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TIME SCALE VARIATION OF SOME SELECTED GENERAL WATER QUALITY PARAMETERS OF BATTICALOA LAGOON, SRI LANKA

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ABSTRACT

The present study was conducted to find out the time scale variation of some water quality parameters of the Batticaloa Lagoon in Sri Lanka from January 2019 to April 2019. Ten sampling locations in the middle part of the lagoon were selected. Nowadays the quality of lagoon water is reducing due to natural and anthropogenic activities such as flooding, dumping garbage at coastal area, draining the household outlets towards the lagoon, washing animals such as cattle and buffaloes near the coastal area, washing fishing equipment inside the lagoon and releasing chemicals from farm land and due to natural disasters. However, no information is available on time scale variation of physico-chemical parameters in the lagoon water throughout the day. Therefore, characterizing spatial and temporal dynamics of water quality in terms of physico-chemical parameters of the lagoon is an important finding to formulate the management plan against its effect on dependent economic activities for instance, fishing, tourism, irrigation and aquaculture industry such as prawn farming and crab culture. The water quality parameters were analysed within a day at different time intervals to identify the relationship between the temperature and other water quality parameters in the study area. Water quality parameters such as temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), pH, Dissolved Oxygen (DO) and Turbidity were measured at 15-30 cm below the water surface from different locations of the lagoon from morning 6.00 am to evening 6.00 pm daily. High values of EC and TDS were recorded in the lagoon water near the bar mouth. The temperature of the water depends on atmospheric temperature by the time at which the sample was taken. The temperature of the lagoon in some areas may also depend on atmospheric temperature, external surrounding factors such as concrete pavement and discharges from surroundings etc. There was no significant variation of EC, TDS and turbidity observed with time during the day. As far as the pH is concerned, the sampling locations, far away from the bar mouth area showed comparatively low pH values. Further, the findings of this study will be considered as baseline information about the time scale variation of water quality and essential tool for future researchers in the Batticaloa lagoon management.

KEYWORDS: *Batticaloa lagoon, Electrical conductivity, Temperature, Turbidity*

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1. INTRODUCTION

Deterioration of water quality is a common phenomenon in many aquatic systems such as lagoons, lakes and rivers etc. These water bodies suffer from anthropogenic activities from the surroundings and the impacts would be further aggravated by the effects of climate change events such as extreme floods & droughts, sea-level rise and subsequent seawater intrusions. Reduction of water quality of the lagoon due to anthropogenic activities is one of the most pressing threat to estuaries causing diminishing water quality as a consequence of urban growth and land use that increase the impervious surface area and non-point source runoff of nutrients and remains (Choi and Blood, 1999).

Batticaloa lagoon is one of the estuarine lagoons situated on the East Coast of Sri Lanka. It is the largest coastal water body in the District and occupies an area of 168 km^2 (Green Tech Consultants, 2009). This lagoon has been subjected to increasing anthropogenic pressure (Sugirtharan *et al*., 2013) and frequent flood owing to the growing population, agricultural and industrial wastes that are discharged directly into the lagoon.

The physicochemical parameters such as temperature, pH, DO, turbidity and salinity are the most important parameters which influence biochemical reactions within the lagoon and are used for testing the water quality of an aquatic ecosystem. According to FAO (1998), the water quality of the water resources may vary throughout the day mostly as a result of photosynthesis, and throughout the night due to respiration. Such changes in the concentration of these parameters are indicative of changes in the condition of the water system (Aknaf *et al*., 2017). There are several studies on the water quality of Batticaloa lagoon that were conducted in the recent past. However, there is no information available to find out the time scale variation throughout the day. Therefore, characterizing spatial and temporal dynamics of Physico-chemical parameters of the Lagoon over a long period is an important step to formulate the management plan against its effect on dependent economic activities such as fishing, tourism, and irrigation and aquaculture industry like prawn farming and crab culture (Sugirtharan *et al.*, 2017). Temporal and spatial complexities of the lagoon mouth also affect the transportation and mixing of saline water and intrusion into the lagoon (Banerjee and Srivastava, 2009). By considering this, the present study was conducted to find the time scale variation of water quality of Batticaloa lagoon as an important step to prepare the management plan for this lagoon.

2. METHODOLOGY

The study area

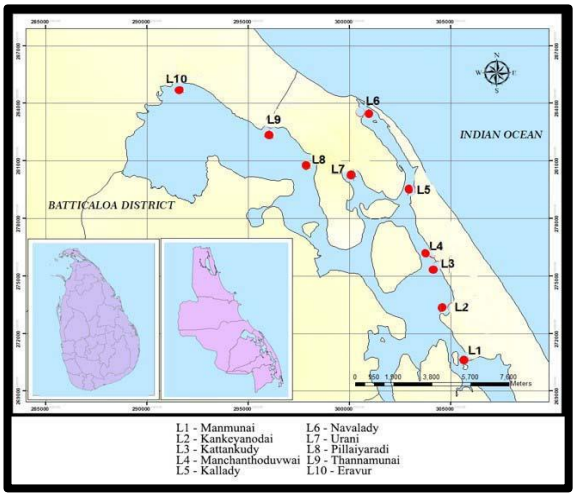

Figure 1: Location of the Study Area.

Batticaloa lagoon located between 7° 24' - 7° 46'N, and 81° 35' - 81° 49'E, is one of the most productive brackish water bodies in Sri Lanka. More than 90% of the lagoon is located in Batticaloa District and the rest lies in Ampara district. Batticaloa lagoon is 56 km long (Shanmugaratnam, 1995) and extends from Kittangi/Kalmunai in Ampara District in the south to Pankudaweli in Batticaloa district in the north. Lagoon area receives about 1000- 1700 mm of rainfall per annum, primarily (about 60%) from the Northeast monsoon (NEM) during October to February. It has a dry spell of five months from May to September. Winds are generally moderate, ranging

Table 1: Time scale variation of water quality parameters of Batticaloa lagoon.

