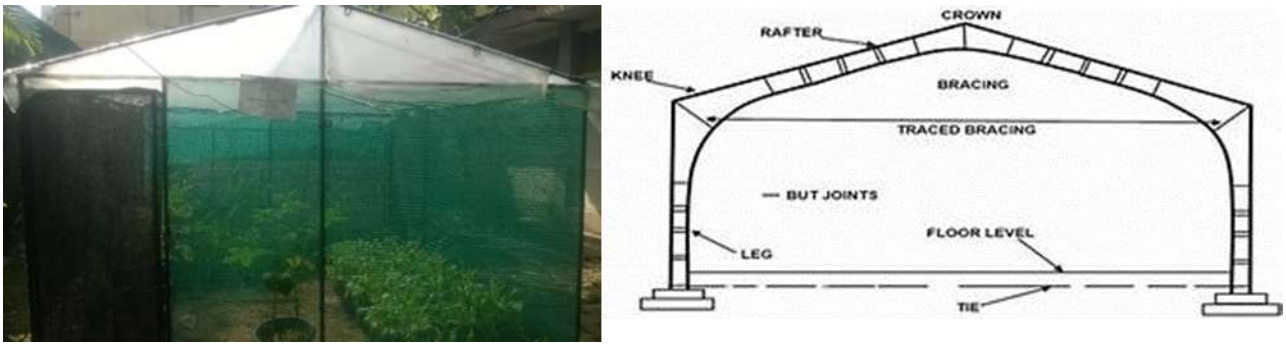
reported that there were no significant differences in RH observed in the inside and outside environment although elevated day time air temperatures in the poly tunnel resulted in higher partial pressure of water. This condition was maintained with the opening of the upper top which helped to maintain the same water vapor concentration compared to the outside (Figure 1 and 2). And also, according to the observed data for RH, there were no significant differences in RH at the inside and outside of the plant house. Therefore, apart from the temperature other conditions were approximately similar for poly tunnel and the plant house.

Table 1. Two different environmental conditions of the experiment

Condition No:	Environmental condition
Condition 1 – Poly tunnel (T1)	Maintained at 35°C – 36°C (Increased the temperature by 3°C more than the average day time temperature of plant house at the Open university (32-33°C). • Five types of growth media – coir dust (M1), coir dust: sand (1:1) (M2), coir dust: sand (1:2) (M3), coir dust: sand: cow manure (1:1:1) (M4) and topsoil (M5).
Condition 2 – Plant house (T2)	Maintained at 32°C – 33°C Ambient temperature. (Diurnal pattern is considered). • Five types of growth media – coir dust (M1), coir dust: sand (1:1) (M2), coir dust: sand (1:2) (M3), coir dust: sand: cow manure (1:1:1) (M4) and topsoil (M5).

(a) **(b)**

Figure 1: a- Front view of the poly tunnel b- Top-vent roof structure of the poly tunnel



(a) **(b)**

Figure 2: a- Front view of the plant house b- Rigid frame structure of the plant House

2.2 Temperature control in the poly-tunnel and plant house

The variation of temperature inside the poly tunnel and the ambient temperature of plant house over a period of 24 hours was observed as shown below (Figure 3). The temperature inside the plant house was lower than the maximum temperature set poly tunnel. Therefore, temperature stress was forced on the plants inside the poly tunnel during daytime while there was photosynthetic activity.

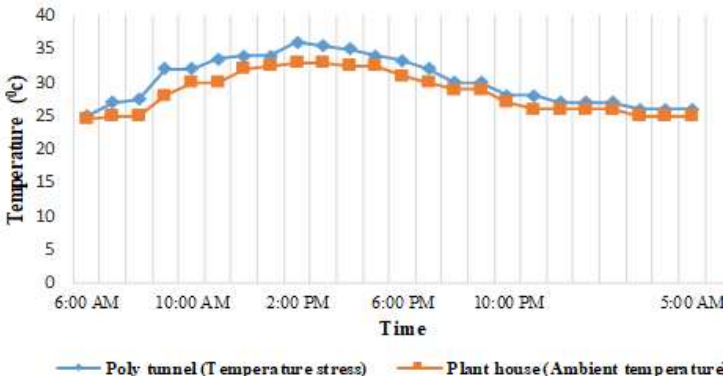


Figure 3. Temperature variations inside of the poly tunnel and plant house

2.3 Treatments

Green leaf coral was the variety selected for the experiment. A nursery was managed to obtain seedlings for the experiment and the field layout are shown in Figure 4 and 5. After the period of nursery, seedlings were transplanted in pots which were arranged according to the treatments of the study. Fertilization was done according to the recommendation of Department of Agriculture. Equal amount of water was applied to each pot once in two days and other intercultural practices were done according to the recommendation.

Table 2: Treatment of the study

No:		Treatment
01	T1M1	Temperature stress, coir dust
02	T1M2	Temperature stress, coir dust: sand (1:1)
03	T1M3	Temperature stress, coir dust: sand (1:2)
04	T1M4	Temperature stress, coir dust: sand: cow manure (1:1:1)
05	T1M5	Temperature stress, topsoil
06	T2M1	Ambient temperature, coir dust
07	T2M2	Ambient temperature, coir dust: sand (1:1)
08	T2M3	Ambient temperature, coir dust: sand (1:2)
09	T2M4	Ambient temperature, coir dust: sand: cow manure (1:1:1)
10	T2M5	Ambient temperature, topsoil

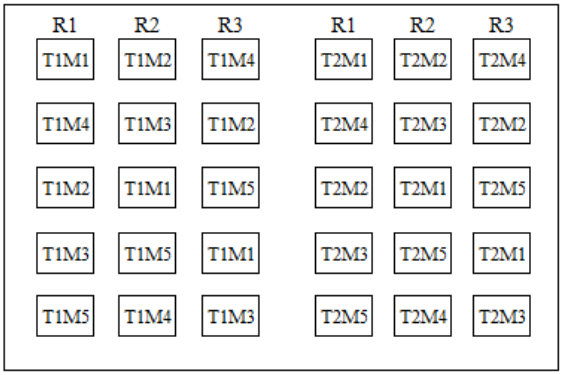


Figure 4: Field Layout

Figure 5: Nursery of the green leaf lettuce

2.4 Media preparation

Five different types of growth media were used. Media were prepared according to the treatments by using coir dust, sand, cow manure and topsoil. Coir dust used for preparation of growth media was sterilized. M1 media was prepared using coir dust, M2 media was prepared using coir dust and river sand in to 1:1. M3 media was prepared by mixing coir dust river sand 1:2 ratio and coir dust, river sand, cow manure 1:1:1 were used to prepare the media of M4. Cow manure which was used for the experiment as dry form. Media M5 was prepared using topsoil and the soil grouped was belonged to reddish brown earth.

Growth parameters, such as average height of the plant, average leaf width, and average root length, average leaf length and leaf area (Table 3) have measured at two weeks intervals during two month (60 days). After harvest yield parameters such as average number of leaves per plants, fresh biomass per plant and dry biomass per plant were measured. Apart from the growth and yield parameters, moisture content and porosity of the media were measured to determine the water retention ability under the temperature stress condition.

Table 3: Parameters collected

Parameters		Method	Unit
Growth parameters	Height of plants	Plant height was measured by meter scale from the point of attachment of growing media up to the tip of the longest leaf.	Centimeter (cm)
	Average length of leaf	length of leaves was measured by a meter scale	Centimeter (cm)
	Average width of leaf	width of leaves was measured by a meter scale	Centimeter (cm)
	Average leaf area	Grid counting method used	cm^2
	Average root length	The length of root from each replicate was recorded and means length was calculated.	Centimeter (cm)
Yield parameters	Average number of leaves	All the leaves of each plant were counted separately and the average number was recorded.	-
	Average fresh biomass of the plant	Leaves were detached by a sharp knife and fresh weight of the plant was taken by an electric balance at harvest and was recorded.	Grams (g)
	Average dry biomass of plant	Fresh leaves were dried at 80 ^{0}C for 48 hours and dry weight of the plant was taken by electric balance	Grams (g)
Moisture content of the media		Soil moisture was measured by gravimetric method (Jalota*et al.,* 1998) before irrigation	%
Porosity of the media		Calculated using the formula[1 - (Bulk density/ Particle density)] X 100	%

The data were statistically analyzed according the General Linear Model (GLM) Procedure and the mean separation was done using the Least Significant Difference (LSD) at P= 0.05 level. SAS Statistical software (university version) was used for the statistical analysis

3 RESULTS AND DISCUSSION

3.1 Soil Parameters

3.1.1 Porosity (%) of the growth media

Porosity percentage is important to predict the characteristics of the growth media such as degree of compaction and ability of water retention. Porosity of the growth media decides the avaliability of water and nutrient elements for plant leading to good growth (Olympious 1992; Kumar and Goh 1999). Table 4 shows the variation of porosity of the different growth media. Treatments with temperature stress and growth media of coir dust: sand (1:2) (T1M3) and ambient temperature and growth media coir dust: sand (1:2) (T2M3) have shown significantly ($P<0.05$) higher percentage of porosity and it might be due to higher proportion of sand than other treatments. These treatments in both temperature stress and no temperature stress were not significantly ($P>0.05$) different. Furthermore, temperature stress with coir dust: sand (1:1) (T1M2) and coir dust: sand: cow dung (1:1:1) (T1M4) treatments have shown higher percentage of soil porosity because each treatment consisted with sand as one of component in growth media. Treatments of temperature stress and topsoil (T1M5) and ambient temperature and topsoil (T2M5) have shown the lowest percentage of porosity because each treatment consist only topsoil. Degree of compaction in the topsoil was greater than other treatments due to its particle sizes and distribution. Mohammadi-Ghehsareh also (2015) reported that the culture media had a significant effect on porosity variations.

3.1.2 Moisture percentage (%) of media

According to the results of the study, moisture percentage of the media has varied depending on the percentage of porosity (Table 4). Therefore, in most of the treatment which have optimum percentage of porosity resulted higher ability for water retention. Therefore, treatment temperature stress, coir dust: sand (1:2) (T1M3) and ambient temperature, coir dust: sand (1:2) (T2M3) contained lower percentage of moisture due to its higher percentage of porosity. Treatments of temperature stress, Coir dust: sand (1:1) (T1M2) and ambient temperature, Coir dust: sand (1:1) (T2M2) have shown significantly higher moisture content due to the its lower porosity. Then the treatments of T1M3 and T2M3 have shown lower moisture holding capacity than T1M2 and T2M2. Treatment of temperature stress, topsoil (T1M5) has shown the lowest moisture percentage due to lower porosity and higher evaporation resulted from temperature stress condition. Moisture percentage of the media was directly proportional to the porosity but, when porosity was beyond the optimum level, moisture percentage of the media was indirectly proportional to it. Mohammadi-Ghehsareh (2015) reported that the water holding capacity of the media is related to particle size and pore size. Smaller particles have a larger surface area than those with larger particles; a large surface area allows higher drain ability from the media. Therefore, media with higher porosity beyond the optimum level has resulted lower moisture content of the media due to higher ability of drainage.

Table 04: Moisture percentage and porosity percentage of the media

Treatment	Moisture %	Porosity %
T1M1	41.667[c]	36[c]
T1M2	68.66[a]	58[b]
T1M3	51.667[b]	65.33[a]
T1M4	59[b]	58.33[b]
T1M5	19.33[d]	26[d]
T2M1	54.33[b]	39.66[c]
T2M2	71.66[a]	58.33[b]
T2M3	57[b]	66.66[a]
T2M4	69.33[a]	58[b]
T2M5	34.33[c]	26.33[d]
CV (%)	5.65	3.89
Temperature	<0.05	0.11
Growth media	<0.05	<0.05
Temperature*Growth media	<0.05	0.34

Values followed by same letter are not significantly different at p =0.05 level

3.2 Growth Parameters

Generally lettuce is harvested in 60 days (8 weeks) after planting. Therefore, growth parameters were measured 6 weeks after planting because this stage considered as the growing period of lettuce.

3.2.1. Height of Plant

According to the analyzed data both factors such as temperature and growth media have significantly influenced (P<0.05) on plant height and also the interaction effect of temperature and growth media has significantly influenced (P<0.05) on the height of the plant (Figure 6 and 7). Treatment of ambient temperature, Coir dust: sand: cow manure (1:1:1) (T2M4) shown the significantly highest plant height and it was significantly different (P<0.05) from all the treatment apart from the treatment of temperature stress, Coir dust: sand: cow manure (1:1:1) (T1M4). T1M4 Treatment was the second-best treatment which has positively influenced on plant height. Treatments with cow manure have shown higher performances in both ambient and stressful temperature. Tandon (1999) reported that the cow manure is the most common organic manure used in agriculture and addition of cow manure to potting medium improves the physical properties of soil, microbial activity and nutrient availability in growing medium especially nitrogen to the crop because it contains 0.35% N, 0.12% P_2O_5 and 0.17% K_2O. Treatment of temperature stress, topsoil (T1M5) has shown the significantly poorest

performances. It might be due to stress conditions resulted from high temperature and poor moisture content and porosity of the media.

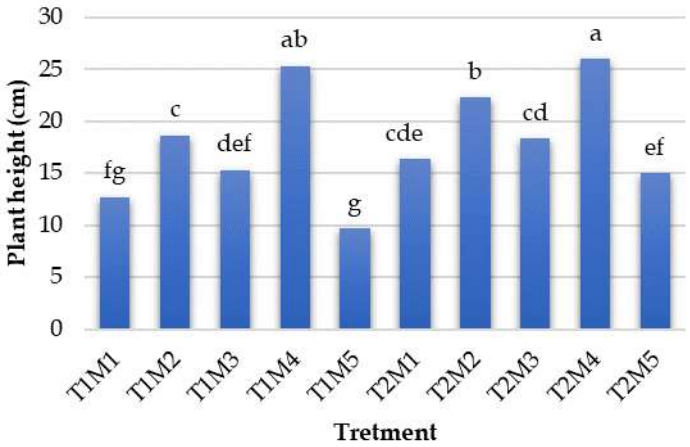


Figure 6: Plant height

T1- Temperature stress T2- Ambient temperature

M1- Coir dust M2- coir dust: sand (1:1) M3- coir dust: sand (1:2)

M4- coir dust: sand: cow manure (1:1:1) M5- Top soil

Values followed by same letter are not significantly different at p =0.05 level

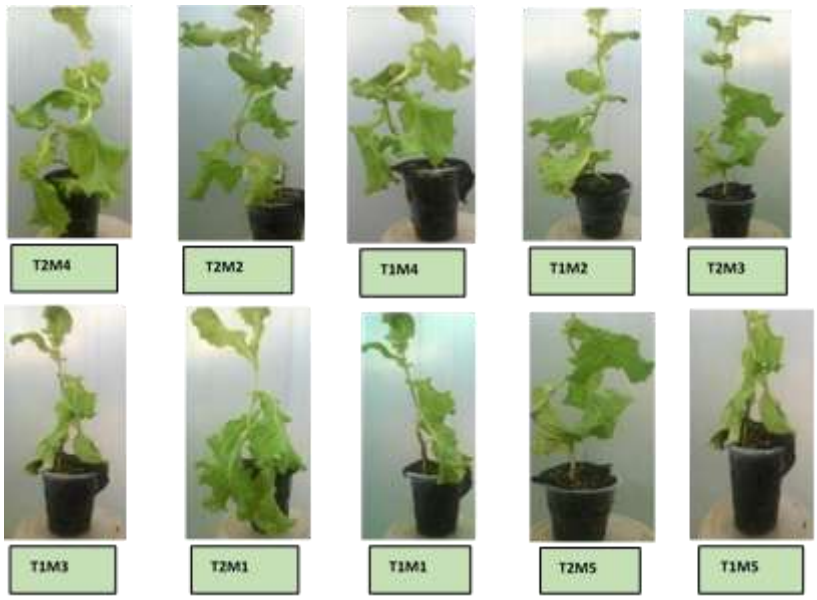


Figure 7: Growth performance at 6 weeks after planting

3.2.2. Average length of leaf

Average length of leaf has shown increasing trend during growth period (Figure 8). According to the analyzed data, temperature, media and their interaction effect have significantly incorporated ($P<0.05$) on the variation of average length of leaf. Treatment with Ambient temperature, coir dust: sand: cow manure (1:1:1) (T2M4) has shown

significantly highest leaf length, but it was not significantly different (P>0.05) from the treatment with temperature stress, coir dust: sand: cow manure-1:1:1 (T1M4) and treatment with ambient temperature, Coir dust: sand (1:1) (T2M2). However, it was significantly different (P>0.05) from all the other treatments. Treatment with Temperature stress, topsoil (T1M5) has shown the lowest leaf length due to the temperature stress and poor water holding capacity of the media. And also the treatments with topsoil either at the ambient temperature or at temperature stress resulted in lower leaf length due to the poor qualities of the growth media. This can be justified according to the findings of Sudeshika et al., (2018). They reported that the lowest leaf length of carrot occurred in topsoil media.

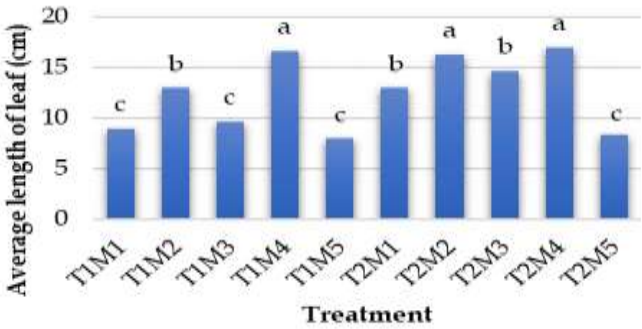


Figure 8: Average length of leaf
T1- Temperature stress T2- Ambient temperature
M1- Coir dust M2- coir dust: sand (1:1) M3- Coir dust: sand (1:2)
M4- coir dust: Sand: Cow manure (1:1:1) M5- Top soil
Values followed by same letter are not significantly different at p =0.05 level

3.2.3. Average leaf width

According to analyzed data temperature and growth media have significantly influenced (P<0.05) on average leaf width (Figure 9). Furthermore, interaction effect also significantly contributed (P<0.05) on average leaf width. During growth period average leaf width has shown increasing trend pattern as like the average leaf length.

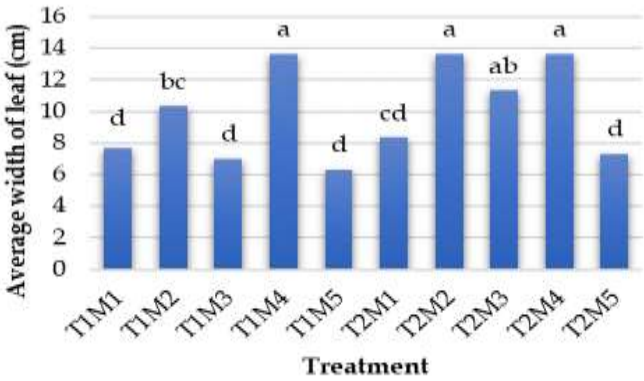


Figure 9: Average width of leaf
T1- Temperature stress T2- Ambient temperature
M1- Coir dust M2- coir dust: sand (1:1) M3- Coir dust: sand (1:2)
M4- coir dust: Sand: Cow manure (1:1:1) M5- Top soil
Values followed by same letter are not significantly different at p =0.05 level

The treatment with temperature stress, coir dust: sand: cow manure-1:1:1 (T1M4) has shown the significantly highest leaf width and it was not significantly different (P>0.05) from treatment with ambient temperature, coir dust: sand-1:1 (T2M2), ambient temperature, coir dust: sand: cow manure-1:1:1 (T2M4) and ambient temperature, coir dust: sand (1:2) (T2M3). Treatment combinations with topsoil (M5) have shown the lowest leaf width.

3.2.4. Average leaf area

During growth period average leaf area has shown in increasing trend (Figure 10). According to the analysis data, both factors such as temperature and growth media have significantly influenced (P<0.05) on Average leaf area. And also, interaction effect of temperature and growth media has significantly influenced (P<0.05) on dependable variable. According to figure 3, Treatment with Temperature stress, topsoil (T1M5) has shown the lowest leaf area and topsoil (M5) media has given lower value either at the ambient temperature due to poor qualities of the growth media. Treatment with Ambient temperature, coir dust: sand: cow manure 1:1:1 (T2M4) has shown significantly highest leaf area. However, it was not significantly variated from treatments of T1M4, T2M2 and T1M2. Media with coir dust: sand: cow manure 1:1:1 (M4) has resulted higher leaf area at ambient temperature stress as well as at temperature stress and it may be due to presence of various components in the growth media. This statement can be justified according to the Sudeshika et al., (2018). They report that the reason could be the variation in nutrient contents in different types of growing media.

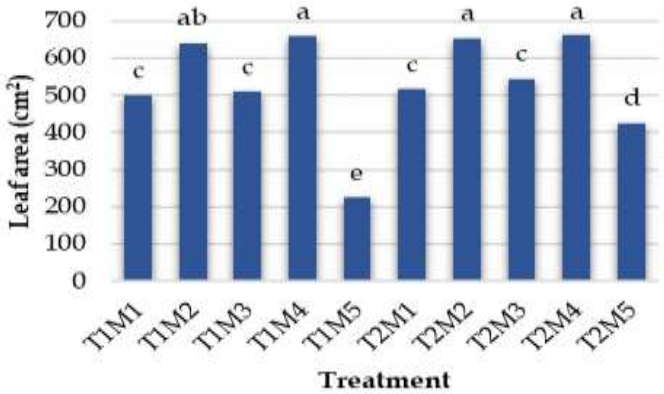


Figure 10: Average width of leaf

T1- Temperature stress T2- Ambient temperature
M1- Coir dust M2- coir dust: Sand (1:1) M3- coir dust: sand (1:2)
M4- coir dust: sand: cow manure (1:1:1) M5- Top soil
Values followed by same letter are not significantly different at p =0.05 level

3.2.5. Average root length

Average root length has significantly variated (P< 0.05) due to influences of temperature, growth media and as well as due to the interaction effect of both factors (temperature * growth media) (Figure 11). Treatment with ambient temperature, Coir dust: sand: cow manure (1:1:1) (T2M4) has shown significantly (P< 0.05) longest roots and it was not significantly differed from the treatment with temperature stress and Coir dust: sand: cow manure (1:1:1) (T1M4), temperature stress coir dust: sand (1:1) (T1M2) and ambient

temperature with coir dust: sand (1:1) (T2M2). Therefore, media with coir dust: sand-1:1 (M2) and coir dust: sand: cow manure-1:1:1 (M4) have shown positive effect in both ambient temperatures as well as in temperature stress conditions.

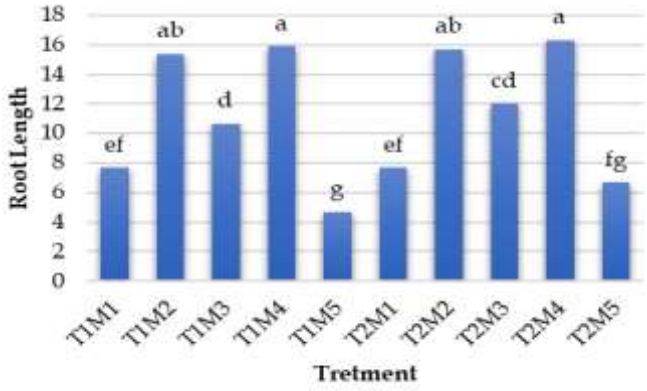


Figure 11: Average root length
T1- Temperature stress T2- Ambient temperature
M1- Coir dust M2- coir dust: sand (1:1) M3- Coir dust: sand (1:2)
M4- coir dust: sand: Cow manure (1:1:1) M5- Top soil
Values followed by same letter are not significantly different at p =0.05 level

Treatment with temperature stress, topsoil (T1M5) has shown the lowest root growth and it was significantly different from all other treatments. Poor root growth in T1M5 treatment might be due to higher rate of evaporation from the media resulted from the temperature stress. Another reason for poor performance was higher soil compaction due to lower soil porosity resulted as a barrier for root elongation. Bilderback et al., (2005) reported that the light and fluffy (well-aerated) medium that promotes fast and strong root growth and adequate water drainage.

3.3 Yield parameters

3.3.1. Average number of leaves

Considering the analyzed data temperature and growth media have significantly (<0.05) affected on average number of leaves (Figure 12). And also, the interaction effect of temperature and media has significantly (P<0.05) influenced on the average number of leaves. The treatment with ambient temperature and coir dust: sand: cow manure (1:1:1) (T2M4) has shown significantly highest number of leaves but it was not significantly different from the number of leaves obtained in treatment with temperature stress and coir dust: sand: cow manure (1:1:1)(T1M4). Growth media with coir dust: sand: cow manure (1:1:1) (M4) produced higher number of leaves at both temperature stress and ambient temperature treatments. It might be due to higher moisture content and porosity percentage of this media. Treatment with temperature stress, topsoil (T1M5) has shown the lowest value for number of leaves than the other treatments. However, it was not significantly different (P>0.05) from T2M5. Apart from the media of M4 with Coir dust: sand: cow manure (1:1:1) media M2 with coir dust: sand (1:1) also have shown higher performances in both under temperature stress and ambient temperature treatments. Bilderback et al. (2005) stated that the combination of organic components decomposes during crop production and may change both the physical and chemical composition of the medium and this may in turn influence the crop growth and development. Therefore, it

might be the reason for positive performances in number of leaves in the media with the combination of coir dust, sand and cow dung.

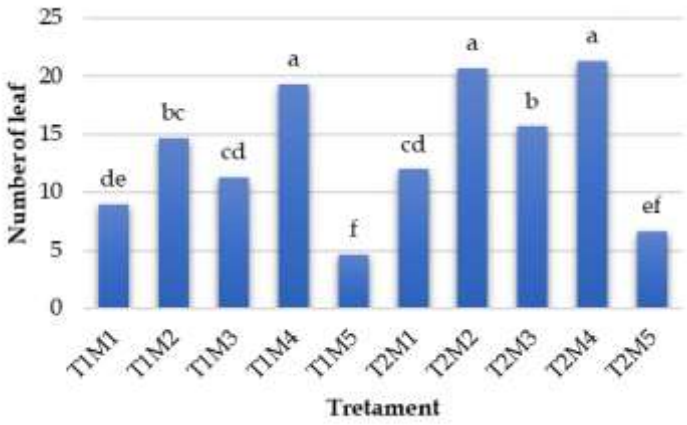


Figure 12: Average number of leaf
T1- Temperature stress T2- Ambient temperature
M1- coir dust M2- coir dust: sand (1:1) M3- coir dust: sand (1:2)
M4- coir dust: sand: cow manure (1:1:1) M5- Top soil
Values followed by same letter are not significantly different at p =0.05 level

3.3.2. Average fresh biomass of the plant

Average fresh biomass of the plant was significantly (P<0.05) different according to both factors temperature and growth media (Figure 13). Interaction effect of temperature and growth media also have significantly (P<0.05) influenced on fresh biomass of plant. Treatment with ambient temperature and coir dust: sand: cow manure (1:1:1) (T2M4) has shown the significantly highest fresh biomass per plant but it was not significant different from temperature stress treatment with coir dust: sand: cow manure (1:1:1) (T1M4) and ambient temperature with coir dust: sand (1:1) (T2M2).

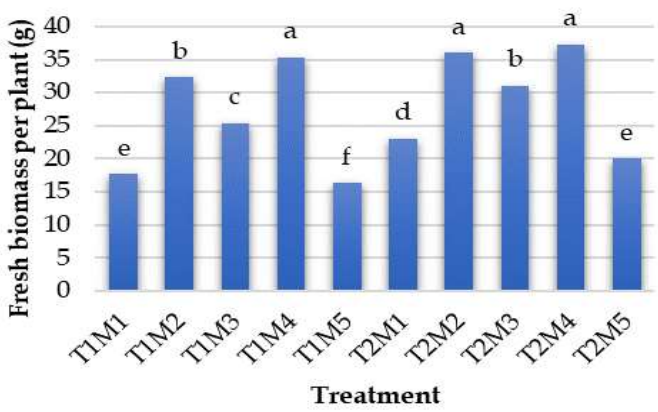


Figure 13: Average fresh biomass per plant
T1- Temperature stress T2- Ambient temperature
M1- coir dust M2- coir dust: sand (1:1) M3- coir dust: sand (1:2)
M4- coir dust: sand: cow manure (1:1:1) M5- Top soil
Values followed by same letter are not significantly different at p =0.05 level

Treatment with temperature stress and top soil (T1M5) has shown significantly lowest fresh biomass. The growth media with coir dust: sand: cow manure (1:1:1) (M4) has shown highest average fresh biomass in both ambient and temperature stress conditions.

4 CONCLUSION

Based on the results it is concluded that the use of growth media of coir dust: sand: cow manure (1:1:1) show highest performances of growth and yield at temperature stress condition and ambient temperature condition because they hold higher moisture percentage and porosity for better aeration and maintained the optimal temperature in root zone even the temperature stress is imposed. Therefore, growth media of coir dust: sand: cow manure (1:1:1) is best suited for Green Lettuce cultivation to combat temperature stress due to global warming.

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A Statistical Fuzzy Inference System by PCA Based Defuzzification for the Improvement of Sugeno Defuzzification Method

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Abstract – *An important aspect of any fuzzy application is that, it can represent the subjective knowledge of the decision maker. Different decision makers may have different perceptions for defuzzified results. Although Sugeno method is considered as the most computationally effective, there is uncertainty about the defuzzified output which generates singleton fuzzy sets objectively. We propose a statistical fuzzy inference system where Sugeno defuzzification method has been directly integrated with the principal component analyzer, fuzzy inference engine, knowledge base and user interface to improve the output. The principal component analyzer has been used for reducing dependencies of categories of a dataset for domains with explicit knowledge as well as with tacit knowledge. The defuzzification process has been implemented by computing singleton fuzzy values using Upper Bound/ Lower Bound method integrated with extracted principal components. The knowledge base represent domain knowledge in terms of fuzzy rules, fuzzy operators and membership functions. Three experiments from three available explicit data sets (Card Payment, non-communicable disease, communicable disease) have been conducted to compare the performance of this method with the Sugeno defuzzification method. Similarly, a data set with tacit knowledge for classification of human mental constitution as per Ayurveda medicine (Manas prakrti) has also been used. For the chosen datasets, the new methodology improved the accuracy by considering the difference between predicted value and actual value. The improvements were up to 98%, 98%, 71%, and 95% for the Card Payment, non-communicable disease, communicable disease and Manas prakrti respectively, while Sugeno defuzzification method shows significantly low accuracy by considering the difference between predicted value and actual value.*

***Keywords**: Sugeno defuzzification method, Extended Defuzzification, Knowledge modeling, Principal Components Analysis, Ayurveda medicine*

1 INTRODUCTION

There are many de-fuzzification methods in use today and research has shown that the best method is mostly problem dependent. Center of gravity method and the mean of maxima method are considered to be the most widely used defuzzication methods. They are computationally inexpensive and easy to implement with fuzzy hardware chips although a full scientific reasoning has not been established. Many researchers have attempted to clarify the logic of defuzzication process (Runkler and Glesner, 1994). Yager

and Filev (Yager and FILEV, 1993) contributed to the process of defuzzication from the perspective of invariant transformation between different uncertainty paradigms, including basic defuzzication distribution, semi-linear defuzzification and generalized level set defuzzification. All these can be seen as an extension of the center of gravity method. It is noted that with the developments of intelligent technologies, some adaptive and parameterized defuzzification methods that can include human knowledge have been proposed such as where neural networks are used for defuzzification.

In Sugeno defuzzification method, output crisp number is obtained by multiplying each input a by a constant, adding up the result to make an equation and then mathematically combining these equations which are called 'rules of strength' or 'degree of applicability'. Sugeno inference system is further described in Section 2.1.

Since Sugeno defuzzification method is a more compact and computationally efficient representation than a Mamdani type fuzzy inference system, it is being used for adaptive techniques for constructing fuzzy models (*Mamdani and Sugeno Fuzzy Inference Systems* 2019). Although many defuzzification methods have been proposed so far, not a single method gives a right effective defuzzified output for common sense knowledge modelling (Xinwang, 2007) (Mendis, Karunananda and Samaratunga, 2013c). The computational results of defuzzification methods often conflict, and theoretically they do not have a uniform framework on computing singleton fuzzy values objectively.

Most of the existing defuzzification methods attempt to make the estimation of a fuzzy set in an objective way. However, an important aspect of the fuzzy applications is that it can represent the subjective knowledge of the decision maker where different decision makers have different perception for the defuzzification results. We propose an improved defuzzification method for a system primarily designed to model tacit knowledge. Design of this system is integrated with a pre-processor and a fuzzy inference system. The principal component analyzer in pre-processor is used for reducing dependencies and is directly integrated with user interface. A prototype of the system has been implemented to verify the defuzzification method by principal component analysis for estimation of a singleton fuzzy value in a subjective way for knowledge based systems.

This article has been structured as follows: Section 2 explains about related work, Section 3 elaborates PCA based defuzzification, while system in practice is discussed in Section 4, Section 5 discusses about experimental setup, Section 6 is about analysis of the results and section 7 concludes and suggests further work.

2 LITRETURE REVIEW

Sugeno defuzzification method and the research being carried out to enhance its applicability with PCA are discussed in this section.

2.1 Sugeno Defuzzication Method

Sugeno proposed a model based on rules where the antecedent was composed of linguistic variables and the consequent was represented by a function of the input variables (Sugeno and Tanaka, 1991; Takagi and Sugeno, 1985). This model uses the fuzzy rules of Sugeno. In fact the output of each rule is a function of inputs f(x1, x2, xp). In general, f is a polynomial and the order of the polynomial gives the order of the Sugeno fuzzy inference model. The most usual form of these kinds of rules is the one shown below, in which the consequent comprises a linear combination of the variables involved in the antecedent.

A typical rule in a Sugeno fuzzy model has the form:

If Input1 = x and Input2 = y, Then the Output is z = a.x + b.y + c

Where Input1 and Input2 are the system input variables, z is the output variable, a, b, c are the numerical constant parameters, and x and y are linguistic labels associated in the form of fuzzy sets. The output level (singleton value) z_i of each rule is weighted by the firing strength W_i of the rule. For example, for an AND rule with Input1 = x and Input2 = y, the firing strength is:

W_i = And Method (F1(x), F2(y))

Where F1, F2 are the membership functions for Input1 and Input2 respectively. The final output of the system is the weighted average of all rule outputs, computed as:

$$\text{Final Output} = \frac{\sum_{i=1}^{N} w_i z_i}{\sum_{i=1}^{N} w_i} \quad (1)$$

The inference performed by the Sugeno model is an interpolation of the entire relevant linear model. The degree of relevance of a linear model is determined by the degree the input data belong to the fuzzy subspace associated with the linear model. The degree of belongingness become the weight in the interpolation process.

This defuzzification method is very useful when the fuzzy set is a series of singleton values. It could be that a set of rules is of the Sugeno type (1st order) format like:

If x is A and y is B then c = k

Where x and y are fuzzy variables and k is a constant that is represented by a singleton fuzzy set.

The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant.

2.2 Various applications in Sugeno type fuzzy inference system combined with PCA

A Sugeno type fuzzy logic (FL) inference system with PCA had been trained and applied to predict permeability of gasses by (Ghadimi et al, 2010). FL modeling results have shown that there is an excellent agreement between the experimental data and the predicted values, with mean squared relative error (MSRE) of less than 0.0095. Research by (Zhang, J., Zhang, Y., and Chang-shui, 2017) proposes a Takagi-Sugeno (TS) fuzzy system that learns through a support vector machine (SVM) in principal component (PC) space (Takagi-Sugeno (TS) fuzzy system- support vector machine) for real-time object detection. The antecedent part of the TFS-SVMPC classifier is generated using an algorithm that is similar to fuzzy clustering. The dimension of the free parameter vector in the TS consequent part of the TFS-SVMPC is first reduced by principal component analysis (PCA).