Time	Mean temperature °C	TDS ppt	EC mS/cm	pH	Turbidity FTU	DO Mg/l	Salinity Ppm
6.00am	27.8^{h}	2.87^{a}	5.51^{a}	7.55^{c}	12.91^{a}	16.01^{a}	14^{a}
7.00am	28.6^{h}	2.95^{a}	5.69^{a}	7.67^{bc}	13.45^{a}	15.47^{a}	14^{a}
8.00am	29.7^{g}	2.91^{a}	5.59^{a}	7.77^{abc}	12.35^{a}	15.80^{a}	14^{a}
9.00am	31.1^{ef}	2.86^{a}	5.53^{a}	7.80^{abc}	16.43^{a}	15.80^{a}	14^{a}
10.00am	32.5^{d}	2.91^{a}	5.60^{a}	7.91^{abc}	16.27^{a}	16.23^{a}	13^{a}
11.00am	33.6^{bc}	2.94^{a}	5.70^{a}	7.93^{abc}	16.08^{a}	15.78^{a}	13^{a}
12.00pm	34.6^{a}	2.84^{a}	5.43^{a}	8.09^{abc}	14.12^{a}	16.10^{a}	13^{a}
1.00pm	33.9^{ab}	2.83^{a}	5.44^{a}	8.19^{ab}	15.88^{a}	17.74^{a}	13^{a}
2.00pm	34.2^{ab}	2.99^{a}	5.79^{a}	8.23^{ab}	18.37^{a}	16.50^{a}	13^{a}
3.00pm	32.8^{cd}	3.03^{a}	5.81^{a}	8.25^{a}	17.09^{a}	15.68^{a}	13^{a}
4.00pm	32.5^{d}	3.04^{a}	5.83^{a}	8.22^{ab}	16.99^{a}	17.28^{a}	14^{a}
5.00pm	31.9^{ed}	3.09^{a}	5.90^{a}	8.22^{ab}	14.70^{a}	16.55^{a}	14^{a}
6.00pm	30.9^{f}	3.06^{a}	5.90^{a}	8.17^{ab}	15.65^{a}	16.93^{a}	14^{a}

from 7–15 km per hour with the stronger evening winds.

The mainland use around the lagoon is agriculture particularly paddy cultivation. Other land uses include urban areas, road networks, and freshwater bodies adjoining the Batticaloa lagoon, the Batticaloa Lagoon itself and associated vegetation such as mangrove. The maximum depth of the lagoon is about 4 meters (Scot, 1989) and the average water depth is around 1.5 m (MG Consultants, 2010).

Sampling locations

Ten (10) locations such as Manmunai (L1), Kankeyanodai (L2), Kattankudy (L3), Manchanthoduwai (L4), Kallady(5), Palameenmadu (L6), Urani (L7), Pillaiyarady (L8), Thannamunai (L9) and Eravur (L10) in the Batticaloa lagoon area were identified in the present study to collect water samples for the analysis during the period from January to March 2019 (Figure 1).

The main reason for selecting those ten locations was to get linear distance from bar mouth in North and South direction of the lagoon to understand the variation in the water quality with the distance.

Surface water samples (15-30 cm depth at all the sampling points) were collected from 6.00 am to 6.00 pm at one-hour time interval within the day. This procedure was repeated three times at each location during 10 days' interval.

At every sampling location, sampling was done in different time intervals. The reason for sampling during the day time is due to the change of the direction of wind breeze that might cause the temperature difference between the land and water. It frequently happens during the day time as the influence of solar heat.

Sample analysis

In-situ field measurements were taken for pH, EC and TDS using portable digital pH/EC/TDS meter (model: HI 98130) and DO using portable digital DO meter (HANNA-Model HI 8043 model) and turbidity by portable digital turbidity meter (HI 93703).

Flow Direction and flow velocity of lagoon water were determined by float method. Finally, measured data were analyzed using MS Excel and SPSS software (version 22).

3. RESULTS AND DISCUSSION

Temperature

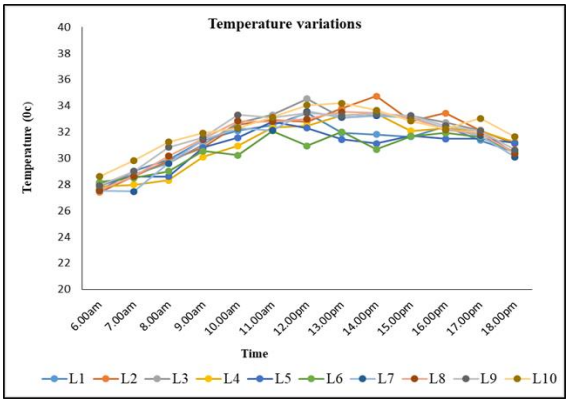

Figure 2: Time scale variation of temperature of Batticaloa lagoon at different locations.

Table 1 and Figure 2 shows the temperature variation within the lagoon during the experimental period. Water temperature is the most important water quality parameter in the aquatic environment. It affects metabolic activities, growth, feeding, reproduction, distribution and migratory behaviors of aquatic organisms (Sugirtharan *et al*., 2015)

The results revealed that the mean temperature of the Batticaloa lagoon ranged from 27.4°C to 33.9 C^0 and the lagoon water temperature were within the acceptable range for the aquatic species (15^0C to 40^0C)**.** The minimum temperature was recorded during the early morning and the maximum temperature was recorded in Eravur at 2.00 pm.

The temperature gradually increased with time and reached the peak in the late afternoon (1.00 pm), then gradually decreased with time. Sugirtharan *et al*. (2017) revealed that, mean temperature of the Batticaloa lagoon ranges from 28.3 ^{0}C to 32.0 ^{0}C during twelve-month sampling period and the lowest temperature (26.1^0C) was experienced in March 2013 at Kattankudy and highest temperature of 33.6^0C was experienced at Sathurukondan during May 2013. It is obvious that water temperature increases as the atmospheric temperature rises. Kaushal *et al*. (2010) also reported that an increase in the river water temperature coincided with the rise of historical air temperature. The higher turbid condition was observed during the sampling at the sites of Kattankudy, Eravur and Kankeyanodai. Suspended particles may also contribute to the rise of temperature in those areas because of their absorption capacity.

Aknaf *et al*., (2017) also reported that water temperature of the Marchica lagoon varied significantly with sampling stations and presented a regular seasonal cycle with minimum in January and a maximum in July, and therefore did appear to pose any hazard to the lagoon system. Sugirtharan *et al*., (2017) reported that the slight variations were due to sampling time and the variation in the atmospheric temperature during day and night and the wind action within the lagoon environment. They further noticed that the Temperature of the lagoon was high (above 33 ^{0}C) during the period of April 2013 to August 2013. During the sample collection the places with higher organic and plastic waste accumulation indicated higher values of temperature.

In the present study, temperature showed significant differences in the mean value between morning and afternoon hours (Table 1). Further, temperature showed a significant positive correlation with the time interval. (r = 0.498, p=0.001).

Time scale variation of Total dissolved solids

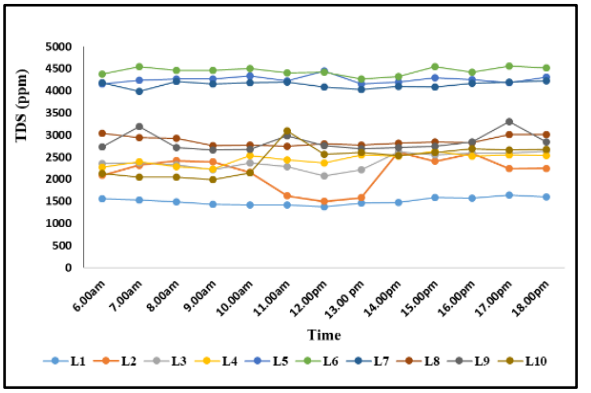

Figure 3: Time scale variation of TDS of Batticaloa lagoon water.

The United States Environmental Protection Agency

(USEPA) Secondary Regulations advise a maximum contamination level (MCL) of 500 mg/l (0.5 ppt) for TDS. When TDS levels exceed 1000 mg/l (1 ppt), it is generally considered unsuitable for human consumption. The present study revealed that TDS concentrations exceeded the desirable limit of 1 ppt. Chapman (1992) indicated that if the EC value exceed the limits in upstream than downstream, the salt intrusion occurs in nearby ground water sources. Bilotta and Brazier (2008) also mentioned that high TDS concentration could cause a reduced development and survival of fish eggs and larvae.

Figure 03 depicted the variation of TDS of Batticaloa lagoon (1.37 ppt to 4.55 ppt) water during the sampling period. As far as the mean TDS values for the study period (January to March) is concerned, a lower mean value (2.83 ppt) was observed at the Manmunai area and a higher value (3.09 ppt) was observed in the Navalady area. However, there is no significant variation found in TDS and EC of the lagoon water collected at an hourly interval within a day (Table 01).

Sugirtharan *et al.,* (2017) reported that the EC and TDS of the Batticaloa Lagoon fall within 0.24 dS/m to 36.6 dS/m and 0.1 ppt to 18.3 ppt, respectively. Lowest value of EC (0.24 dS/m) and TDS (0.1 ppt) was found at Manmunai area (L13) during February 2013 and the highest EC (36.6 dS/m) and TDS (18.3 ppt) were observed during October 2013 at Navalady (L1) which is very closer to the sea outlet than to the other locations. In the figure 3 the three lines at the top of the graph indicated the places where the EC value is greater than the other places. The places which close to bar mouth, distance wise showed higher values because of the sea water intrusion due to the lagoon.

Time scale variation of Electrical conductivity

A similar trend was also observed in the EC of the Batticaloa lagoon at a different time interval, where mean EC values ranged from 5.43 - 5.9 mS/cm. The higher value of TDS and EC was observed in the places such as Navalady (L6) and Kallady (L5) which are located closer to the ocean. The direction of water movement due to the wind pattern might have influenced the variation of ionic concentration of the lagoon during morning and evening time. At the same time, the tidal effect may also be the reason for the change in EC and TDS value because of the opened bar mouth.

Time scale variation of pH

The pH ranged from 7.0 to 9.2. The lowest value was observed at Manmunai area (L1) and the highest value was observed in Thannamunai area (L9).

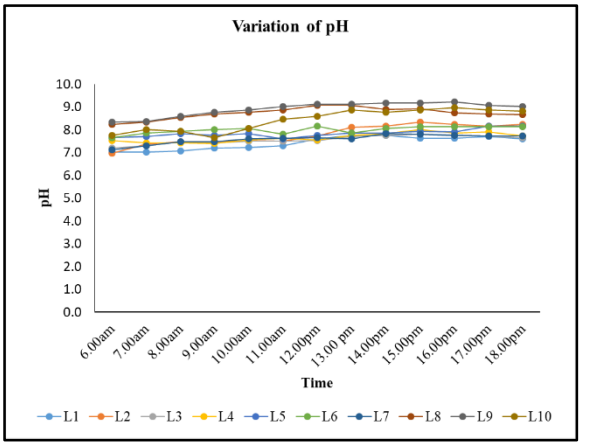

Figure 4: Time scale variation of pH in Batticaloa lagoon.

The variation of pH value at different locations might have been influenced by several factors such as bottom sediments, presence of organic matter, microbial activity, algal blooms, concentration of basic ions, amount of urban wastage discharged into the lagoon, connection with seawater, agricultural runoff and presences of industries which release their effluents into the lagoon etc.

The pH of lagoon water collected at 6.00 am showed significant mean differences with the samples collected after 1.00pm (Table 1). However, no significant difference in pH values were noticed among the other samples collected at 6.00am to 12.00pm. Similarly, there is no significant mean pH differences observed for the samples collected from 1.00 pm to 6.00pm. Hydrogen ion concentration or pH is one of the vital environmental characteristics

which decides the survival, metabolism, physiology and growth of aquatic organisms (Lawson, 2011). Sugirtharan *et al*., (2017) revealed that, the pH variation in Batticaloa lagoon was ranging from 7.32 to 8.87 and the difference of pH at 18 different locations during twelve sampling occasions indicates that the highest pH (8.87) was observed at Sathurukondan during May 2013, whereas the lowest pH (7.32) was noted at Kiddangi, and these pH values varied at different locations.

Time scale variation of Dissolved Oxygen

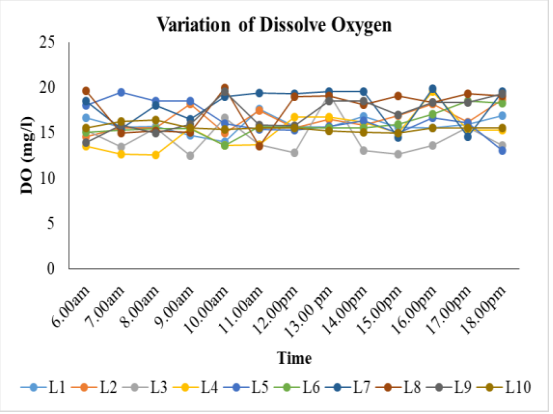

Figure 5: Time scale variation of DO in Batticaloa lagoon.

The present study found that the DO was ranging from 12.5mg/l to 19.93mg/l during the sampling period (January to March). The study was conducted during the monsoon period, and thus lagoon water height was increased due to the accumulation of water may be the reason for the high DO content during this period. Aknaf *et al.* (2017) reported that very low dissolved oxygen concentration may be created by the dreadful conditions of carbon-based matter, the very low hydrodynamics and too raised up temperatures. Higher dissolved oxygen concentration in Nador lagoon waters were found for the period of winter time reaching 12.75 mg/l and the low level was recorded in the summer (2.5 mg/l).

However, there were no significant differences in the mean values of DO was found with the time interval within a day (Table 01). Sugirtharan *et al*. (2017) reported that mean values of DO concentration of the samples collected in all locations in the Batticaloa lagoon ranged from 5.9 mg/l to 7.6 mg/l in different Locations and showed that there was no any spatial variation with the increasing distance from bar mouth. The present study also did not find any relation between DO value and distance from bar mouth. The increase in turbulence of the lagoon observed during sample collections might have increased DO concentration in most of the locations.

Time Scale Variation of Turbidity

The present study indicated the lowest value of 1.7 (FTU) at Navalady where the appearance of water was very clear. The highest value was observed (47.5FTU) at the Pillaiyarady area during the sampling period and lagoon water with suspended solids during sample collection due to heavy wind. As far as the mean values of turbidity from all locations are concerned, it varied from 12.35 – 18.37 FTU.