A linear SVM is then used to tune the subsequent parameters in the principal component space to give the system better generalization performance. The TFS-SVMPC is used as a classifier in a camera-based real-time object detection system. The paper by (Chang, 2009)

discusses the robust control for Four Wheels Steering (4WS) vehicle dynamics when the road adhesion conditions change and the sideslip angle is unavailable for measurement. The non-linear model of the vehicle is first represented by an uncertain Takagi Sugeno model and the robust output stabilization of the vehicle is considered. The controller and the observer are designed in terms of Bilinear Matrix Inequalities (BMI) problem. A method is then proposed to get the BMI formulation resolved sequentially where simulation results indicate that considerable improvements in the vehicle handling can be achieved when the vehicle is governed by the proposed fuzzy observer-based controller.

A hybrid learning algorithm, which combines the least-square method and the back-propagation algorithm, is used to identify the parameters of the network in (Jassar et al, 2009) which describes an adaptive network based inferential sensor that can be used to design closed-loop control for space heating systems. PCA has been used with Takagi-Sugeno (TS) fuzzy logic to improve power system stability. In the paper by (Ramanujam et al, 2014), a fuzzy based Principal component function coupled with Taguchi's design of experiment is used for optimization of machining parameters for minimum surface roughness and power consumption, and maximum material removal rate. Taguchi based design of experiment facilitates the finding of the most relevant information about the feature of the system to be optimized. Córdoba describes a new method relying on fuzzy k-means clustering of spatial principal components in (Córdoba, 2013).

3 PROPOSED METHODOLOGY TO IMPROVE DEFUZZIFICATION BY PRINCIPAL COMPONENT ANALYSIS

The proposed model has been implemented using the architecture as shown in Fig. 1. Description of the model is given assuming a data set is collected using a questionnaire and focusing on tacit knowledge.

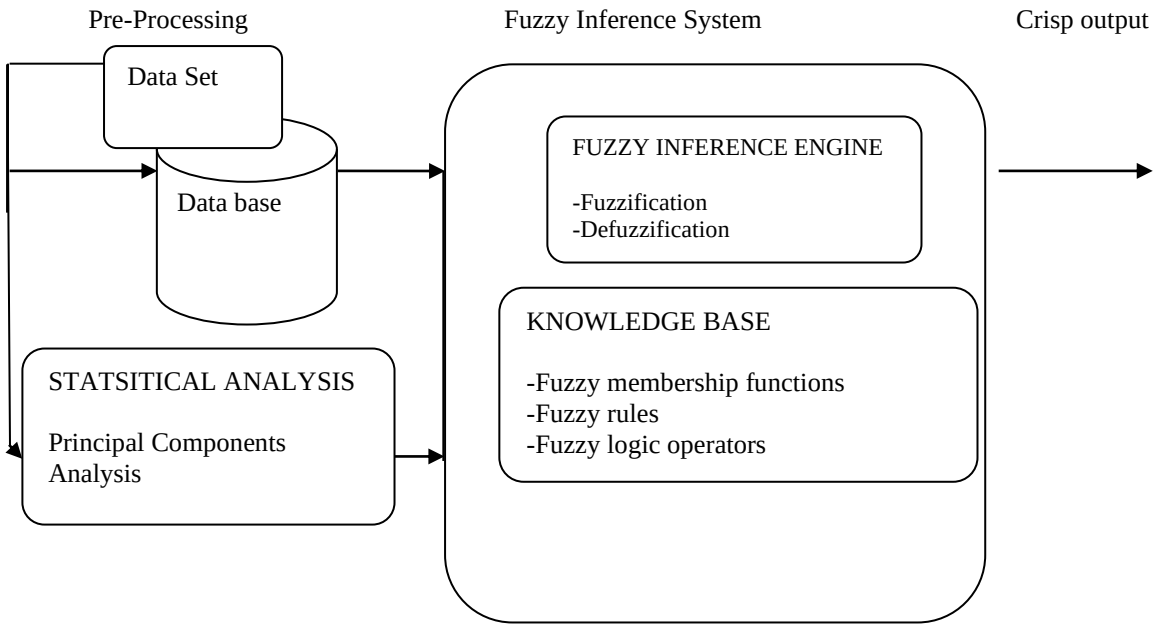

Figure 1 Overall Design of the proposed system

3.1 Principal Components Analyzer

Knowledge has been extracted from the experts and formulated into a questionnaire based on the relevant domain. It has been evaluated using Likert scale technology (Richards and Bush, 2003). Experimental setup for all 4 data sets is described detail in Section 4. In the first instance of tacit knowledge acquisition, a pilot survey has been done for the purpose of extracting Principal components. The SPSS statistical package is used for conducting the functions of Principal components extracting

For partitioning n number of segments of the questionnaire, following computation is concluded.

$$X = \sum_{i=1}^{m}\sum_{j=1}^{t} a_{ij}S_i + \sum_{i=m+1}^{p}\sum_{j=1}^{t} a_{ij}S_i + \ldots + \sum_{i=q+1}^{r}\sum_{j=1}^{t} a_{ij}S_i \qquad (2)$$

Where a_{ij} are the elements of Principal Component matrix and S_i answers for the questions, given in the category.

3.2 Fuzzy inference system

The output results of the Principal Component Analyzer would be the input for the fuzzy inference system. It consists of fuzzy inference engine and knowledge base. In the case of Sugeno defuzzification process, finding the singleton values is considered as an automated process by the principal component analyzer. This module has been implemented using Visual Basic, for widening scope of generating crisp output.

3.2.1 Knowledge base

The knowledge base consists of fuzzy membership functions, fuzzy rules and fuzzy logic operators. Fine tuning analysis for output generated by the fuzzy inference system have been processed using Fuzzy membership functions, fuzzy rules and fuzzy logic operators in the knowledge base. The knowledge base has been implemented using VB 6.

General format of rules governing the tacit or explicit domains are as follows:

RULE#1: IF REFINER1 is REFINE1 or REFINER2 is REFINE2 THEN CLASSIFIER = k_1

RULE#2: IF REFINER1 is REFINE1 or REFINER3 is REFINE3 THEN CLASSIFIER = k_2

……..

RULE#n: IF REFINER1 is REFINE1 or REFINERn is REFINEn THEN CLASSIFIER = k_n

Here: Input fuzzy variables are REFINER1, REFINER2 … REFINERn

Input fuzzy values are REFINE1, REFINE2 … REFINEn

Output fuzzy variable is CLASSIFIER

3.2.2 Fuzzy Inference Engine

The fuzzy inference engine carries out the functions of fuzzifier and defuzzifier whereby the fuzzy inference system reaches a solution. The principal component analyzer is integrated with the fuzzy inference engine.

The zero-order analyser takes only one singleton value from fixed values of the Classifier which defines Singleton values (k_1, k_2 ……..k_n). For all other values the membership function is defined as zero.

Here k_1, k_2 and k_n are SINGLETON values for the singleton fuzzy membership functions "REFINER1 REFINER2, REFINER1 REFINER3, …., REFINERn-1 REFINERn"

X_U and X_L are Upper bound value and the Lower bound value in the Likert scale. The basic procedure is to calculate the fuzzy value and take the average of upper and lower bound.

To calculate singleton value (kn), take the proportion of uncertainty values based on Upper Bound/ Lower Bound method (Zhang, J., Zhang, Y., and Chang-shui, 2017):

To calculate singleton value (kn), take the proportion of uncertainty values:

$$k_n = ((X_{Un-1} + X_{Un}) + (X_{Ln-1} + X_{Ln}))/((((X_{U1} + X_{U2}) + (X_{L1} + X_{L2}))_+ ((X_{U1} + X_{U3}) + (X_{L1} + X_{L3}))_{+\ldots+} ((X_{Un-1} + X_{Un}) + (X_{Ln-1} + X_{Ln}))))$$

$$classifier = \frac{\begin{array}{l}(Max(\mu_{REFINE_2}(X_2), \mu_{REFINE_1}(X_1)) * K_1 \ldots + (Max(\mu_{REFINE_1}(X_1), (\mu_{REFINE_{n-1}}(X_{n-1}) * K_{n-1} + \ldots. \\ (Max(\mu_{REFINEn}(X\ ), \mu_{REFINE_n}(X_n))K_n\end{array}}{\begin{array}{l}(Max(\mu_{REFINE_2}(X_2), \mu_{REFINE_1}(X_1)) + (Max(\mu_{REFINE_n}(X_{n-1}), (\mu_{REFINE_1}(X_1) + .. + \\ (Max(\mu_{REFINE_{n-1}}(X_{n-1}), \mu_{REFINE_{nn}}(X_n)\end{array}} \quad (3)$$

3.2.3 Database

Extracted principal components have been stored in MS Access database, which integrated with the Principal Component Analyzer through the developer interface. The data extracted from the questionnaire is stored in the database which is integrated with the user interface.

3.2.4 User interface

The user interface facilitates both developer and general user. Once knowledge engineer develops a particular system for the required domain with interaction of the expert, a general user will be given a facility of using the framework for decision-making purposes. So, it has been divided as the user interface in developer mode and general user mode. General user will be able to use a developed system using a questionnaire for a different domain, which has been implemented as a form linked to the database.

4 EXPERIMENTAL SETUP

For the experimental setup, three (3) numbers of explicit knowledge datasets as payment card, non-communicable diseases and communicable diseases were considered. Analysis of Manas Prakriti in Ayurveda has been considered for domain of tacit knowledge. This has been tested to find error of defuzzification by PCA and defuzzification technique in Sugeno type fuzzy inference system.

4.1 Payment Card Data Analysis

This dataset includes consumers' use of cash by harmonizing payment diary surveys from seven countries. The seven diary surveys were conducted in 2009 (Canada), 2010 (Australia), 2011 (Austria, France, Germany and the Netherlands), and 2012 (the United States). This analysis finds cross-country differences — for example, the level of cash usage difference among countries.

4.1.1 Constructing the questionnaire

Payment card is defined in columns as countries with either a debit or a credit card in 7 countries (Australia, Austria, Canada, Germany, Netherlands, France and US) and calculations are based on questionnaire and diary surveys. Consumers have been categorized according to age, education and income and are defined as variables of the dataset (Bagnall et al, 2014). Only rarely a consumer can become so totally dominated by one type of category (age or education or income) while the other type of categories lose their power. This is justified to predict type of consumers in combinations, such as age & education, age & income and education & income subjectively.

Further, this is justified to predict value for type of category type objectively as given below:

Let c_1 be Max (age, education, income) and c_2 be Min (age, education, income). Then, Predicted value = $(c_1+c_2)/2$

Table 1 Data set for consumption ability of a debit or a credit card

Category	Countries						
	AUSTRALIA	AUSTRIA	CANADA	FRANCE	GERMANY	NETHALANDS	US
Debit card -age							
18-35 0.96	0.96	0.95	0.97	0.91	0.96	1	0.77
36-60 0.94	0.94	0.89	0.98	0.91	0.95	0.99	0.79
60+ 0.88	0.88	0.69	0.94	0.86	0.91	0.99	0.69
Credit card - age							
18-35 0.96	0.33	0.21	0.76	0.25	0.31	0.6	0.52
36-60 0.94	0.57	0.28	0.84	0.36	0.43	0.62	0.69
60+ 0.88	0.46	0.2	0.83	0.29	0.24	0.62	0.84
Debit card-education							
low	0.94	0.79	0.89	0.81	0.86	0.99	0.71
medium	0.86	0.91	0.98	0.9	0.98	0.99	0.86
high	0.91	0.96	0.97	0.96	0.99	0.99	0.8
Credit card-education							
low	0.48	0.13	0.62	0.22	0.16	0.44	0.56
medium	0.41	0.31	0.77	0.31	0.39	0.55	0.81
high	0.45	0.42	0.91	0.36	0.68	0.75	0.92
Dedit card-Income							
income low	0.88	0.78	0.96	0.83	0.89	0.98	0.62
medium	0.95	0.9	0.97	0.93	0.96	0.99	0.82
high	0.94	0.93	0.97	0.96	0.97	0.99	0.82
Credit card-Income							
income low	0.27	0.11	0.64	0.23	0.2	0.36	0.36
medium	0.53	0.2	0.84	0.32	0.27	0.6	0.75
high	0.54	0.42	0.95	0.52	0.54	0.86	0.91

In the research work that stated above, the method of analyzing category is not consistent. Although practitioners use a questionnaire, several problems like dependencies among the questions in the questionnaire and analysis of the categories of consumers are visible.

4.1.2 Experiment

The Payment card scheme is applied to the proposed statistical fuzzy inference System as another application. The experiments are carried out in five different environments to enable the defuzzification by PCA and defuzzification technique in Sugeno type fuzzy inference system.

Calculation of Predicted Value

c_1 =Max (ag,ed,in); c_2 = Min (ag,ed,in)
Predicted value = $(c_1+c_2)/2$

Calculation of Error -> Error= Predicted value- actual value

4.2 Global Health estimates summary tables: Projection of deaths by cause, age -Non communicable diseases

This workbook contains summary projections of non-communicable diseases by cause, gender, age and region. These projections are an update of previous projections released in 2006 and in 2008. A set of relatively simple models were used to project future health trends for baseline, optimistic and pessimistic scenarios, based largely on projections of economic and social development, and using the historically observed relationships of these with cause-specific mortality rates (Health statistics and information systems, WHO, 2019)

Similar to the procedure explained in Section 4.1, a questionnaire was constructed with the data set and the experiment was carried out.

Female and calculations are based on projections by deaths by age in non-communicable diseases. Non-communicable diseases have been categorized according to malignant neoplasms, mental and behavioural disorders and neurological and are defined as variables of the dataset. Only when a patient becomes totally dominated by one type of category, the other type of category lose its power.

This is justified to predict type of non-communicable diseases in combinations, such as Malignant neoplasms Mental and behavioural disorders, Malignant neoplasms Neurological and Mental and behavioural Non-communicable diseases dataset is defined in column as age with either male of disorders Neurological subjectively.

Further, this is justified to predict value for type of non-communicable diseases objectively as: Predicted value = $(c_1+c_2)/2$

Let c_1 be Max (Malignant neoplasms (mn), Mental and behavioural disorders (md), Neurological (nc)) and c_2 be Min (Malignant neoplasms (mn), Mental and behavioural disorders (md), Neurological (nc)).

The non-communicable disease data set is applied to the proposed system of statistical inference System as another application in a different domain. The experiments are carried out in five different environments to enable the defuzzification by PCA and defuzzification technique in Sugeno type fuzzy inference system as given below.

Calculation of Predicted Value

c_1 =Max (md, mn, nc); c_2= Min (md, mn, nc)

Predicted value = $(c_1 + c_2)/2$

Calculation of Error -> Error= Predicted value- actual value

4.3 Global Health estimates summary tables: Projection of deaths by cause, age - communicable diseases

This workbook contains summary projections of communicable diseases by cause, gender, age and region. These projections are an update of previous projections released in 2006 and in 2008. A set of relatively simple models were used to project future health trends for baseline, optimistic and pessimistic scenarios, based largely on projections of economic and social development, and using the historically observed relationships of these with cause-specific mortality rates (Health statistics and information systems, 2019).

Similar to the procedure explained in Section 4.1, a questionnaire was constructed with the data set and the experiment was carried out.

4.3.1 Constructing questionnaire

Communicable disease data set is defined in columns as age with either male of female and calculations are based on projections by deaths by age in communicable diseases. Communicable diseases have been categorized in to Childhood-cluster diseases, Parasitic and vector diseases and Nutritional deficiencies and are defined as variables of the dataset. This is justified to predict type of communicable diseases in combinations subjectively.

Let c1 be Max (Childhood-cluster diseases (cc), Parasitic and vector diseases (pv), Nutritional deficiencies (nd)) and c_2 be Min (Childhood-cluster diseases (cc), Parasitic and vector diseases (pv), Nutritional deficiencies (nd)).

Then, Predicted value= $(c_1+ c_2)/2$

The communicable disease data set is applied to the proposed system of statistical inference Systems (ESPCA) as another application. The experiments are carried out in five different environments to enable the Sugeno defuzzification with PCA and without PCA as shown in Section 5.

Calculation of Predicted Value:

c_1 =Max (cc, pv, nd); c_2 = Min (cc, pv, nd)

Predicted value = $(c_1 + c_2) / 2$

Calculation of Error -> Error= Predicted value- actual value

4.4 Analysis of Manas Prakriti

Manas Prakriti in Ayurveda domain is considered as an area in clinical psychology, which involves commonsense knowledge of Ayurveda experts for its analysis. This is because Manas Prakriti criteria is very personal and there is an Ayurvedic theory behind how it should be done [39]. Manas Prakriti is classified in to three types: Satva, Rajas or Tamas. One type of Manas Prakriti usually predominates and polarizes our mind and life according to its qualities. Souls become Satva, Rajas or Tamas in nature. However, in the ordinary, unrefined field of human nature, one type of Manas Prakriti seldom prevails. Our lives are an interplay of shifting currents of good and evil or truth and falsehood etc. Only a rare human being can become so totally dominated by one type of Manas Prakriti where other two types have no power. Such extreme types are supposed to be hardened criminal or complete Tamas type, the super achiever or complete Rajas type, and the selfless saint or complete Satva type. However, even these types can have their admixtures of the other type of Manas Prakriti. This occurance is the basis to predict type of Manas Prakriti in combinations, such as satva rajas, satva tamas and rajas tamas subjectively.

Further, this is justified to predict value for type of Manas Prakriti objectively as given below:

Let c1 be Max (satva, rajas, tamas) and c_2 be Min (satva, rajas, tamas).

Then, Predicted value= $(c_1 + c_2)/2$

Recognition of Manas type is conducted by using a questionnaire based on fundamentals and features of mind constitutions described in identification of mind constitutions in Manas Prakurthi under Clinical examination. Questions given are user-friendly but based on medical theories of Ayurveda, which is used for finding constituent type, which probes the mind with even repeating questions. This has been used for classification of individuals for many centuries. There has been no research into improve the questionnaire although people have realized that the classification is not acceptable sometimes. However, Manas types consist in combination and analysis is based on subjective criteria (Dubey G.P, 1978). Although practitioners use a questionnaire but lead several problems like dependencies among the questions in the questionnaire and analysis of the temperamental groups.