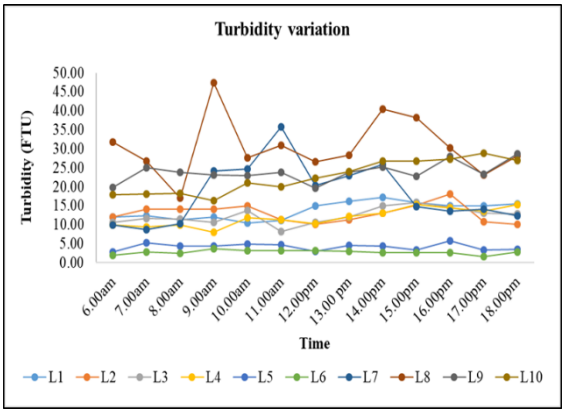

Figure 6: Time scale variation of turbidity in the Batticaloa lagoon.

Further, there is no significant mean differences observed with the time interval within a day (Table 1). Sometimes, turbidity values changed suddenly due to external factors such as heavy wind, flow speed etc. UNEP and WHO (1996) also reported that turbidity in water also depends on wind speed, the water flow speed, presence of suspended particles, drainage from urban wastage, effects of bottom-feeding fish, the density of phytoplankton,

agricultural runoff and rainfall. Sugirtharan *et al*. (2017) further revealed that high contents of suspended solids with runoff water from neighboring area enter into the lagoon during intense rainfall, and heavy wind amplified the tidal action of lagoon thus increasing the turbidity. They further reported that the mean values of turbidity fluctuated from 10 to 25 FAU. Opening of sluice gate to drain the excess water from major irrigation tank of the Batticaloa district also carries sediments from upper catchment area to the lagoon.

pattern of water temperature was mainly related to air temperature. The sampling locations which are far away from the bar mouth area showed lower EC and TDS. TDS, salinity, EC had non-significant positive correlation with temperature whereas the pH shows a highly significant positive correlation. In addition, the DO shows significant negative correlation with temperature. Wind and tidal action also influenced on the changes of turbidity in lagoon water.

Table 2: Correlation coefficient values of water quality parameters of Batticaloa lagoon.

	Temperature	**TDS**	**EC**	**pH**	**DO**	**Turbidity**	**salinity**
Temperature	1						
TDS	0.024	1					
EC	0.071	-0.302**	1				
pH	0.244**	0.075	-0.089	1			
DO	-0.117*	-0.343**	-0.026	-0.189**	1		
Turbidity	0.023	-0.388**	0.090	0.454**	0.037	1	
Salinity	0.026	-0.008	-0.032	-0.005	-0.040	-0.065	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed)

Pearson correlation coefficient values of water quality parameters of Batticaloa lagoon

The table 2 illustrates that TDS, salinity, EC had non-significant positive correlation with temperature. The pH shows highly significant positive correlation with temperature. The DO shows significant negative correlation with temperature.

4. CONCLUSION

The temperature followed by pH are the major parameters that varied significantly with the short time scales within a day. Other parameters such as EC, TDS, turbidity and DO did not significantly vary within a short time scales of the day. Changing the

These findings help in understanding the degree of variability of basic water quality parameters at a short time interval within a day.

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FALL OF THE WATER FALLS: A LEGAL ANALYSIS ON IMPACTS OF MINI-HYDRO POWER PROJECTS ON NATURAL SPRINGS IN SRI LANKA

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ABSTRACT

Mini-hydro power plants are becoming a popular method of generating power using natural streams and waterfalls. Mini-hydro power plants are targeting the areas which are high in ecological sensitivity and bio-diversity. Sri Lanka is blessed with natural waterfalls and streams in wetlands which add beauty to the environment and also create a base for endemic fauna and flora. Constructing mini-hydropower plants has become a profitable commercial business as it considers the economic benefit rather than the ecological value in the areas. When compared with the large hydropower generation projects, mini-hydro power plants generate a lesser amount of power while the environmental cost becomes higher. Since the waterfalls and natural streams are endangered with high and inadequate number of mini-hydro power plant constructions, making a path to disappearing of waterfalls and draining the streams. Several legislations have been enacted for environmental protection while restrictions are imposed for safeguarding biologically sensitive areas. Central Environmental Authority is governing and examining the process of issuing license and process of conducting Environmental Impact Assessments(EIA). Even though EIAs and Initial Environmental Examinations (IEEs) are carried out in this aspect, there are several loopholes in those procedures which causes risk to natural water springs and waterfalls. The study examines whether the existing EIA process in Sri Lanka is effective in ensuring that the mini-hydro power projects are environmentally benign. Black Letter Approach was used for this research and qualitative data analysis method was followed. Sustainable development goals should be upheld than considering monetary benefits when conducting development projects and special legislations should be enacted governing this particular area. The number of license issuing for the construction of Mini-Hydro power plants should be limited and alternative power generation methods which are suitable to Sri Lanka should be encouraged.

KEYWORDS: *Waterfalls, Mini-hydro power plants, Sri Lanka, Sustainable development, Environmental impact, Environmental Law*

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1. INTRODUCTION

Sri Lanka Sustainable Energy Authority (2017) provides that the hydro power is a main contributor to the power demand of Sri Lanka. While the government of Sri Lanka conducts major hydro power generation projects, the private sector is permitted to carry out mini-hydropower projects which supply less than 2.5% of the total contribution to the national electricity grid (Perera, 2017). The First mini hydropower project in Sri Lanka was started on 30th April 1996 at Dick Oya area by Hydro Tech Lanka (PVT) Ltd with a capacity of 1MW. Perera (2019) claims that more than 145 mini-hydro power plants are currently being active and more than 73 new projects have been approved while 1400km area of rivers and streams are going drained, destroying more than 50 waterfalls. Moreover, he claimed that 50% of the projects generate 1MW or lower than that. Several local companies are investing for these projects including installing power plants and selling the generated power to the Ceylon Electricity Board with the approval of Sustainable Energy Authority and Central Environmental Authority (CEA).

Even though mini-hydro power plants have economic benefits in generating electricity and turning into a profitable business nowadays, they have various effects on environment (Silva, 2015). Sri Lankan legal system contains the provisions for the protection of environment, however, the impact of mini-hydropower plants reveals the requirement of strengthening the legal provisions on this area. In this study, the researcher attempts to uphold the question of constructing high number of mini-hydro power plants using waterfalls, which generate lower amount of electricity while causing a huge environmental impact. The objectives of this research is to suggest other alternative methods for generating energy and to implement a proper Environmental Impact Assessment (EIA) process.