4.4.1 Constructing the questionnaire

Commonsense knowledge of human type has been acquired via questionnaire and informal interviews with Ayurveda expert. The knowledge extracted from Ayurveda expert has been mapped in to questionnaire consisting of 65 number of questions. This knowledge has been entered to system using the *developer mode* of the system (Mendis et al, 2012) (Mendis et al, 2016). Using the questionnaire editor, each question of the questionnaire and the marks-range using Likert Scale has been stored in to the database. The Table 3 below depicts a part of the questionnaire.

Table 2 A part of the questionnaire regarding Mental Constitution

	Question	Strongly disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly agree
1	You like to provide food for animals.	1	2	3	4	5
2	You do not indulge in flesh.	1	2	3	4	5
3	You are willing to help a disable person to get into a bus.	1	2	3	4	5
4	You believe in invisible force.	1	2	3	4	5
5	You believe that your own good or bad actions bring your fortune or misfortune.	1	2	3	4	5
6	You believe that your good deeds bring your fortune in life after death/ attainment.	1	2	3	4	5
7	You can easily forget your unpleasant experiences.	1	2	3	4	5
8	You do not become angry by being not punctual.	1	2	3	4	5
9	Distribution is better than personal collection of wealth.	1	2	3	4	5
10	You recommend equal distribution of wealth for all	1	2	3	4	5
11	It is your habit to be punctual for your duties	1	2	3	4	5
12	You always try to use the pedestrian crossing to cross a main road.	1	2	3	4	5
13	You always walk on the right side of a main road and it is your habit	1	2	3	4	5

4.4.2 Experiment

The communicable disease data set is applied to the proposed system of statistical inference Systems (DPCA) as another application. The experiments are carried out in five different environments to enable the Sugeno defuzzification with PCA and without PCA as given below.

Calculation of Predicted Value:

c_1 =Max (satva,rajas,tamas)
c_2 = Min (satva,rajas,tamas)
Then, Predicted value= $(c_1 + c_2)/2$

Calculation of Error -> Error = Predicted value- Actual value

5 ANALYSIS OF RESULTS

Results have been analyzed by comparison of error with PCA based defuzzification and with Sugeno defuzzification method.

5.1 Card Payment

Error has been compared with PCA based defuzzification and Defuzzification method in Sugeno Type Fuzzy inference system for Card-payment dataset.

Table 3 Average error in card payment

Singleton group	Average error (%)
case 1:k1 = 0.25, k2 = 0.5, k3 = 0.75	49.84
case2:k1 = 0.3, k2 = 0.6, k3 = 0.8	69.92
case3: k1 = 0.2, k2 = 0.5, k3 = 0.8	49.71
case4: k1 = 0.4, k2= 0.6, k3 = 0.8	80.07
case5: k1 = 0.2, k2 = 0.6, k3 = 0.85	64.71
PCA	1.02

5.2 Non Communicable Diseases

Error has been compared with PCA based defuzzification and Defuzzification method in Sugeno Type Fuzzy inference system for non-communicable disease dataset.

Table 4 Average error in non-communicable diseases

Singleton group	Average error (%)
case 1: k1 = 0.25, k2 = 0.5, k3 = 0.75	40.69
case2 : k1 = 0.3, k2 = 0.6, k3 = 0.8	59.29
case3: k1 = 0.2, k2 = 0.5, k3 = 0.8	49.71
case4: k1 = 0.4, k2= 0.6, k3 = 0.8	80.07
case5: k1 = 0.2, k2 = 0.6, k3 = 0.85	64.70
PCA	1.39

5.3 Communicable Diseases

Error has been compared with PCA based defuzzification and Defuzzification method in Sugeno Type Fuzzy inference system for communicable disease dataset.

Table 5 Average error in communicable diseases

Singleton group	Average error (%)
case 1: k1 = 0.25, k2 = 0.5, k3 = 0.75	39.87
case2: k1 = 0.3, k2 = 0.6, k3 = 0.8	57.09
case3: k1 = 0.2, k2 = 0.5, k3 = 0.8	44.16
case4: k1 = 0.4, k2= 0.6, k3 = 0.8	59.28
case5: k1 = 0.2, k2 = 0.6, k3 = 0.85	60.29
PCA	28.77

5.4 Manas Prakriti

Error has been compared with PCA based defuzzification and Defuzzification method in Sugeno Type Fuzzy inference system for tacit knowledge modelling in Manas Prakriti.

Table 6 Average error in Manas Prakriti

Singleton group	Average error
case 1: k1 = 0.25, k2 = 0.5, k3 = 0.75	37.88
case2: k1 = 0.3, k2 = 0.6, k3 = 0.8	57.68
case3: k1 = 0.2, k2 = 0.5, k3 = 0.8	36.48
case4:k1 = 0.4, k2= 0.6, k3 = 0.8	68.37
case5: k1 = 0.2, k2 = 0.6, k3 = 0.85	50.88
PCA	4.81

Error has been compared with PCA based defuzzification and Defuzzification method in Sugeno Type Fuzzy inference system for communicable disease dataset.

Comparison of average error in defuzzification methods, both implicit and explicit domains are shown in Figure 2.

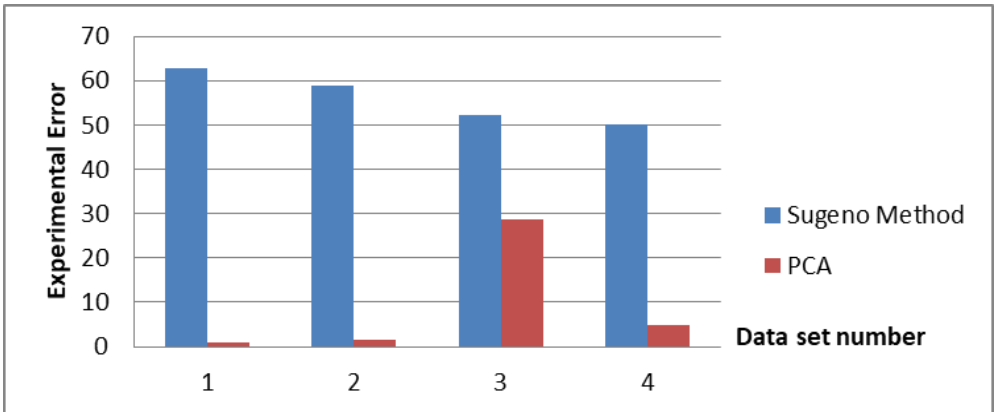

Figure 2. Comparison of average error in defuzzification methods

It is shown that error (difference between expected outputs an actual output) is minimized by 97%, 94%, 21% and 80% for the data sets Card set, Non-communicable diseases, Communicable diseases and Manas Prkritui respectively by PCA based defuzzification. The key feature required to evaluate PCA based defuzzification is whether the system derives a crisp output equal to a conclusion derived by an expert who works in the same domain. Here, we expect to investigate the observations that have been derived from a particular selected explicit and implicit domains in to a further analysis. In this sense we tested on aspects viz.

- Whether principal component analysis affect defuzzification differences.
- Whether any improvement is made for existing Sugeno defuzzification process.

By testing this aspect, it can be arrived at a crisp output that PCA based defuzzification works in an agreeable way with a domain expert.

6 CONCLUSION

The proposed system extracts tacit or explicit knowledge, fuzzify them and gives a defuzzified decision as output. The defuzzification process of Sugeno method is improved by applying principal components analysis. Here, singleton values in Sugeno defuzzification method have been computed by using integrated principal components analysis approach. In this approach carefully planning of the questionnaire is important and different experts may propose different questionnaires since their emphasis of domain knowledge are different. Domain knowledge collected was analyzed to generate the appropriate fuzzy membership functions for classification of the knowledge. Defuzzification for classified knowledge has been achieved by the PCA based defuzzification where defuzzification is done with principal component analysis.

The implemented prototype of the system facilitates a user in modeling explicit/implicit knowledge that has not been modelled in existing mechanism of defuzzification method of Sugeno type inference system. The evaluation was done for explicit datasets such as card payments communicable diseases and non-communicable diseases. The evaluation of the defuzzification by PCA for domains with tacit knowledge was done by testing of the system with Aurvedic Manas Prakrithi dataset. This is considered as an automated way of computing singleton fuzzy values with minimum error when comparing the existing manual defuzzification method of Sugeno type inference system. This approach reduces inconsistency and is able to extract conclusions in higher level of accuracy than of Sugeno defuzzification process.

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Effect of Water Requirement on Growth, Yield and Peelability of True Cinnamon (*Cinnamomum zeylanicum* Blume)

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Abstract: *This research was planned to study the effect of water requirement on growth, yield and peelability of vegetatively propagated Sri Gemunu and Sri Wijaya cultivars of true cinnamon.The experiments were conducted in the field and nursery of the National Cinnamon Research & Training Center (NCRTC), Department of Export Agriculture (DEA), Palolpitiya, Matara during the year 2018. Three experiments were planned separately for nursery stage, acclimatization stage and mature stage with 10 weeks, 6 months and 5 years old vegetatively propagated Sri Wijaya, Sri Gemunu and Normal type cinnamon varieties respectively. Experiment was arranged as a complete randomized design with five water requirement treatments: 180 ml (fresh water at field capacity) as the control treatment (T1) 100ml (T2), 150ml (T3), 200 ml (T4) and 250ml (T5) with five replications at nursery and acclimatization stages. To study the effect of water requirement at mature stage on peelability five treatments; no water as the control treatment (T1), 05 l (T2), 10l (T3), 15l (T4) and 20l (T5) with five replication arranged incomplete randomized design. The results revealed that Sri Wijaya has shown significantly highest mean shoot length in 250ml water requirement followed by 200ml water requirement at nursery stage after 10 weeks. Sri Gemunu has shown significantly highest mean leaf area, fresh and dry shoot weight and fresh root weight at 250ml water requirement followed by 200ml water requirement at nursery stage after 10 weeks. At Acclimatization stage among 6 months old cinnamon plants, Sri Wijaya and Sri Gemunu have shown higher performances in length of shoots and number of leaf circles at 200ml and 250ml water requirement. During the maturity stage among 5 years old cinnamon plants both Sri Gemunu and Sri Wijaya have shown the lowest time for peeling (<12 minutes) at 15 liters and 20 liters/plant water requirement treatments. Further both Sri Wijaya and Sri Gemnu have shown highest thickness of fresh bark (>1.1mm) at 15 liters and 20liter per plant water requirement treatments. Therefore the best water requirement for vegetatively propagated Sri Wijaya and Sri Gemunu at nursery stage and acclimatization stage is 200ml-250ml per plant. The best water requirement for Sri Wijaya and Sri Gemunu at mature stage is 15-20 liter per plant to achieve lowest peeling time and higher thickness of fresh bark. Further studies are essential to determine the irrigation requirement and efficiency values under different variables, different areas of agro climatological zones to make the best management practice (BMP) in Sri Lankan Agriculture.*

Keywords: *cinnamon, growth, peelability, water requirement*

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1 INTRODUCTION

Water Requirement is the amount of water required by the plants for its survival, growth, development and to produce important and valuable economic parts. This requirement can be applied either by precipitation or by irrigation. Numerous studies on water

consumption and water requirements of agricultural crops such as tea, coffee, cocoa, avocado and banana were conducted since long time ago (Mills, 1895). Most of these studies primarily involved in the measurement of water delivered to the irrigated farms (Jensen, 1968). Unlike other agriculture crops, water requirement of true cinnamon is not studied and estimated yet in Sri Lankan conditions.

Cinnamon is the dried bark of the perennial tree of Cinnamomum zeylanicum blume of the family Lauraceae. Ceylon cinnamon is the true cinnamon, and it is native to Sri Lanka. It is originally grown wild in central hill country of Sri Lanka. True cinnamon is mainly grown in low country wet zone (WL3 and WL4), and intermediate zone. The soil type in the areas is Red Yellow Podsolic soil with 5.5 - 6.5 pH. Optimum temperature is between 250 ^{o}C - 300 ^{o}C and the rainfall range from 1875mm - 3750mm (Department of Export Agriculture, 2015). The major product is cinnamon quills which account for 90% of the whole industry (Department of Export Agriculture, 2015). "True Cinnamon" is the major spice crop in Sri Lanka and the fourth largest export agriculture crop that earns around Rs. 24,000 million as export income to the country (Department of Export Agriculture, 2015). Cinnamon bark is used as spice and as a flavouring agent in beverage, bakery products and various natural medicinal treatments such as, preventing of the unwanted clumping of the blood platelets, improves the ability of normalizing the blood sugar levels of persons, prevents heart disease around the world.

Cinnamon is mainly propagated by seeds. However, as the floral behaviour shows proto gynous dichogamy in nature, the cross pollination occurred predominant. Therefore, to maintain pure lines in plant production of the introduced varieties, Sri Gemunu and Sri Wijaya are vegetatively propagated. Therefore, true cinnamon is cultivated as both vegetatively and as seedling. Thus, the water requirement can be varied according to the plant type and also to the growth stage (Mehetha and Pandey, 2015).

Cinnamon is cultivated as a rain-fed crop mainly in wet and intermediate zones. However, water deficit problems are very common among nursery level and in the dry zone areas where cinnamon is currently extending to grow due to the high price demand for the product in the international market. However, it is known that water stress, causes difficulties in peeling of stems at mature stage. Peelability is directly depended on the amount of water absorbed by mature cinnamon plants. With the inadequate water capacity, growers are constantly facing the inability of peeling the bark off properly which ultimately causes a significant drawback in whole productivity of cinnamon industry in terms of time and effort. When a proper irrigation system is provided, it may be possible to observe high growth resulting in good shoot root characteristics even in dry areas. Cinnamon industry is the oldest industry in Sri Lanka but does not use irrigation systems at grower level.

Studying the effect of water requirement is one of the essential components in irrigation planning (Brouwer et al, 1989). Although the "crop water requirement" has been estimated for many crops, it is not yet attempted for cinnamon. Evapotranspiration is the combination of two different processes whereby water is lost from the surface of soil by evaporation and on the other hand from the crop by transpiration (Allen et al., 1998). Evapotranspiration helps in predicting when and how much water is required for any particular crop. Water requirement depends mainly on the nature and the crop's growth stage; such as initial stage, developing stage and mature stage and environmental conditions (Doorenbos and Pruitt, 1997). On the other hand, different crops have

different water-use requirements under the same weather conditions Therefore, this experiment is designed to estimate the water requirement and its effect on growth performance, production and peelability of true cinnamon plants.

2 METHODOLOGY

2.1 Experimental site

The experiments were conducted in the field and nursery of the National Cinnamon Research & Training Center (NCRTC), Department of Export Agriculture (DEA), Palolpitiya, Matara during the year 2018. Location of the study site is latitude 60 1´ 41´´ N and longitude 800 33´ 34´´ E. Altitude is 52m. Agro ecological zone is low country wet zone (WL3) and the soil is Red Yellow Podsolic (Ultisol) with soil pH of 5.5 - 6.5. Temperature of the study site varies between 250ºC and 300 ºC, relative humidity (RH) is always greater than 50% and the mean annual rainfall ranges between 2000mm and 2500mm. The maximum precipitation was recorded as 45.2 mm in November. The mean pan evaporation is ranged 2.50 - 3.66 mm/day during the research period (January – December 2018) at the WL3 ecological zone.

2.2 Experiments

Three different experiments were conducted to determine water requirement at;
1. Nursery stage of vegetatively propagated (VP) plants.
2. Acclimatization stage of VP plants of true cinnamon and
3. Maturity stage of true cinnamon plants with effect on peelability of stems.

2.2.1 Experiment I

The water requirement of the vegetatively propagated cinnamon at nursery stage was determined in this experiment. Mature semi hard wood branches of varieties Sri Wijaya, Sri Gemunu and Normal types cinnamon were collected from the field of NCRTC. The surface soil, coir dust, cow dung and river sand (1:1:1:1 ratio) were used to prepare the Department of Export Agriculture (DEA) recommended potting mixture for nursery stage. The field capacity of the potting mixture was measured using pressure plate apparatus. In this experiment, the water requirement treatments were 250ml, 200ml, 150ml, 100ml, and field capacity (180ml) as the control. The experiment was consisted five replicates (5x5 experimental units) for each treatment. Three varieties of cinnamon for each treatment and two plant cuttings per each pot were used this experiment and this experiment was arranged as completely randomized design. The growth parameters were measured using manual instruments and Sky Leaf Root Analyze machine at the NCRTC at 10 weeks.

2.2.2 Experiment II

Six months aged vegetatively propagated plants of Sri Gemunu and Sri Wijaya of cinnamon were randomly selected from the nursery of the NCRTC for determination of the water requirement at acclimatization stage. In this experiment, the treatments were 250ml, 200ml, 150ml, 100ml, and field capacity as the control. The experiment was consisted five treatments and five replicates (5x5 experimental units) for each treatment. Completely Randomized Design structure (CRD) was used for this experiment. The

growth parameters were measured using manual instruments and Sky Leaf Root Analyze machine at the NCRTC at eight-month age.

2.2.3 Experiment III

Five years aged vegetatively propagated cinnamon varieties such as Sri Gemunu and Sri Wijaya plants were randomly selected to study the water requirement and the effect on peelability of stems after harvesting. Five water supply treatments such as, no water (control), 05, 10, 15 and 20 liters of water per plant were used in this experiment. The frequency of water per plant was applied in two days interval. The Completely Randomized Design (CRD) is used for the experiment were tagged and treated them with water to measure the peelability. The runoff from the soil surface was reduced using polythene mulch. The suitable stems of two types of cinnamon varieties such as Sri Gemunu and Sri Wijaya plants were selected and these stems were connected with water filled 100ml of measuring cylinder (measured in cm) and then peeled them to gain knowledge about firmness of the bark in cinnamon.

2.3 Soil properties

Field capacity and moisture content of the potting mixture was measured using pressure plate apparatus and oven drying method.