2. METHODOLOGY

This study was conducted using the Black Letter Approach (Doctrinal Methodology). The research was mainly focused on collecting, evaluating and discussing the existing legal provisions. Moreover, it was conducted for determining the adequacy of the contemporary substantive and procedural legal provisions. Identifying the relevant legal provisions, discussing the ambiguities of those provisions and providing solutions were the main concerns. Qualitative method was used as it focuses on gathering descriptive data related to the research area. As primary sources, legislations of Sri Lanka including Acts and Ordinances were referred. Special Ordinances and Acts connected to the area of environmental protection and sustainable development have been discussed. Secondary sources for this study were journal articles, authoritative textbooks, conference proceedings, policy reports, websites, and web articles. Data was collected by referring to webpages of Central Environmental Authority (CEA), Ministry of Power and Energy, Rainforest Protectors of Sri Lanka Association, Sustainable Energy Authority, Center for Environmental Justice etc.

3. RESULTS AND DISCUSSION

Mini-hydro Power Plants and their Contribution to the National Electricity Grid

Hydropower projects which generate less than 10 MW fall into the category of "mini-hydro power projects". Mini-hydro power plants have commenced to assist the national power grid since 1996, contributing 1MW in its first attempt. Since then the number of mini hydro projects has been increasing day by day namely Ma Oya Mini Hydropower project, Magala Ganga Mini Hydro-power project, Bambarabatu Oya Mini Hydropower Project, Atabage Mini Hydropower project, Ethamala Ella Mini Hydropower project etc. According to the annual report of Sustainable Energy Authority (2015) the total contribution of these mini-hydro plants to the national power supply is approximately 3%, and according to the current reports, there are more than 145 active mini-hydro power projects in Sri Lanka. More than 120 mini-hydropower projects have been approved to commence. However, there is a long queue to obtain permission for proposed mini-hydro power plants in Kithulgala because these investments provide high profits in return. Even though the mini-hydropower projects were measured as an effective method of generating energy, it has harmful effects to the environment including disappearance of waterfalls.

Environmental Impact of Mini-hydro Power Plants

The major effect of mini-hydro projects is the disappearance of waterfalls which supply the main source to generate its power. According to Silva (2015) more than 50 waterfalls have disappeared while 1400km river length has been blocked. Moreover, he claimed that two waterfalls named as Athawatunuwawa Ella and Diganahinna Ella in Belihul Oya (Mandaramnuwara Valley) have drained due to the uncaring constructions of mini-hydro power plants that occurred during the last fifteen years.

According to Perera (2017), over 500 acres of paddy fields are affected without water due to the construction of Manakola, Deegalahinna and Medapitiya mini-hydro plants in Belihul Oya Valley. According to Silva (2015), "Eli Hatha" waterfalls situated near Malimbada area also got effected due to a mini-hydro power plant which blocks and carries away the water of the second waterfall out of seven waterfalls, resulting the disappearance of the second waterfall. Streams which are high in bio diversity and ecological validity are becoming dead zones due to obstruction and diversion of water. Breeding patterns of endemic and native fish species have been disturbed and it risks the existence of species and affects the whole ecological system (Rodrigo, 2016).

Moreover, absorbing water for mini-hydro power plants causes a significant loss of ground water resulting various social and environmental issues. Disappearance of waterfalls and biodiversity in those areas harms the tourism industry which is one of the main income resource of the country.

Draining waterfalls and streams in mountain areas is creating social and health issues to the people who live down streams as they are facing a shortage of water. Illegal activities are carried out causing high damage to the environment in tropical areas such as timber trading, illicit drug making, sand mining etc. Sustainable development strategies should be used, as waterfalls are not only adding beauty to the environment, but also create the base for the natural biological eco-system.

Existing Legal Framework

State Land Ordinance No.8 of 1947 interpreted in its Section 70 that the word "stream" includes any river, creek, Ela and branches of these flowing in a natural channel and "public streams" are all the other streams which are not private streams. According to the said Ordinance, there should be reservations near any public stream prohibiting any nearby constructions. Section 77 of the Ordinance permits to divert water and construct bridges and other works under a permit issued on behalf of the state while it should concern the rights and effects towards the people who live in the area. Article 12(1) of the Sri Lankan Constitution ensures the 'Right to Equality' as a fundamental right, while Article 17 and Article 126 empower the public to the fundamental rights petitions to the Supreme Court against executive and administrative actions. *National Environment Act No.47 of 1980* is the main legal document in Sri Lanka for management and protection of the environment. Under Section 2 of the Act, Central Environmental Authority (CEA) has been established as the responsible institution in order to examine the administration and protection of the environment. The requirement of conducting EIA was established in its Amendment Act No.56 of 1988 including the stage of acquiring public comments before granting permission. Obtaining license was made mandatory with applicable to prescribed projects as set out in the extraordinary gazette No.1533/16 dated 25.01.2008. EIA process consists of two levels which are based on IEE. IEE is a report which addresses the significance of the impact of the projects where the possibility of such impacts will be measured according to their intensity. Thereafter, the identified impacts will be studied with suggested options which have minimum impact on environment in order for granting approval. Project Approving Agencies (PAA) are established under the provisions of the Act under the supervision of CEA. All those agencies and institutions are responsible for maintaining a balance between sustainable development and protection of environment. The CEA has a duty to conduct awareness Programmes for the public and prevent any conduct which provides any environmental harm. The National Environment Act has provisions to prevail any other written law in a situation of inconsistency or

conflict. Therefore, obtaining approval from the CEA for conducting EIA is a legal requirement before constructing a mini-hydro power plant. *Fauna and Flora Protection (Amendment) Act No.22 of 2009* made provisions for management of plans and assessments of impacts for national reserves including the procedure for obtaining approval from Director General of Wild Life Authority of Sri Lanka before starting development projects.

Adequacy of Existing Legal Provisions

There are various environmental issues of mini-hydro projects implemented during past years notwithstanding the existence of legal provisions governing the area. Mini-hydro power plants are located in extremely sensitive ecosystems like tropical forests where there is rich biodiversity. Contribution of a waterfall towards the natural balance of the environment is priceless as it increases the oxygen level of the water while reducing the ammonia level. The power generation plants situated very far from the national electrical grid's transmission lines and public transportation systems (Rodrigo, 2016). Massive constructions of mini-hydropower plants disturb the sensitivity of the environment and harm the natural activities of the ecosystem. Waterfalls are blocked building barriers to its natural paths resulting the disappearance of waterways. People who reside in those areas have to face lots of complications due to the disturbances caused to natural waterways. They have to adapt themselves to face the changes in the environment including deforestation, change of water flows and draining of the natural water springs.