2.4 Agronomy practice

The VP cuttings were prepared from Sri Gemunu and Sri Wijaya while normal type (true) cinnamon variety was selected from farmers as farmers grow Normal type (true) cinnamon. No fertilizer and other chemicals were applied during the period of experiment. Weeding was done in the field before starting the experiment and overflow also prevented using polythene barriers during the experiment.
Statistical analyses were performed using SAS 9.0 version and analysis of variance (ANOVA) along with Duncan's multiple range test.

3 RESULTS AND DISCUSSION

3.1 Soil Moisture Content of the potting mixture

Moisture content was determined using oven dry method. The moisture content of the prepared potting mixture was 41.22 %. Cow dung, coir dust, surface soil (Red Yellow Podsolic) and the river sand (1:1:1:1 ratio) were included in the potting media in this study. Usually surface top soil and river sand (1:1) were used in potting media by cinnamon growers (DEA, 2015).The coir dust and moist cow dung has higher moisture holding capacity. Coir dust has a strong capillarity that provides more uniform moisture conditions for roots. These conditions were able to increase aeration in the potting mixture and reduce drying of the surface and conserve the moisture of the potting mixture in the polyethylene bags. Coir dust increases the volume of the potting mixture that is suitable for root development and improved access to moisture and fertilizer (Godawatta and De Silva, 2014).

3.2 Growth performance of vegetative propagated cuttings at nursery stage after 10 weeks

3.2.1.Length of shoots

Effect of water requirement on mean shoot length of vegetatively propagated Sri Wijaya, Sri Gemunu and Normal varieties is shown in Figure 1. Sri Wijaya has shown significantly highest mean shoot length (26cm) at 250ml of water requirement but not significantly (p=>0.05) different to the mean shoot length of Sri Gemunu (18cm) and Normal type (23cm) varieties. Sri Wijaya has shown second highest mean shoot length at 200ml water requirement and which was also not significantly different from the mean shoot length of Sri Gemunu and Normal varieties. Sri Wijaya and Sri Gemunu have shown lowest mean shoot length (<13cm) at 100ml water requirement. David et al (1999) reported that the lowest water regime has significantly affected plant eco-physiological responses and plant growth which agrees with this study finding. Results reveal that the vegetatively propagated Sri Wijaya and Sri Gemunu prefers higher water requirement of 200ml to 250ml for shoot growth.

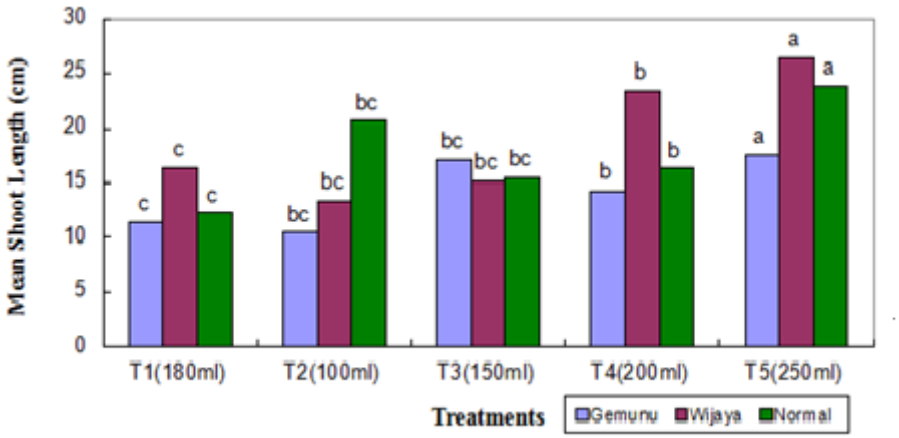

Figure 1. Effect of water requirement treatments of 180ml (field capacity), 100ml, 150ml, 200ml and 250ml on mean shoot length.

3.2.2. Leaf Area

Effect of water requirement on mean leaf area of vegetatively propagated Sri Wijaya, Sri Gemunu and Normal varieties is shown in Figure 2. Sri Gemunu has shown significantly highest mean leaf area (>24cm^2) at 250ml of water requirement but not significantly (p=>0.05) different to the mean leaf area (>15cm^2) of Sri Wijaya and Normal type varieties. Sri Gemunu has shown the second highest mean leaf area (<20cm^2) at 200ml water requirement and which was not significantly different from the mean leaf area of Sri Wijaya and Normal varieties at 200ml water requirement. Sri Wijaya has shown the highest mean leaf area at 250ml water requirement treatment compared to the other water requirement treatments. Sri Wijaya and Sri Gemunu have shown lowest mean leaf area (<10cm^2) at 100ml water requirement. Results reveal that the vegetatively propagated Sri Wijaya and Sri Gemunu prefers higher water requirement of 200ml to 250ml for better vegetative growth compared to the lowest water requirement of 100ml

which agrees with the findings of Hansen (2016). Higher water supply significantly influenced the leaf area in all cinnamon varieties.

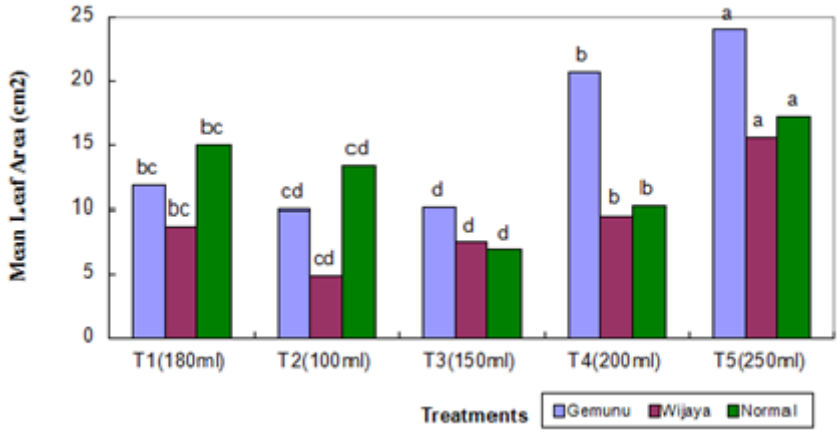

Figure 2. Effect of water requirement treatments of 180ml (field capacity), 100ml, 150ml, 200ml and 250ml on mean leaf area at nursery stage after 10 weeks.

3.2.3. Fresh weight of shoots

Effect of water requirement on mean fresh weight of shoots of vegetatively propagated Sri Wijaya, Sri Gemunu and Normal varieties is shown in Figure 3. Accordingly, the varieties were significantly different on Duncan's multiple range test at 0.05% level (Pr>Fwas<0.0001). Sri Gemunu has shown significantly highest fresh shoot weight (about 10g) at 250ml of water requirement. However, the highest fresh shoot weight of Sri Gemunu was significantly different from all the other treatments of water requirement. Sri Wijaya has shown highest mean fresh shoot weight at 250 ml water requirement treatment compared to all the other water requirement treatments. Sri Gemunu has shown the lowest mean fresh shoot weight (4g) at 100ml water requirement.The well grown leaves with shoot's weight of Sri Gemunu was comparatively higher than that of Wijaya and normal varieties of cinnamon.

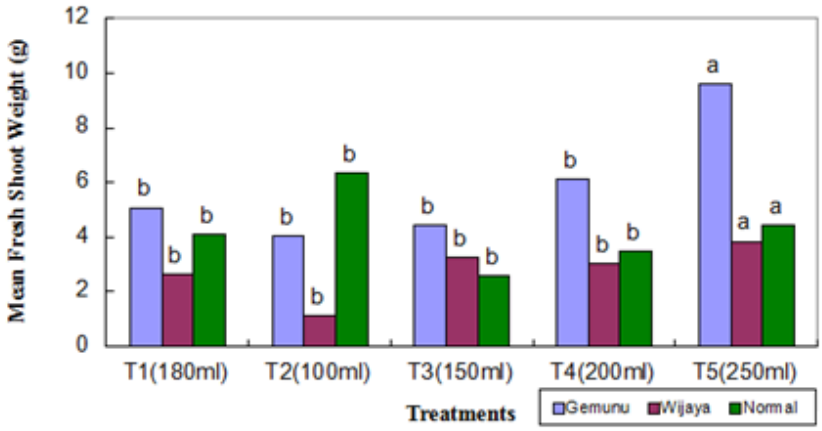

Figure 3: Effect of water requirement treatments 180ml (field capacity), 100ml, 150ml, 200ml and 250ml on mean fresh shoot weight at nursery stage

3.2.4. Dry weight of shoots

Effect of water requirement on mean dry weight of shoots of vegetatively propagated Sri Wijaya, Sri Gemunu and Normal varieties is shown in Figure 4. The different water requirement levels were significantly affected the dry shoot weight of each variety. Sri Gemunu has shown significantly highest dry shoot weight (3g) at 250ml water requirement treatment. Sri Gemunu has shown the second highest dry shoot weight (2.5g) at 200ml water supply treatment but it was not significantly different from that of 250ml water requirement treatment. Sri Gemunu has shown the lowest dry shoot weight (<1.5 grams) at 100ml water treatment. Normal cinnamon has shown the highest dry weight of shoots (<2.5g) at 100ml water supply treatment. However, all studied varieties were also significantly different from each other in dry weight of shoots. According to the SAS analysis, there was a significant interaction between variety and water requirements on Duncan's multiple range test at 0.05% level (Pr> F was <0.0001). This implies that the interaction effect of dry shoot weight to water requirement was significantly different. Transpiration from aerial parts of the plant surface and the rate of plant's metabolism increases in highest water requirement of 250ml of water than the lower water requirement in the potting medium. As a result vegetative growth increased and the dry weight of shoots also increased in highest water supply to the potting mixture. Similar observations to the present study were reported by Vijayakumar et al., (2016), that the crops will transpire water at the maximum rate when there is adequate soil water.

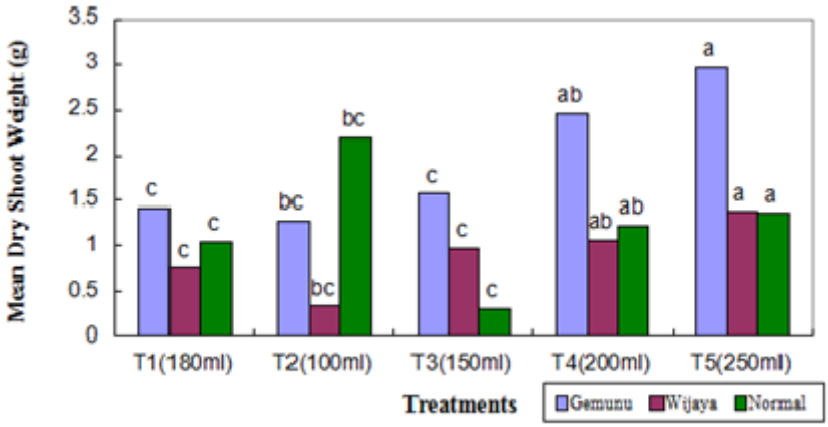

Figure 4: Effect of water requirement treatments 180ml (field capacity), 100ml, 150ml, 200ml and 250ml on mean dry shoot weight at nursery stage

3.2.5. Fresh weight of roots

Effect of water requirement on mean fresh weight of shoots of vegetatively propagated Sri Wijaya, Sri Gemunu and Normal varieties is shown in Figure 5. Sri Gemunu has shown the significantly highest fresh weight of roots (9.5g) at 250ml of water requirement treatment. Sri Gemunu has shown the second highest fresh weight (6g) of roots at 200ml water requirement treatment. The lowest fresh root weight (4g) of Sri Gemunu was measured at 100ml of water requirement treatment.Normal variety has shown the highest fresh root weight (6 g) at 100ml of water requirement treatment. There was a significant interaction between variety and water requirement levels. This implies

that the different requirement levels of water have significant effect on fresh root weight of vegetative propagated cinnamon plant varieties.

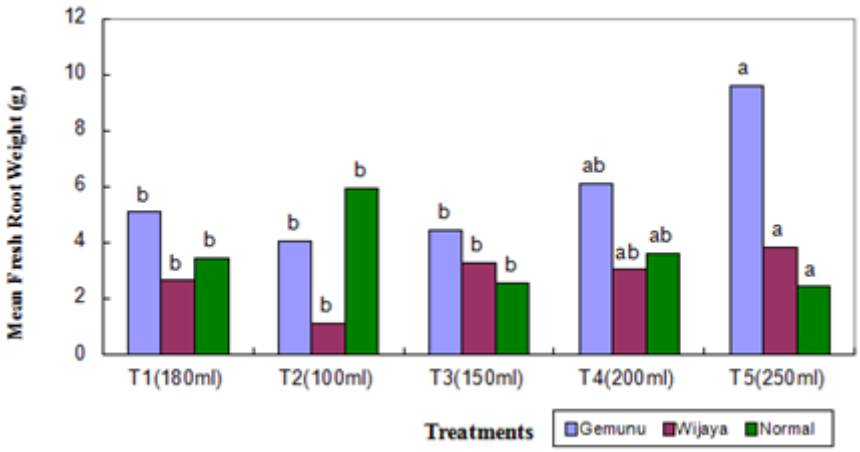

Figure 5: Effect of water requirement treatments: 180ml (field capacity), 100ml, 150ml, 200ml and 250ml on mean fresh shoot weight at nursery stage

Shoot and root growth were affected by different water requirement levels. The results from average data analysis of single and interaction effects have shown that shoot and root growth of vegetatively propagated Sri Gemunu, Sri Wijaya Normal plants were lower when cinnamon was grown in the lower water requirement of potting media and the wilting appearance was observed during the experiment. Normal cinnamon variety is not required to propagate as vegetatively propagated plants; they can be grown as seedlings. In contrast to the seedling plants, the nursery stage of vegetatively propagated plants has no tap root system, however; they have only the lateral roots. Those roots can absorb water and dissolved nutrients (ions) for plant growth and development when there is adequate water in the potting mixture. Normal cinnamon plants have showed highest shoot and root growth in lowest water requirement of 100ml. According to the results of the experiment, the highest water supply level has influenced highest growth performances on shoot and root in vegetatively propagated Sri Gemunu followed by Sri Wijaya in nursery stage. Similar observations to present study were reported by William et al. (2000) that the lowest water regime was significantly affected plant eco-physiological responses, plant growth and water consumption. Pallardy (1981) also reported that absolute maximum rooting depths or lateral spreads might still be greater in wetter systems because plants are often bigger there. For example, lateral root spreads and maximum rooting depths influence how many neighbours compete for resources and determine the potential pool of resources available to plants in an ecosystem (Caldwell & Richards, 1986 ; Caldwell et al., 1998; Fitter *et al.,* 1991; Canadell*et al.,* 1996; Casper and Jackson, 1997).

3.3 Growth performance of 6 month old vegetatively propagated plants at acclimatization stage

After the nursery stage, 6 month old vegetatively propagated plants of Sri Gemunu and Wijaya were removed from protected culture and then they were placed in an open area (under 50% of tree shed) to be completely acclimatized. Unlike protected culture, the environmental factors such as sunlight, wind velocity, solar radiation and temperature are directly affected to the of plant growth parameters in an unprotected culture (open

field). Environmental factors significantly affected the water loss from plants through transpiration from aerial parts of the plants, evaporation from upper part of the soil, plant surface and potting medium (evapotranspiration). Plants absorb more water to compensate the water loss through evapotranspiration and as a result water requirement was increased and it has caused significant performances due to those effects. The results of twenty- five weeks aged vegetative propagated Sri Wijaya and Gemunu plants on mean length of shoots, mean number of leaves and leaf circles, in each treatment are presented here.

3.3.1. Length of shoots

Effect of water requirement on mean length of shoot of vegetatively propagated Sri Wijaya and Sri Gemunu varieties in acclimatization stage is shown in Figure 6. Sri Wijaya has shown significantly highest shoot length (>35cm) at 200ml of water requirement and the second highest (30cm) was observed in 250ml water requirement treatment. However, the shoot length of Sri Wijaya at 200 ml and 250 ml water requirement treatments were not significantly different to each other. Sri Gemunu has shown second highest mean shoot length (33cm) at 200ml and 250 ml water requirement treatments. Sri Wijaya has shown the lowest shoot length (<20cm) at 100ml water supply treatment and it was not significantly different from the shoot lengths obtained in 150ml and 180ml water supply treatments. Sri Gemunu has shown the lowest shoot length (21cm) at 180ml water supply treatment and it was not significantly different from shoot lengths obtained in 100ml and 150ml water supply treatments. There was a significant difference at water requirements on Duncan's multiple range test at 0.05% level (Pr>Fwas<0.0001). According to the SAS analyze, there was no significant interaction between variety and water requirements on Duncan's multiple range test at 0.05% level (Pr>Fwas<0.0716).

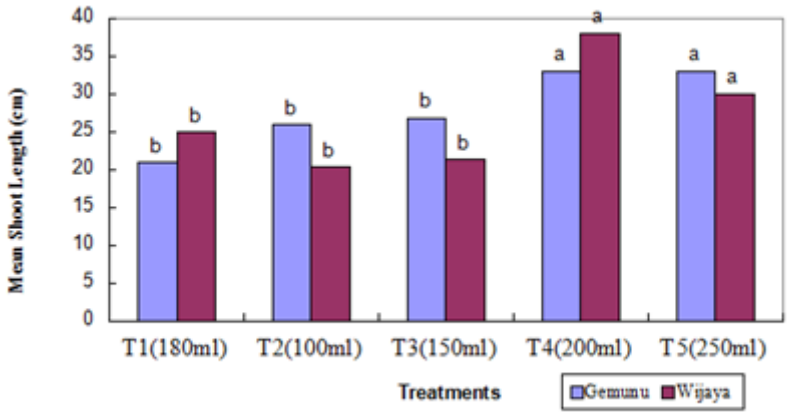

Figure 6: Effect of water requirement as 180ml (field capacity), 100ml, 150ml, 200ml and 250ml on mean length of shoots at acclimatization stage

3.3.2. Leaf circles

Effect of water requirement on mean number of leaf circles of vegetatively propagated Sri Wijaya and Sri Gemunu varieties in acclimatization stage is shown in Figure 7. Sri Wijaya has shown significantly highest number of leaf circles in (5) at 250ml water requirement treatment and it was not significantly different from the number of leaf circles in Sri

Wijaya at the 180ml and 200 ml water requirement treatments. Sri Wijaya has shown the lowest number of leaf circles (3) at 100ml and 150ml of water requirement treatments. However there is no significant different from the number of leaf circles observed in 100ml and 150ml water requirement treatments. Sri Gemunu has shown significantly highest number of leaf circles (<5) at 180ml water requirement treatment. However this treatment was not significantly different from the number of leaf circles in Sri Gemunu at the 200ml and 250 ml water requirement treatments.The lowest number of leaf circles in Sri Gemunu (<3) was observed at 100ml of water requirement treatment and this treatment was not significantly different from the number of leaf circles observed in Sri Gemunu at 150ml water requirement treatment.