All the mini-hydro plants require a huge flow of water path and a prominent drop as in waterfalls attracting the constructors. Even though there are precautionary steps and legal requirements to fulfill before providing approval for EIA in mini-hydro projects, the inadequacy and ineffectiveness of those proceedings cause serious issues. Flow rate of the natural waterways and general ecology of the environment are not getting sufficient attention during the EIA process which resulted in the disappearance of waterfalls due to the constructions of mini-hydro projects. Sri Lanka's EIA system was criticized as a corrupted and manipulated mechanism due to political influence and bribes given by the investors to officers in regulating agencies for obtaining license (Nizam, 2017). Constructing mini-hydro power plants without following proper EIA procedure causes several other damages such as draining of waterways and natural springs, deforestation, threatening the wild fauna and flora including endemic species etc. 'Anda Dola', which is located at Galle is the most recent target of Mini-Hydro projects while concrete channels have been constructed through 'Dellawa' rain forest which belongs to Sinharaja rain forest complex (Dissanayake, 2016). Those constructions have been ongoing in the protected forest reserve of Sinharaja forest and negligence of the developers causes hazardous results to the entire area including the stream, endemic fauna and flora and the soil. Moreover, Dissanayake (2016) claimed that mini-hydro power project would damage a section of 6.5 kilometers of 'Anda Dola' as its water was taken away to the power plant located in several kilometers far away and resulted in the extinction of many endemic species.

Obtaining public comments is a necessary part of the EIA process, but in practice, it fails to achieve the objectives of the EIA. Lack of awareness of the people who live in particular areas is a major issue in this context. Public comments and protests are based on political and personal reasons hiding the actual reasons which have to be addressed (Dissanayake, 2016). PAA has the authority to approve or refuse the application for construction of mini-hydro projects, but evaluators are simply reliant on the documents other than directing actual researches before approving the projects. Moreover, the political influences on these decision making proceedings are risking the environmentally rich areas by granting permission for huge constructions of mini-hydro projects.

The Association of Rainforest Protectors of Sri Lanka has forwarded a letter to several international organizations including UNESCO (United Nations Educational, Scientific and Cultural Organization), UNFCC (United Nations Framework Convention on Climate Change), UNEP (United Nations Environment Program), IUCN (International Union For Conservation of Nature) and to local public

authorities emphasizing the explosive growing of mini-hydro projects in the areas of endangered rainforests and specially in buffer zones of them threatening the rare flora and fauna and destroying unspoiled streams and waterfalls (Perera,2019). Establishing a fish ladder to safeguard the passage of travelling species in the stream up and down ways is an essential element when constructing mini-hydro projects. As Rodrigo (2016) explains, most of the projects do not include this in their constructions and even the available fish ladders are not in expected standards.

People who live in the downstream areas are the ones who get affected by such activates as sudden disappearance of a natural waterway causes lots of harm to all the surrounding which depended on it for years. In some situations, the monitoring reports has not been forwarded to the CEA resulting the responsible authority unaware about the harm caused by approved projects unless public protests occurred.

According to the findings of Krishantha (2018) environmentalists declared that Kithulgala eco system, which contains high biological diversity is at high risk due to the suggested construction of mini-hydropower plant in that area. The nature of the land in this area is not stable and has the risk of landslides, which makes it unsuitable for the construction of a power plant. Kithulgala biodiversity zone can be named as one of the utmost sensitive zones in Sri Lanka, which is going to be endangered because of these projects. Struggling to acquire the approval through political influence while the CEA's consent is still pending can be understood as the major reason behind the creation of high number of mini-hydro power plants.

In *The Environmental Foundation Ltd vs, the Central Environmental Authority and Others* (CA 1556/2004), the petitioner challenges the validity of the CEA's approval given to a private company for constructing the Bomuruella mini-hydro power project in Kandapola-Seetha Eliya forest reservation as it was given without considering the EIA report. Furthermore, the permission was granted by referring to Technical Evaluation Committee's recommendations. The Court of Appeal held that Technical Evaluation Committee has no jurisdiction granted by *National Environmental Act* as a PAA and issued a writ of Certiorari quashing the decision given by the CEA for its failure to exercise discretion in good faith towards the public.

A case against Kehelgamu Oya Mini-Hydro Power Project (CA/Writ/29/17) which was located at Kithulgala River was filed by Center for Environmental Justice. As argued by the petitioners, the project has been carried out without being subjected to proper EIA or IEE from PAA as required by law. In *Ananda Padmasiri vs Sustainable Energy Authority and Others* (SC FR 191/2017) filed regarding Maru Kanda mini-hydro power project which was based on Kuru Ganga river which has already four other ongoing projects. Construction of the new projects causes severe damages to the people who uses its water for bathing and other purposes due to the draining of the river. One of their key argument was the lands which used for the projects are river reservations and unavailability to use for commercial purposes, highlighting the inadequacy of EIA carried out.

Center for Environmental Justice Vs Sustainable Authority and Others (SC FR 137/2017) was against for Athwelthota mini-hydro power plant situated at Palindanuwara which was commenced without conducting a proper EIA as claimed by the petitioners. As per their argument, the project was carried out in a highly ecologically sensitive area created by Athwelthota waterfall which has endemic fish species and endangered species and the project is detrimental to its environment.

The importance of following the EIA process was interpreted in *Bulankulama and others vs Secretary, Ministry of Industrial Development and Others* (2000) 3 Sri LR 243 (Eppawela Phosphate Mining Case). As decided, the proposed project was not provided for EIA and it was not approved by the CEA. In his judgment his lordship Amerasinghe J. citing the Indian Judgment of *M.C. Mehta v Kamal Nath* (1997) 1 SCC 388, established that natural recourses of public are held on trust for them by the state as guaranteed by Article 27(14) and 28(f) of the Constitution. The judgment further highlighted the authority of CEA as the statutory authority for conducting EIA process. In *Ravindra Gunawardena Kariyawasam v Central Environmental Authority and Others* (SC FR

141/2015), popular as Chunnakam Power Plant Case, the CEA was found in omission of duty towards the public by granting permission to carry out the operation of the project without issuing a license, or carrying out a proper EIA.

Recommendations to Overcome the Issues and to Improve Existing Legal Framework

Perera (2017) claims that waterfalls are not only an element which adds beauty to the nature but also contain vital ecological benefits such as increasing the oxygen level of the water by water filtering. Moreover, he explains that it can be named as an 'ecological crime' to destroy waterfalls as it reduces water pollution and increases the livelihood of the streams. As Nizam (2017) highlighted, CEA mostly granted conditional approvals which are hard in implementation and lacks the gravity on environmental protection. Standards of CEA should be strictly considered before granting approval for mini-hydro projects especially for extremely sensitive matters such as endemic species and endangered species which are highly dependable on the natural environment of the selected areas. CEA should provide adequate resources to carry out assessments on ecological basis as per the request of the parties of proposed projects. CEA lack sufficient expertise and capacity related to construction of mini-hydro projects (Nizam, 2017), therefore sufficient training and knowledge should be given to officials. Flow rate of the water paths and the general ecology of the zone should be carefully studied during the EIA process under the supervision of the professionals. Voluntary agencies and eco-friendly activists devoted for environmental protection including general public should be taken as an aid in the process of monitoring these projects. Environmental groups who are ready to voluntarily participating for conducting awareness programs should be encouraged (Rupasighe, 2007). Revealing true information including possible threats, to the general public is a duty of the responsible authorities. The decision making process should be conducted without political interferences in order to maintain EIA process effectively.

A report which contains reasons for approval or rejection should be available to the general public within a minimum time period from the date of granting it where the public can be aware about the transparency of the process. CEA should effectively monitor the activities of the project developers to ensure that the construction process is in accordance with the approved structure. In situations where the construction method overrides the approved methods, CEA should take immediate measures to cancel the project or remove illegal constructions before it become hazardous. PAA must pay attention to the complaints against the proposed projects without deciding on political influence. CEA should provide supervision on the progress of the constructions to monitor the process and its compatibility with the approved quality and standards. Fish ladders should be established compulsorily in every mini-hydro project in accordance with the prescribed standard.

The approval for mini-hydro projects within protected forest reserves should not be permitted by the Forest Conservation Department as it damages the natural habitat of the bio diversity. All the operations of approved mini-hydro power plants which have hazardous effects on environment should be ceased and CEA should reconsider the EIA process in order to minimize corruption (Perera, 2017). Sustainable Energy Authority and Ministry of Power and Energy should strictly limit mini-hydro projects which have harmful effects and promote environmental friendly solutions for generation of power such as rooftop solar panels, wind turbines using offshore wind, generating energy using garbage and generating power using sea waves etc. As Perera (2019) suggests, rooftop solar and waste-to-energy projects should be considered instead of mini-hydro projects. Sri Lanka, being an island surrounded by sea which has monsoon winds, wind turbines and sea wave energy generation can be used effectively for generating power as per the Sri Lanka Sustainable Energy Authority (2017) suggests. CEA should take immediate measures to cancel all the mini hydro projects constructed without adhering to the approved manner. Granting approval for new projects should be kept in hold until finding proper solutions for existing issues. EIA process has location sensitivity and should be considered in each case's merits whereas significant impacts can be minimized through proper planning (Pushpakumara, Wijeyawickrama & De Silva, 2003).

The Government should encourage the researchers and inventors for inventing new technology in power generation projects using solar and sea wave energy which is practically suitable for Sri Lanka. Higher fines and punishments should be imposed on the wrongdoers who violated the legal provisions. As interpreted in the Indian judgment of *Vellore Citizens Welfare Forum v Union of India* (1996) 5 SCR 241, polluter pay principle should be applied not only for providing compensation for victims and for recovering the cost of environmental destruction. Finally, the researcher is suggesting that enacting a special legislation to this particular area will be suitable to govern the entire process in strong a manner.

4. CONCLUSION

Renewable power generation plans are essential for sustainable development of the country but environmental factors should be highly considered during that process. Mini-hydro power plants are based on the waterfalls, using the water to generate electricity. Due to inadequate protection of legal provisions and corruptions that occur during EIA process have resulted in unrepairable harm to the biodiversity of the environment. Major hydropower plants have actively participated in the power generation while there are many more mini hydropower plants ongoing, supporting minimally to the national power grid, but having high environmental cost. While there are possible environment friendly solutions such as solar power, wind turbines and sea wave power generation, increasing the number of mini hydro power plants based on waterfalls without considering the environmental value of these zones would not support the objectives of sustainable development. The contribution of a waterfall to balance the ecological natural behavior of the environment is priceless and it adds enormous beauty to the nature. Fall of the waterfalls will not be far away if the necessary legal measures are taken to protect the nature when constructing mini-hydro projects.

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IDENTIFICATION PARADES: AN INTERROGATION OF IDENTITY AND HISTORY IN THE POSTCOLONIAL NOVELS *ICE CANDY MAN* BY BAPSI SIDHWA AND *ANIL'S GHOST* BY MICHAEL ONDAATJE

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ABSTRACT

Postcolonial literature becomes a source through which dominant ideologies can be challenged and deconstructed. It is a potential site of resistance that reveals the way in which imperialist power structures strive to oppress, silence or erase the subjugated and the lingering effects of this process upon postcolonial nations. Ice Candy Man (1989) by Bapsi Sidhwa and Anil's Ghost (2000) by Michael Ondaatje are two postcolonial novels that examine the concepts of identity and history in terms of the marginalizing hierarchies and discourses constructed through different power structures. Ondaatje's Anil's Ghost examines the political turbulence in Sri Lanka during the 1988/89 Insurgency through the lens of the diaspora using the character of Anil, a forensic pathologist who returns to her native country to conduct a Human Rights investigation. Bapsi Sidhwa explores the violence of the Partition of the Indian subcontinent in Ice Candy Man through the trajectory of Lenny from being a susceptible young girl to a mature and experienced person. The main research problem addressed in this study is whether the concepts of identity and history are discursively constructed based on underlying hegemonic power structures that are marginalizing and oppressive. These two postcolonial narratives are analyzed by conducting a textual analysis in order to understand how the concepts of history and identity are multifaceted and fluid, thereby challenging hegemonic perspectives that construct a single story. The way in which identity and history are subjectively experienced and constructed will be analyzed from a postcolonial theoretical framework. This study will contribute towards the understanding of postcolonial literature as a point of resistance to hierarchical ideologies or colonial discourses by voicing marginalized narratives.

KEYWORDS: *Ice Candy Man, Bapsi Sidhwa, Anil's Ghost, Michael Ondaatje, Postcolonial Identity, History*

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1. INTRODUCTION

Ice Candy Man (1989) by Bapsi Sidhwa and *Anil's Ghost* (2000) by Michael Ondaatje are postcolonial novels that examine the concepts of identity and history by discussing the marginalizing hierarchies and discourses constructed through different power structures. Nayar (2008) defines postcolonialism as any strategy that "opposes systems of domination by any power" (p. 17). It refers to a form of cultural resistance that contests any form of discrimination and exploitation by giving 'agency' to the colonial subject, thereby challenging imperialist power structures that seek to oppress the subjugated. Postcolonial theory explores how colonial discourses allow the expression of selected opinions and knowledge while silencing and erasing others. Thus, postcolonial theory analyses how hegemonic structures are embedded in texts and attempts to redefine and represent the marginalised, both within "Third World" and "First World" nations. This understanding is used as a framework within which the two postcolonial novels have been analysed in this research. Ondaatje's *Anil's Ghost* (2000) examines the political turbulence in Sri Lanka during the 1988/89 Insurgency through the lens of the diaspora using the character of Anil, a forensic pathologist who returns to her native country to conduct a Human Rights investigation. Sidhwa, a Pakistani-American novelist explores the violence of the Partition of the Indian subcontinent in *Ice Candy Man* (1989) through the trajectory of Lenny from being a susceptible young girl to a mature and experienced person. These narratives interrogate the hegemonic perspectives towards these historical contexts and attempt to unveil the multifaceted nature of what is considered to be the single story. History is examined by analysing how memory and truth are constantly constructed and reconstructed based on discursive power structures. The static nature associated with identity is also dismantled by showing how the postcolonial, diasporic, national and personal identities are subjected to continuous change.