The present study showed, water requirement has a significant effect on the leaf growth and then the number of leaf circles at acclimatization stage. When plants were at open field and the rate of photosynthesis, biochemical reactions and respiration were higher due to effect of environmental factors and these influence the absorption of more water through the root system. When the water requirement levels were lower than the field capacity level of water requirement (180ml) it has significantly affected the number of leaf circles. Hansen (2016) reported the similar observations to the present study that the lowest water regime was significantly affected plant eco-physiological responses, plant growth and water consumption.

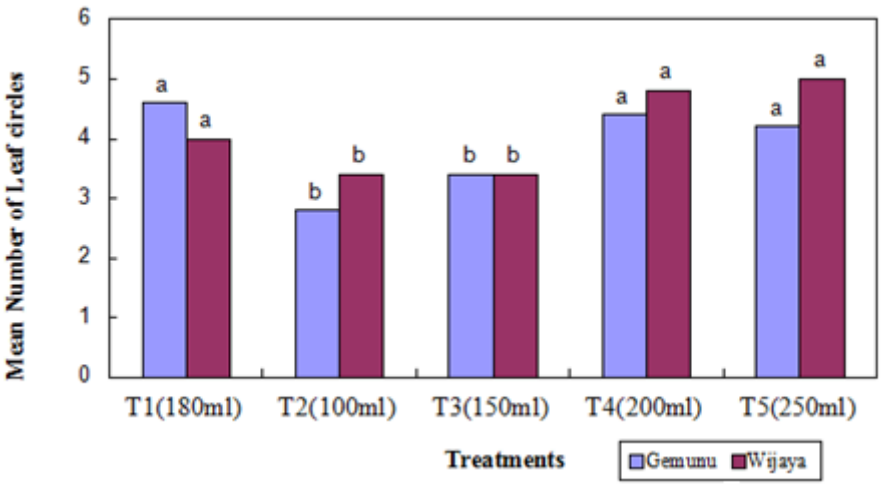

Figure 7. Effect of water supply as 180ml (field capacity), 100ml, 150ml, 200ml and 250ml of water on mean number of leaf circles.

3.4 Peelability of 5 years aged vegetative propagated plants of at maturity stage

3.4.1. Total peeling time

Effect of water requirement on total peeling time of 5 years old vegetatively propagated Sri Wijaya and Sri Gemunu varieties in maturity stage is shown in Figure 8. The total peeling time is consisted of scraping time, rubbing time, and peeling time. Sri Wijaya has shown significantly lowest peeling time (<12 minutes) at 20 liters of water requirement treatment and it was not significantly different from the peeling time of Sri Gemunu at 20

liters of water requirement. These treatments were significantly different from all the other water requirement treatments. The highest total peeling time was observed at no water treatment (control) of Sri Gemunu and it was approximately above 22 minutes. However, Sri Wijaya has taken highest time for peeling at control treatment and 10 liter water requirement treatment, but these treatments were not significantly different from each other. Further there is no significant different between varieties within the same water requirement treatment.

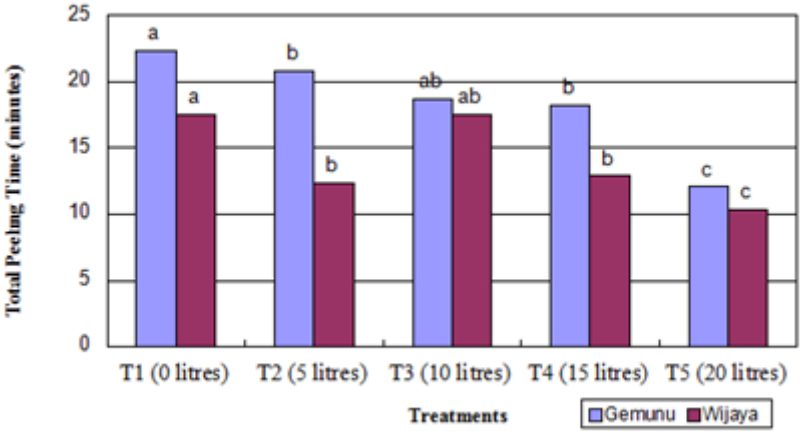

Figure 8: Effect of water requirement treatments: No irrigation, 5 liters, 10 liters, 15 liters and 20 liters on mean total time required for peeling of harvested stems of Sri Gemunu and Sri Wijaya at mature stage

Highest water requirement could have improved the water absorption by the plants and this could have loosened the tissues around the cambium. The scraps of the fresh stem were smooth and bark firmness was increased due to the applied water. Figure 9 shows the negative correlation between water requirement and total peeling time of stems. Accordingly, Sri Gemunu has shown highest R^2 (0.8692) in the regression plot and that showed that the peelability is better in Sri Gemunu than in Sri Wijaya.

3.4.2. Thickness of fresh barks

Effect of water requirement on thickness of fresh barks of 5 years old vegetatively propagated Sri Wijaya and Sri Gemunu varieties in maturity stage is shown in Figure 10. Sri Wijaya has shown significantly highest thickness of barks (>1.1mm) at 20 liter water requirement treatment and Sri Gemunu has shown significantly highest thickness of bark (1.1mm) at 15 liter water requirement treatment. However there was no significant difference between 15 liters and 20 liters of water requirement treatments but these treatments were significantly different from all the other water requirement treatments. Sri Wijaya has shown the lowest thickness of fresh bark (0.30 mm) in no water treatment and it was not significantly different from 5 liters and 10 liters of water supply. However there was no significant difference in cinnamon bark thickness between Sri Wijaya and Sri Gemunu in all water requirement treatments.

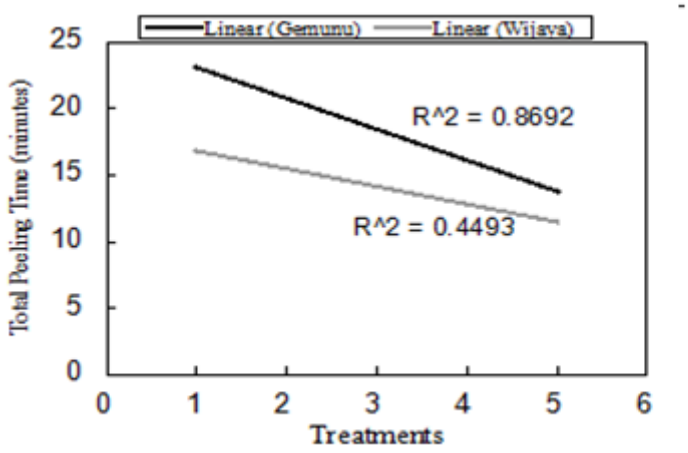

Figure 9. Regression analysis between total peeling time and water requirement treatments: no water, 5, 10, 15 and 20 liters on total peeling time of vegetatively propagated Sri Wijaya and Sri Gemunu

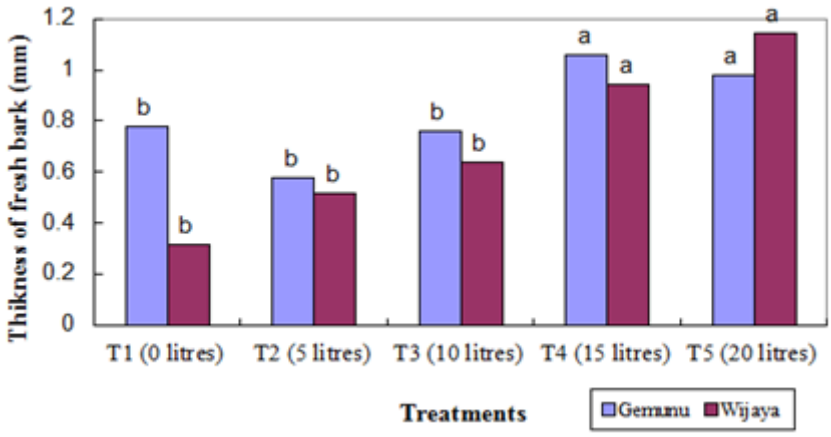

Figure 10.Effect of water requirement treatments as no water, 5, 10, 15 and 20 liters/plant on thickness of fresh bark of vegetatively propagated Sri Wijaya and Sri Gemunu cinnamon varieties

4 CONCLUSIONS

At nursery stage (10 weeks old) Sri Wijaya has shown higher shoot length at 250 ml water requirement and Sri Gemunu has shown higher performances on leaf area, fresh and dry weight of shoots and fresh weight of root at 250 ml water requirement. At acclimatization stage (6 months old) Sri Wijaya and Sri Gemunu have shown higher performances in length of shoots and number of leaf circles at 200ml and 250ml water requirement. During the maturity stage (5 years old) both Sr Gemunu and Sri Wijaya have shown lowest time for peeling at 15 liters and 20 liters/plant treatments. Further both Sri Wijaya and Sri Gemnu have shown highest thickness of fresh bark at 15 liters and 20 liter per plant treatments. Therefore the best water requirement for vegetatively propagated Sri Wijaya and Sri Gemunu at nursery stage and acclimatization stage is 200ml-250ml per plant. The best water requirement for Sri Wijaya and Sri Gemunu at mature stage is 15-20 liter per plant to achieve lowest peeling time and higher thickness of fresh bark.

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Improving the Customer Experience using a Fair Call Distribution Model

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Abstract – *Call centers are widely used to handle customer service, technical support or sales. Call center agents are on the front lines of customer service, entrusted with the demanding task of pleasing and appeasing customers. Customers may get frustrated when they keep on hold before making contact to a call agent. Therefore it is a crucial task to increase the customer experience with the limited resources available such as skilled call center agents, technology infrastructure etc. Currently, many measures have been taken by the call centers to avoid delays and to increase customer satisfaction. When increasing the customer experience, the productivity and efficiency play a key role for the growth of the businesses. This paper presents a novel call distribution model that the call management software developers can use in their solutions to address the challenges faced by existing call distribution software. A suitable forecasting model was identified to forecast an hourly average call waiting time of calls in all the implemented queues in a call center. The extracted data are transformed into an algorithm written in Python then fed into the Holts Winter algorithm's additive method. Then a solution was introduced to capture the unpredictable scenarios where forecasting of average call waiting time can differ from the predicted values. To guarantee the fair call consumption, an algorithm was introduced for the allocation of calls from different queues to a common pool. In addition to that, a regression analysis has been performed to find the factors of callers that affect the performance of call center agents.The histograms are drawn for the data before and after applying the model shows that the distribution has been changed from negative skewness to a positive skewness which concludes that the model has improved the call distribution. The Age and Gender of the callers have less impact on the agent's performance.*

***Keywords**: Customer experience, call center performance, fair call distribution model, Classification and regression trees*

1 INTRODUCTION

Customer service is a critical aspect of any business, but sometimes managing the phone calls can become a burden that undercuts daily operations. As a solution businesses take the call center service or maintain their own call centres. The following information was collected in the call arrival process after studying the call center operation in Sri Lanka.

Following mechanism explains how the basic call arrival and distribution happens in three banks and three sales and retail industry call centres in Sri Lanka. The names of the call centres will not be revealed.

If we consider the call arrival process, there are no regular arrivals, the time interval

between two successive arrivals is not a constant (probability distribution of time between successive arrivals). Instead they arrive at random times which can be considered as a Poisson stream of arrivals. In other words, there are two successive arrivals which are independent from each other and also exponentially distributed. The average arrival rate can be calculated later with this information and also by analyzing the data. Calls arrive as separate individual calls not in bulk or batches. The number of customers that call is finite. Service mechanism (Call handling mechanism) and implemented queue characteristics are such that, Agents are assigned with one or more skills, e.g. agent1 has Sinhala and English skills and agent2 has English and Tamil skills. Queues are named with respect to the skills of the agent, e.g. English queue and Sinhala queue.

The first call in the queue is served by the longest idle agent with the respective skill. If two agents have same idle time then the round robin algorithm is executed to select an agent. Pre-emption of calls is not allowed. They do not recommend disconnecting a customer call in order to answer another prioritized call. However, a call may get disconnected for many other reasons without completing the expected task. The service time/ call handling time is independent from other calls and do not depend upon the arrival process. Service times are exponentially distributed. All queues are merely FIFO queues.

Most of the existing approaches are coupled with distribution of calls by considering only the current calls in the queue and available agents. However, in this research past calling trends are determined by forecasting the queue length in the next hour to optimize the call distribution and also unpredictable situations are handled using an algorithm.

Another important aspect considered was to find the factors that affect the performance of a call center agent which expose a hidden side of data. Factors such as age, gender, geographical location of the caller and the job title are considered to have an effect on the call handling time of agents which indirectly effects their performance. However, with the sample dataset used for this research, only the gender and age are taken into consideration. Nevertheless, the same algorithm can be used with another dataset to make the output more meaningful by taking many factors into consideration. With the help of this algorithm, the call center supervisors can improve their decision-making process to improve the performance of agents.

This paper is organized as follows: Section 2 describes the Literature survey while Section 3 focus on the System design. Implementation is explained in Section 4 while Section 5 discuss the results. Finally Conclusion and Future work are given in Section 6.

2 LITERATURE SURVEY

Koole & Mandelbaum (2002) discuss about skill-based routing with on-line and off-line strategies. Online strategy determines an idling agent to attend a caller first, and for an arriving call, who will be the agent to cater. Offline strategy is the determination of overall number of agents required for company's permanent or temporary pool of agents; and out of these, how many and who should occupy a given shift. It does not involve any forecasting for average waiting time of calls for next hour. Moreover, no solution is taken to overcome unpredictable situations by taking average waiting time of recent past data.

Kyper, Douglas, and Blake (2012) propose an operational business intelligence system for call centers. They propose a decision tree-based solution to increase the service levels of call center agents. This approach enables the managers to identify the key factors and role

they play in determining service levels. Here they have analyzed the factors such as weekday, time, Number of calls (ACD calls), abandoned calls, average handling time (AHT), average speed of answer (ASA) and maximum delay. After the creation of decision tree by using Statistica's implementation of CART (Classification and regression trees) it is represented on a Correlation matrix to depict which variables have the greatest impacts on service levels. However, in this paper the customer attributes were not taken into consideration when finding the factors related to the service level or performance of agents.

In the paper of (Bogart, et al., 2001), they target to optimize the call-center performance by selecting the best call center agent to handle a particular call. The service matrices considered here are proficiency, profitability, customer satisfaction and agent satisfaction. When a call of a particular type becomes available, the agents with same types are considered and the agent with best score is selected to handle the call. After the call is disconnected the performance of that agent is recalculated. This revision process gives more weight to the valuations of more recently handled calls to reflect the performance of agent. In this research, the caller's demographical values are not taken into consideration.

Chishti & Spottiswoode (2014) estimated agent performance in a call center. After an agent makes few calls, performance characteristics such as customer satisfaction, duration of calls etc are assigned to the agent. Then the call distribution is done mainly based on this performance scores.

According to the research (Jack et al., 2006) there are four key resource management decisions that must be addressed in order to improve service quality and effectively manage call center operations: the efficient deployment and use of labour, effective leveraging of technology, capacity management, and demand management. Therefore, this research proposes a model that addresses these four key resource management decisions.

The aim of this research is to introduce an effective, efficient and fair call distribution model for a call center and to find the factors that affect the performance of a call center agent. The model could be used in optimizing the fair call distribution and hence to increase the performance of the call center agents. Similarly, our proposed research tries to identify the characteristics of customers that affect call center performance.

3 SYSTEM DESIGN

This section consists with the block diagram of the overall design of the system, the flow charts and the explanation of the design. Fig. 1 shows the overall design of the Fair call distribution model. The model is composed with two key components, namely Fair call distribution model and a module to find the factors affect the performance of call center agents. Both of these components pave the way to increase the performance of a call center.

The distribution model distributes the calls to available agents efficiently while finding the customer attributes which effect the performance of the call center agents. Then the call center supervisors can take accurate decisions on deploying agents accordingly. The two components are explained in detail.

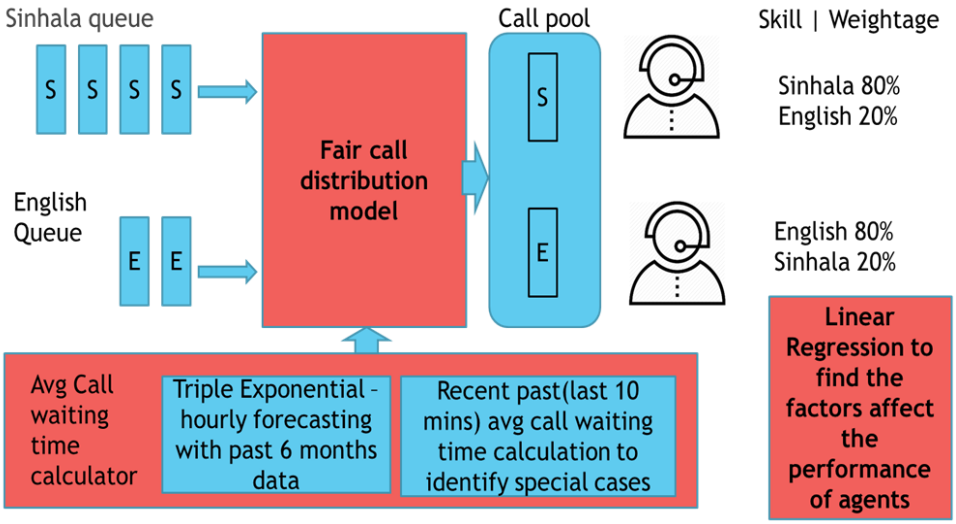

Fig. 1. Overall Design of the Fair-Call Distribution Model

3.1 Fair call distribution model

If we consider the arrival of calls through an Interactive Voice Response (IVR) in a call centre there exist many queues based on the language preference of the users or the skill requirement to respond the call. The nature of the queue varies based on the business requirements. If we focus on the users from Sri Lanka, these queues could be Sinhala, English and Tamil. But these queued calls should be routed to the agents based on the following concerns and scenarios.

- Availability of multi skilled agents (eg: Sinhala - Marketing, English - Marketing, Tamil- Credit cards etc.).
- Call maximum waiting time in the queue should be the main consideration.

In addition to above scenarios the following are to be considered in order to achieve an accurate model.

- Hourly forecasting to be done based on past few months data to predict the average waiting time of calls for next hour. By doing this the patterns also can be identified, e.g. peak hours etc.
- Estimation of the average waiting time based on recent past data (10 mins) after a call is cleared (answered) from the call queue. By doing this, any sudden change that happens due to unpredictable factors could be addressed, e.g. sudden issue in ATMs etc.

Based on both results, the best average waiting time to be considered and consume the queue accordingly to improve the productivity of the call center. As it was explained under the Introduction, existing mechanism of call distribution has several issues; for an example if Sinhala queue has 15 calls and English has 5 calls and if the available agents have both the skills then although the Sinhala queue with more calls should be consumed more, same call consumption weightage is given to both the queues. This leads to a higher dropped call percentage in the Sinhala queue due to the long waiting time in the queue. Hence the performance is degraded.

3.2 Linear regression to find the factors affects the performance of call center agents

This module outputs how accurately the customer attributes such as age and gender (independent variables) affect the performance (dependent variable) of agents. For example, when age increases call handling time of agents may increase but there can be no effect from the gender of the caller. With these results it helps the supervisor of the call center to train the agents accordingly to handle the customers with identified attributes. The system design is illustrated in Fig.2.

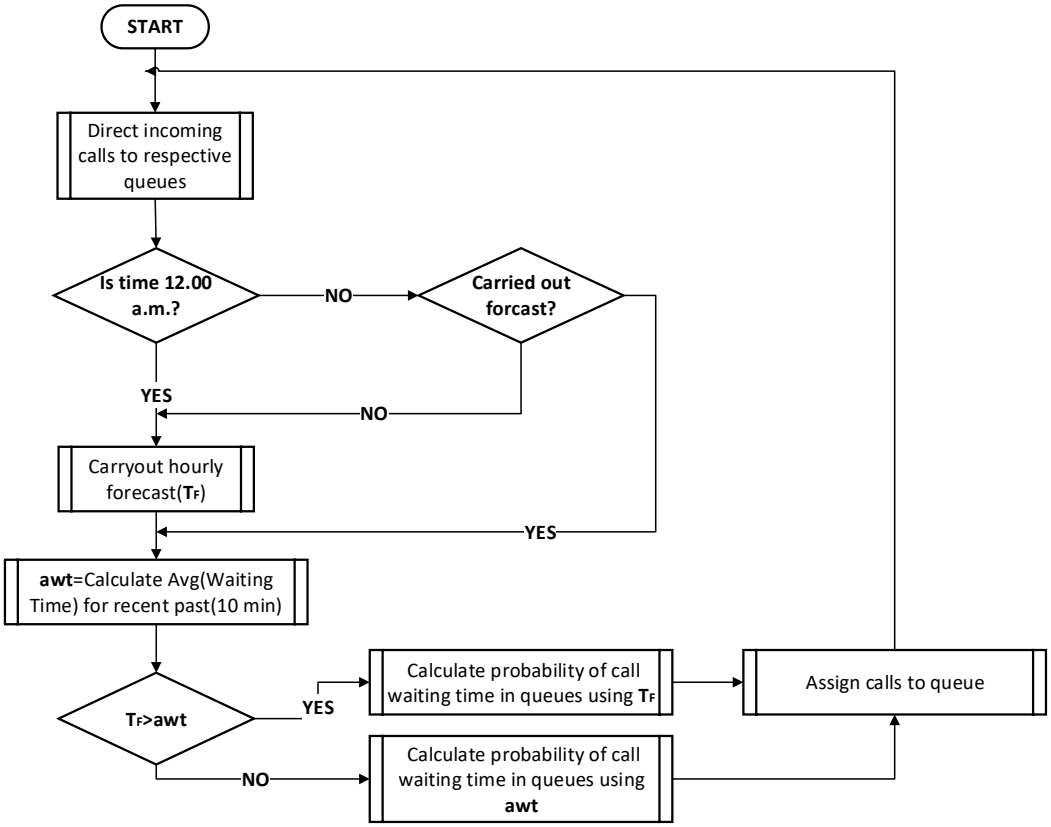

Fig. 2. Overall Flowchart

When calls hit the Interactive voice response (IVR) the user is asked to press a number to select a language. This differs from company to company and whenever they select the respective queue, the calls will be added to the queue. To initiate this process every day at midnight the forecasting process happens. In brief, the average call waiting time, number of calls and call duration are forecasted from the last 6 months data. Next major step is to carry out the calculation of average waiting time from recent past data. This will be run every 10 minutes and the calculation is done from the past 10mins data only. If the forecasted average waiting time is greater than the past 10mins average call waiting time the forecasted value is selected and vice versa. This is to treat the worst case scenario.

After implementing the necessary algorithms which are illustrated and explained in detail later in this section, the calls are allocated to a common pool where the agents

consume from it according to the skills they possess. 'Carryout hourly forecast' subroutine is further elaborated in Fig. 3. Forecasted values for Average call waiting time (TF), Average call duration (CD) and the No of calls (NC) for next 24 hours are the outputs from the sub routine.

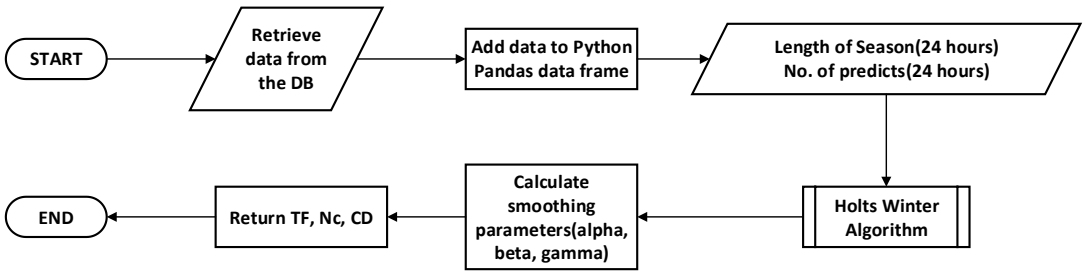

Fig. 3- Hourly forecast of Average Call Waiting time(T_F), Average call duration(CD) and No. of calls(N_C)

The following three queries are used to query the Postgres Database and to retrieve data from the database (DB). To retrieve average waiting time, the data table is grouped by date and the by hour. The date and time field are stored as a string. Hence it is casted to a text and then to interval format. Then the epoch is extracted from it and calculated the average of it. Here queue time is used to calculate the average waiting time of each of all the available dates in the given data set.

```
SELECT
AVG(EXTRACT(epoch FROM queuetime::text::interval)) AS value,
EXTRACT(hour FROM starttime::timestamp ) AS hr,
CAST(starttime::DATE AS text) AS dates
FROM public.call_cdrdetail
GROUP BY
dates, hr
```

Similarly, call duration, the queue time, ring time, hold time and talk time is summed to get the hourly called duration. For hourly calls, a count of all the calls is taken by grouping with date and hour.

The extracted data are transformed into Python pandas data frame. Then the data frame is fed into the Holts winter algorithm's additive method. Additionally, length of the season is input as 24 (see below for explanation). Number of hours to predict is input as 24 hours so that when the system is run at midnight the hourly forecasted values are generated for the whole day. This makes the system faster. If this is to be done at every hour it will take a long time for the calculation hence slow down the system.

The smoothing parameters namely alpha, beta and gamma needed for the Holts winter algorithm for fitting process is calculated by the Python SciPy library. This module finally returns the hourly forecast of average waiting time, call duration, no of calls and it is stored in the memory for later processors. The following graph generated from the data (Fig. 4. & Fig. 5.) shows how average waiting time changes hourly.

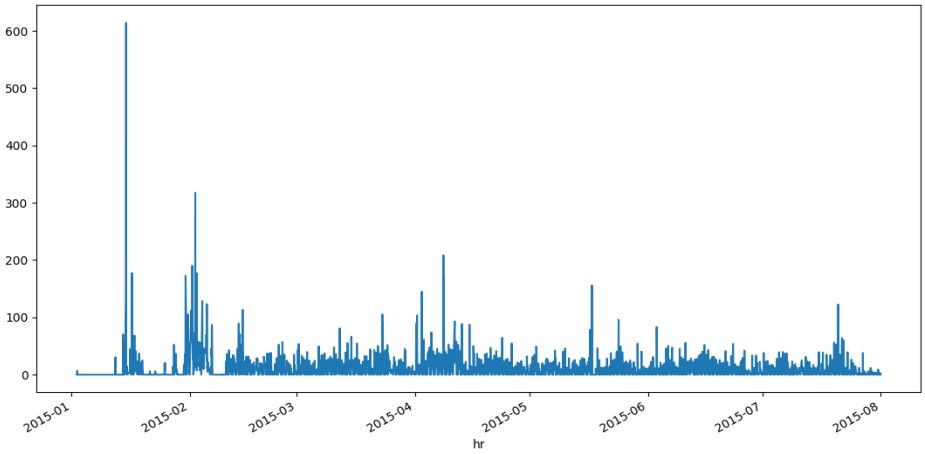

Fig. 4. Hourly average waiting time for 6 months

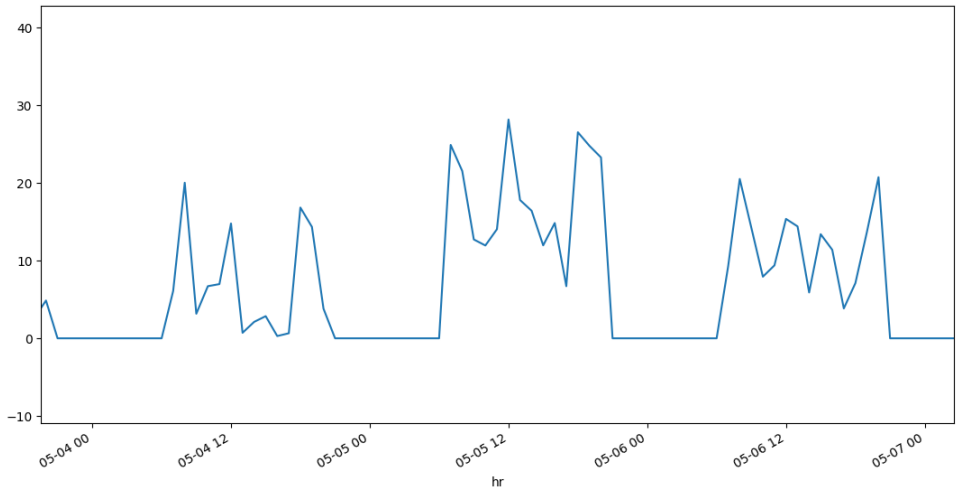

Fig. 5. Hourly average waiting time for 3 days

From the above graph we can see seasonality in the hours of the days which we observe in the 24 hours. Additionally, the peaks in the diagram show the additive nature of the data set. This describes how the 4 components Trend, Seasonality, Cyclic effect and Outlier together form the time series. In this case we can roughly see the same size peaks throughout the time series. Since we can observe seasonality and we need to give more weight to the recent past data, Triple Exponential Smoothing (Holt's winter) method is used for forecasting. The predefined subroutine, average call waiting time of recent past in the main flow chart is illustrated in Fig.6. below.

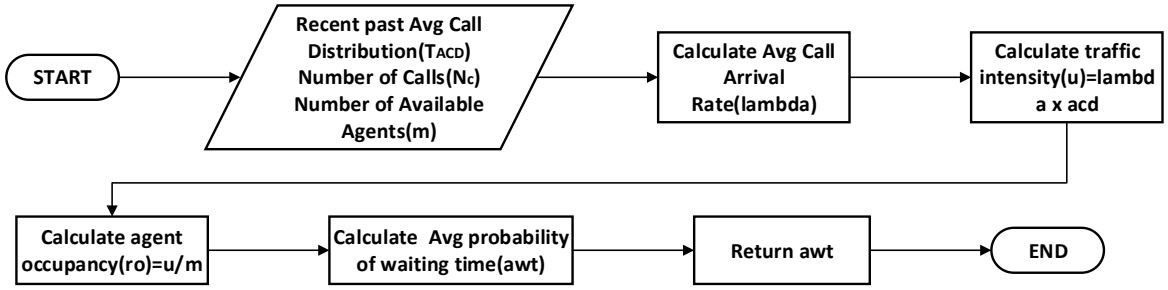

Fig. 6. Calculate Average Waiting Time (awt) for Recent past

Here firstly the recent past average call duration(TACD), no of calls(Nc), number of available agents(m) are taken as inputs to the module, and from those the following calculations are derived. The first parameter needed is the average customer arrival rate. It does not matter what time the unit is used to specify the arrival rate, if the same time unit is used for the average call duration. Also, the results we shall get for waiting time will be in these time units. Average call arrival rate (lambda) is calculated in seconds for this scenario (no of calls per second). Then it is needed to calculate the traffic intensity as a preliminary step to the rest of the calculations.

Traffic intensity(u) = lambda x Tacd.

The volume of calls is described as the traffic here. Next step is to calculate the agent occupancy. The agent occupancy, or utilization, is now calculated by dividing the traffic intensity (u) by the number of agents (m). The agent occupancy will be between 0 and 1. If it is not less than 1 then the agents are overloaded, and the Erlang-C calculations are not meaningful, and may give negative waiting times.
Then the Erlang-C formula is calculated from the above values,

$$E_c(m,u) = \frac{\frac{u^m}{m!}}{\frac{u^m}{m!}+(1-\rho)\sum_{k=0}^{m-1}\frac{u^k}{k!}} \tag{1}$$

The above equation gives the Probability a call has to wait in the queue. In other words it is the probability that a call is not answered immediately. The value is stored and proceeds further to calculate the average waiting time for a call from the same values calculated above.

$$awt = \frac{E_c(m,u)\,.acd}{m(1-\rho)} \tag{2}$$

The awt is passed to the main module in order to compare it with the forecasted average waiting time. The next predefined subroutine is to allocate the calls based on an algorithm which is illustrated as Fig.7.

When the probability of waiting of a call is calculated the next step is to allocate the calls to a common pool. So according to the percentage a certain amount of calls are allocated from all the queues to the pool. The percentages are user customizable; if they want to release 8 calls to pool if the percentage of probability of waiting is 80% they can do so. In this case the number of calls for more than 80%, in between 80% to 60%, 60% to 40%, 40% to 20% and less than 20% is 8, 6, 4, 2 and 1 respectively. By doing this, if the probability of waiting of English queue is 80% then 8 calls are released to the queue where as if probability of waiting of the Sinhala queue is less than 20% only one call is released to the common pool. Hence the queue which has the highest probability of waiting is consumed more quickly than the one with less probability of waiting. This provides a fair call distribution among all the queues.

This process runs continuously and allocate if the call pool is not full. And also the size of the call pool can be configured as the call center wants. But it is recommended not to increase the size to a very large value which eventually allocates all the calls in the queues to the pool. Hence it might lose the purpose of having a common call pool.

4 IMPLEMENTATION

The implementation of the research is three-fold. The first part of the implementation is the python module which generates the calls automatically. The second part is the Call Distribution Model Executor which executes the implementation of the algorithms given as Fig. 5. and Fig.6., which forecasts the values for Average call waiting time forecasted (T_F), Average call duration (CD) and the No of calls (N_C) for next 24 hours and calculate average call waiting time of recent past respectively. The third part is the simulator which simulates the process of adding call agents to the system and answering the phone calls.

4.1 Automatic call generation

This module generates a random number of calls which is in the range of the selected data set. For example, if the average number of calls per second is 2 in the dataset, then this module generates random calls in the range of 1-3 calls per second. The UUID library is used to generate a unique call id for each call. These randomly generated calls are randomly assigned to three queues namely Sinhala, English and Tamil which creates an equivalent call center queuing scenario. This process runs in a separate thread. The database used for queuing is Rabbitmq. Fig.8. shows the generated calls for English queue by the simulator. This has published 0.2 calls per second to this queue.

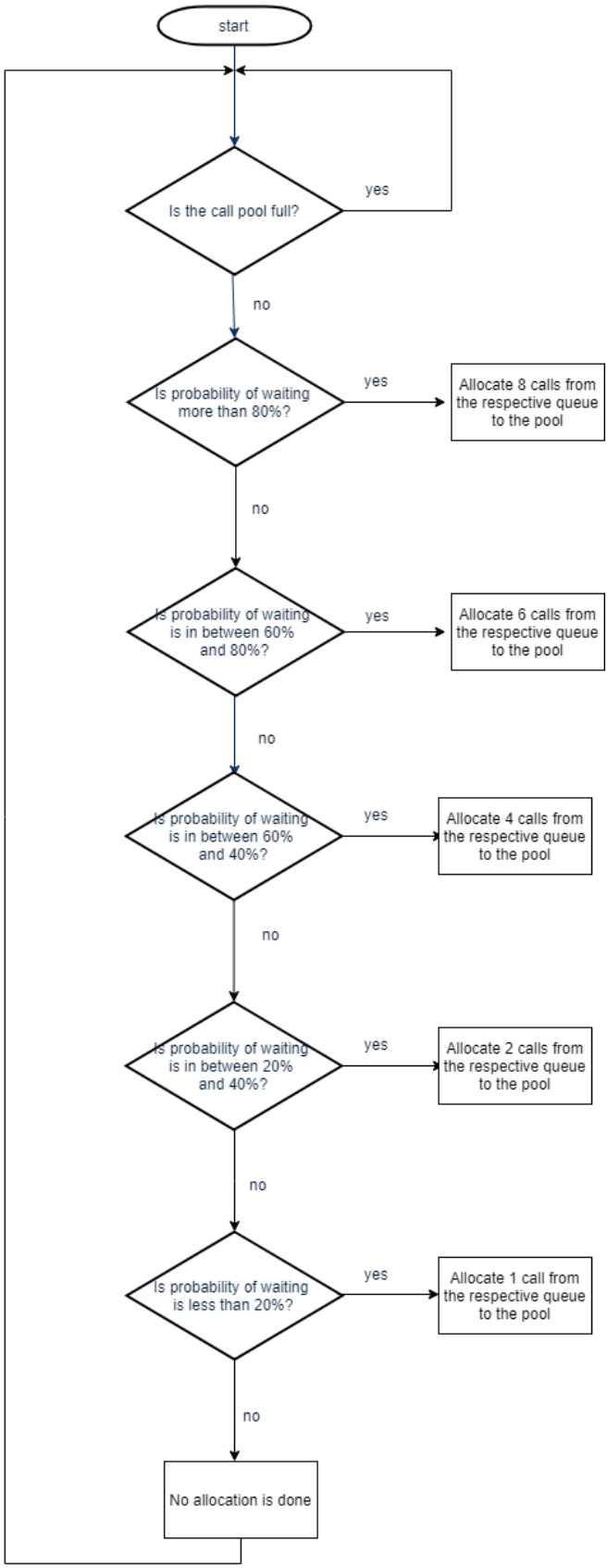

Fig.7. Call allocation

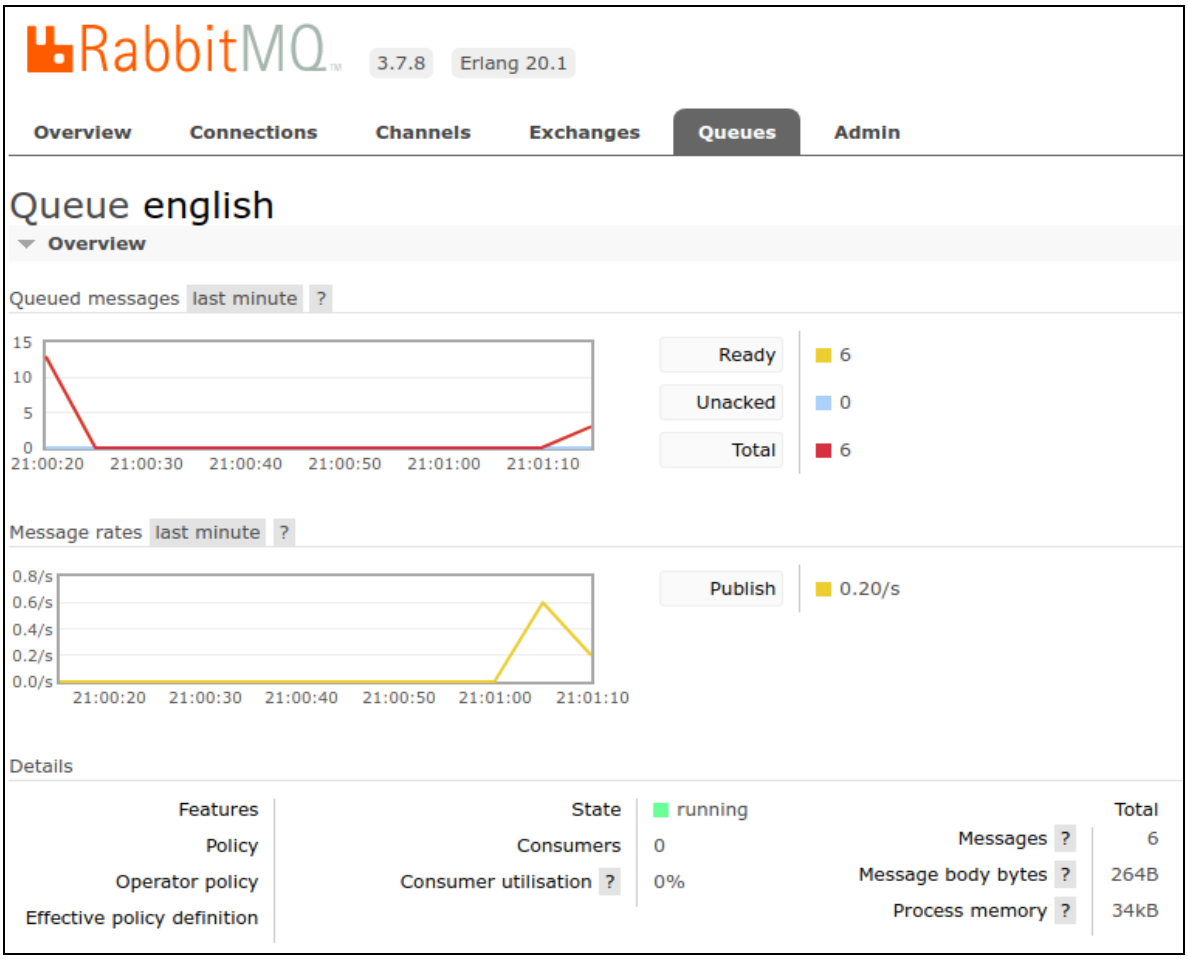

Fig. 8. Queue with generated calls on RabbitMQ

4.2 Call distribution model executor

Main two tasks of this module are to execute forecast module and obtain the result, and calculate the recent past average call waiting time. This module also allocates the calls to the pool continuously if the pool is not filled completely. Fig.9. shows the calls being added to the pool by the system. The content of the pool and the unique id of the call are printed in the console.

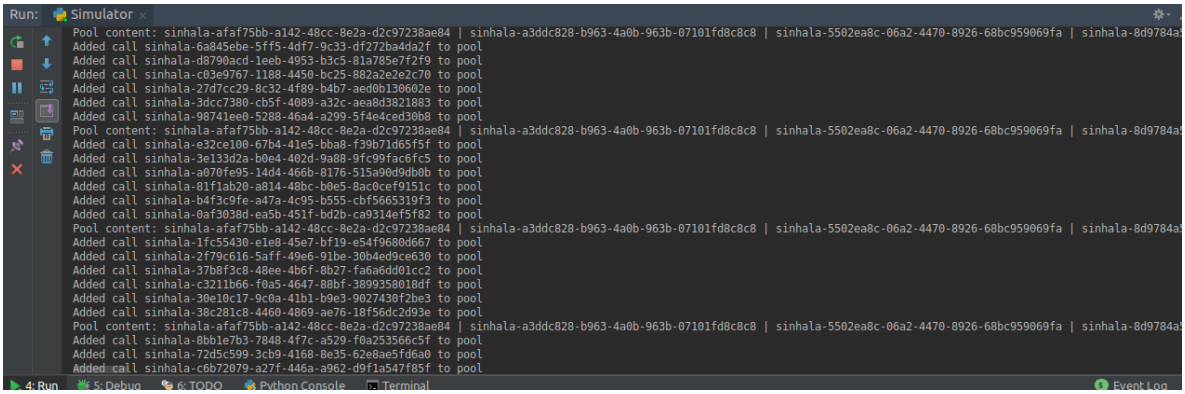

Fig.9. Console printed with Call pool content and adding calls to pool

4.3 Agent simulator

This module acts as the call consumer, in other words, the call center agents that answer the calls from the pool. This is a separate process which populates fixed number of agents with different skills assigned to them and maintains their states either busy or idle. In this module the idle agents are continuously checked from the common call pool. Here the longest waiting time of the calls are considered in the queue. Additionally when the call is assigned to an agent it changes the state of the agent to busy. After a random amount of time the agent will be set to idle which makes him or her eligible to get another call in the pool if available. The agent skill mapping is kept in a configuration file and read when assigning calls to them.

The developed simulator and the model is hosted in Github as an open source module so that anyone can clone it and use the model as they wish. The inputs to the model need to be provided as commented on the code and the result will be output as per the code documentation.

5 RESULTS

The triple exponential smoothing is applied on the data set and the forecasted results shown in Table 1 were obtained for 23 hours. After the simulation is done the produced data was analysed. Generally a distribution is said to be skewed when the data points cluster more towards one side of the scale than the other. Two histograms were plotted for Avg. waiting time of calls based on the data without applying the model and after applying the model using the library matplotlib of Python on the data set that resides on PostgreSQL database.

Table 1 Forecasted VALUEs

hour	Average waiting time (s)	Hourly call duration (s)	Hourly number of calls (s)
1	37.38622872	23.2581623	65.37746255
2	32.56356598	19.44916123	65.59549346
3	28.03944731	14.45124874	53.44429661
4	29.25202378	12.56638919	51.93914562
5	30.6029016	77.5729184	63.50875526
6	31.1682098	82.92883046	58.91373504
7	31.30256876	128.0418687	86.04626242
8	38.14160511	97.14657546	53.84483597
9	31.37589741	91.54853043	45.74589742
10	35.15192562	109.8908125	27.07844803
11	33.45972967	119.3882491	39.31147433
12	29.64324847	107.7967737	47.1378073
13	29.80444981	126.8065349	74.39456476
14	34.43415893	96.31180268	65.82200563
15	29.34250948	101.4789155	58.047216
16	29.02997513	94.23250772	49.42606323
17	32.37987017	76.47119423	54.82979939
18	31.55174534	82.50261882	60.75318754
19	33.28120974	29.06742184	59.44293341
20	38.08821864	32.75691207	58.1304044
21	30.3535002	27.92847535	67.27790114
22	27.24552455	93.18462166	61.21933822
23	34.6509044	111.8813531	72.71916061

The mode, median and mean was calculated by the following code where df variable is the pandas data frame that holds the data.

The histogram in Fig.10. shows how the call waiting time has been distributed before the model has been introduced.

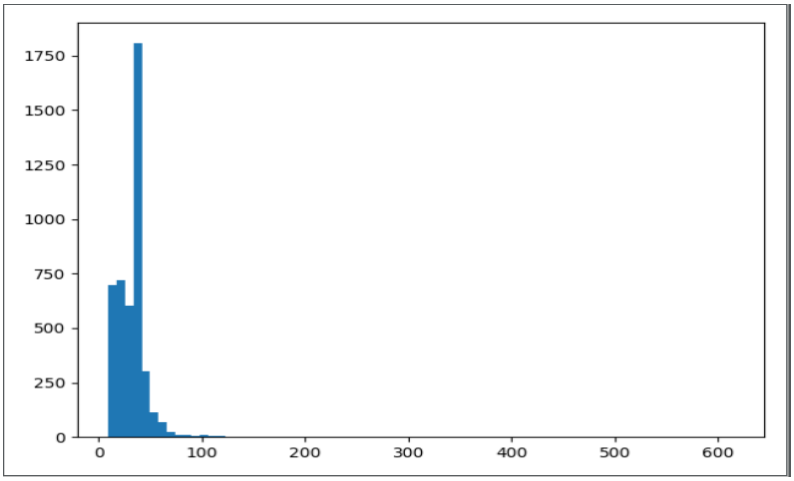

Fig.10. Histogram call waiting time without mode

The values are:

Mean	32.374
Median	34.342
Mode	35.246

So from the above values, Mode > Median > Mean

Therefore it can be concluded that the distribution is negatively skewed before applying the developed call distribution model. The following figure shows the histogram generated after applying the model.

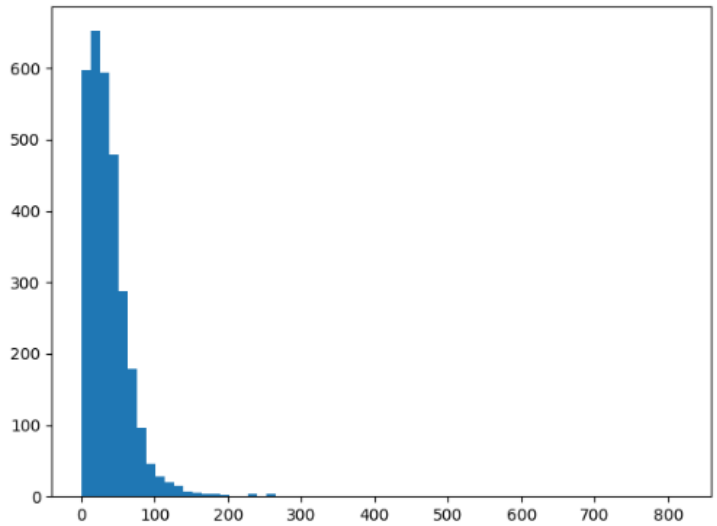

Fig.11. Histogram call waiting time with model

The values are:

Mean	37.594
Median	30.836
Mode	21.246

So from the above values, Mean > Median > Mode

Therefore, it can be considered as a positively skewed distribution after applying the developed call distribution model. Further, it is certain that the model has improved the existing call distribution. Comparison of call average time before and after applying the model

Table 2 Comparison of average waiting time

Date	hour	Previous average waiting time	current avg waiting time
2/14/2015	17	57.5032449	47.78991837
2/14/2015	18	64.9465102	54.25361224
2/14/2015	19	54.173	33.17222222
2/14/2015	20	41.19930769	23.29853846
2/14/2015	21	127.3001111	113.274555
2/14/2015	22	40.662	57.49266667
2/14/2015	4	70.522	70.522
2/14/2015	5	15.5688	11.4233999

The simulator UI result is added in Fig.12. to show how the comparison before and after model is applied. Here the call generation per minute can be changed and observe the output.

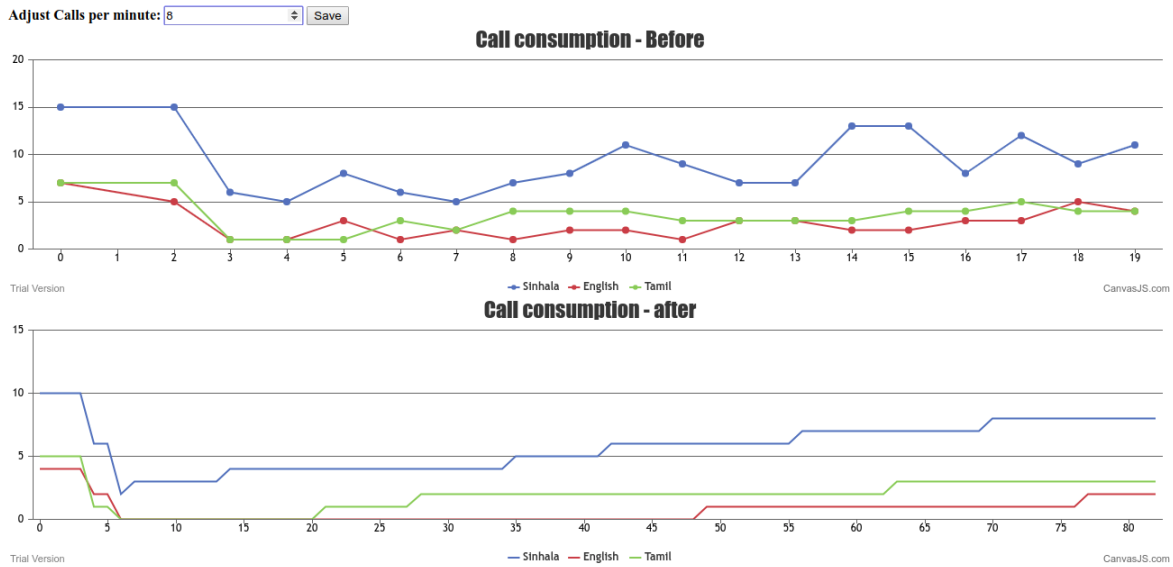

Fig. 12. Call Consumption Comparison

The remaining part of the research was to identify the factors of the call that affect the performance of call center agents. An SQL query was used to retrieve data by handling data issues. By running the algorithm written using the Linear Regression algorithm the following results were obtained.

```
{'variables': [u'hr', u'gender', u'skill', u'age', u'month']
'equation': 'talk_time=176.24 - 4.2099*hr - 0.8173*gender +
14.9396*skill + 0.4202*age - 0.5794*month',
'removed_var': []}
```

According to the above result, gender and age of callers, month year and hour the customers have called the call center, the language they have talked with the agents are given as inputs. The linear equation obtained from the module is,

*talk_time=176.24 - 4.2099*hr - 0.8173*gender + 14.9396*skill + 0.4202*age - 0.5794*month*

Talk time or the call handling time is taken as the 'y' variable and other variables are in the equation with the calculated co efficient for each variable. The coefficients depict the weight of each variable to the waiting time of a call. The sign of the variable says how y behaves when the respective variable changes. For example, when age of a caller increases by 0.4202 units, the waiting time of the call has a tendency to increase. Therefore from the above data it can be concluded that age and gender has an effect on the call waiting time.

6 CONCLUSION

Unpredictable situations and the normal behaviour or the seasonal trend of call arrival can be captured and used to optimize the performance of the call queues and hence the customer experience. It is certain from this analysis that if all the calls in different queues are treated equally at all the situations the performance cannot be increased. Hence by considering the unpredictable situations and taking the last few months' call waiting trends into consideration the call allocation can be highly optimized. This is tested for a constant number of agents. This can be further improved by testing the algorithm for different number of agents, i.e. Decreasing the call center agents for different numbers of calls in the queues etc.

The age and gender influence the call handling time of agents which indirectly affects their performance. However, with the sample dataset that is used for this research, only the gender and age are taken into consideration. Nevertheless, the same algorithm can be used with another dataset to make the output more meaningful by taking many factors into consideration such as geographical location of the caller, the job title, etc. These results could be used to identify the necessary training should be given for call center agents. For example, if age has a higher tendency to make the call center performance low then agents can be trained in order to handle elder callers more effectively.

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