2. METHODOLOGY

A textual analysis of the two novels *Anil's Ghost* by Michael Ondaatje and *Ice Candy Man* by Bapsi Sidhwa was conducted based on a subjective ontological perspective. The main research problem addressed in this research is whether the concepts of identity and history are discursively constructed based on underlying hegemonic power structures that are marginalizing and oppressive. These two concepts are interrogated in light of how these two postcolonial texts are able to challenge dominant ideologies by proving how identity and history are fluid and multifaceted. This research is a non-positivist and qualitative study that is based on the assumption that a single truth or reality does not exist. A constructivist epistemological stance has been adopted to understand how identity and history are subjectively experienced and constructed. A postcolonial theoretical framework has been used to analyze the various nuances of identity and history that can be highlighted in *Anil's Ghost* and *Ice Candy Man.* The theories of Homi Bhabha, bell hooks, Stuart Hall and Edward Said are some of the central concepts referred to within the research. The setting, historical context, narrative style, character portrayals and the plotline of these two postcolonial texts were used to formulate interpretations and argue the multiplicity and fluidity of identity and history.

3. RESULTS

The way in which history and identity are discursively constructed through power structures that aim to marginalize and oppress is made evident by highlighting how postcolonial texts act as "sites of resistance" (Hooks, 1990,). Gender, sexuality, social class, ethnicity and race become factors that influence the way in which identities are perceived and constructed. Therefore, the concept of identity is an amalgamation of such markers of identity and cannot be understood as something fixed or singular. The existence of hegemonic power structures that influence these constituents of identity makes it a fluid and complex element that is subjected to constant change. Similarly, particular memories, experiences and people that constitute history are erased or eclipsed by dominant representations of the past. Dominant ideologies or discourses manipulate the way in which the past is remembered and constructed. History changes according to shifts in these power

hierarchies. Thus, both identity and history are multifaceted, fluid and fragmentary.

4. DISCUSSION

4.1 Identity

Identity, especially in relation to a postcolonial nation or community is a complex aspect that is directly affected by their colonial past and experiences. As stated by Ashcroft, Griffith and Tiffin (2004), the postcolonial identity crisis is "the concern with the development or recovery of an effective identifying relationship between self and place" (p. 8). It is a process in which postcolonial identities are constantly shifting and are dependent upon social, cultural, physical, linguistic and political factors. This "development or recovery" (Ashcroft, et al. 2004, p. 8) of identity and its intricacies can be analyzed through postcolonial literature. The concept of identity as fixed or static is dismantled in both *Anil's Ghost* and *Ice Candy Man* by drawing on its multiplicity and changeability. *Anil's Ghost* is written using different voices or protagonists such as Anil, Sarath, Gamini, Ananda, Sirissa and Palipana. The interwoven nature of these different stories makes the narrative dense and confusing. This becomes a tool through which the multiplicity of voices and the rejection of a single story or perspective are highlighted. Therefore, the fluidity of identity and the way in which it is constantly reconstructed can be explained through the different sections of the novel that contain various voices. The first section of the novel is titled Sarath but Anil's voice seems to dominate. This elucidates how Anil is exploring the character of Sarath and his different layers just as she is exploring Sailor and constructing his identity. Moreover, Ondaatje (2000) shifts between the different voices abruptly and provides glimpses into the past of the different characters as seen through the italicized sections in the novel. However, each of these stories are linked together which reflects how identity is not fixed or singular, but is constructed through different strands that makes a whole. The seamless connection between these perspectives also shows the interchangeability of identity where these characters can be linked to each other through their experiences and perceptions. Thus, hegemonic understandings of identity, both national and personal are dismantled. Similarly, Sidhwa (1989) uses the perspective of the child protagonist Lenny, a polio-ridden young girl to examine hegemonic ideologies of identity that exist within the text. Belonging to the ethnic minority of the Parsee community in Lahore, Lenny's experiences of the pre-Partition, the Partition riots and the period immediately after the Partition provides an important lens through which this particular historical context can be examined. Lenny is an outsider to the larger Indian caste based hierarchies that existed at the time. Lenny's Parsee background frees her from the pressures of having to fit into or respect caste hierarchies. This allows her to adopt an unprejudiced view of her surroundings. Lenny's interactions with people belonging to different ethnic, religious, caste and class backgrounds such as Hari, Imam Din, Ranna, Papoo, Ayah and her many admirers enrich the plot with different perspectives. The voices of the Hindu, Muslim, Sikh, Parsee communities and even that of the colonizer are blended into the narrative to provide a kaleidoscopic view of the Partition riots that led to the 'cracking' of India. Hence, the use of multiple voices dismantles the formation of a single, dominant perspective that marginalizes individuals or communities.

Furthermore, the subject positions of the two authors as members of the diaspora also become important in the discussion of marginalizing power structures. The way in which margins can be converted into sites of resistance can be discussed through how both Ondaatje (2000) and Sidhwa (1989) use the central characters of Anil and Lenny respectively to bring in different perspectives that redefine the histories and experiences of postcolonial nations. The concept of the empire writing back is prominent in postcolonial writing. It has become elemental in interrogating myths and stereotypes created by the West or the 'centre' about the 'Orient' or the 'Other' that "relegate them to marginal and subordinate positions". (Ashcroft, et al. 2004, p. 7). As a member of the diaspora, Anil is unable to understand and connect with the experiences and opinions of locals such as Sarath and Ananda. Moreover, her inability to secure a

sense of belonging in her native country locates Anil's character within a "liminal" space that "transfers the meaning of home and belonging, across a 'middle passage' … that span the imagined community of the nation-people" (Bhabha, 1994, p. 200). Thus, her diasporic identity situates her within a space that transgresses boundaries and challenges power hierarchies. As Piciucco (2018) argues, 'she possesses a "transnational nature" … representative of the "in-between" location of postcolonial consciousness, with insight into both East and West, and yet fully exemplary of neither' (p. 165). This marginal position invites interrogation of the concept of identities and nation by highlighting its multiplicity and fluidity. Thus, as Cook (2004, p. 3) also states, the notion of multiculturalism incorporated through the transnational identity of Anil helps to dismantle the dichotomy of the Orient and the Occident constructed by hegemonic power structures. Furthermore, Anil's diasporic identity becomes a source through which the different facets of the other characters are revealed and negotiated. Her journey provides insight into individual lives such as that of Sarath, Gamini and Ananda who were unwillingly drawn into the political turmoil of the country by various political, ethnic or racial forces. These individual perspectives that appear to be marginal become "a site of radical possibility, a space of resistance" (hooks, 1990, p. 341) that helps to dismantle Eurocentric perspectives of the civil wars that occurred during the 1988/89 Insurgency period. Moreover, as argued by Pillainayagam (2012, p. 3), the roots of these conflicts can be traced to the effects of colonization where the divisions between the Sinhala and Tamil communities were aggravated. Issues of race and ethnicity emerged and resulted in the disruption of the national, social and religious identities of Sri Lanka. Thus, the direct influence of the imperialist project on postcolonial nations and the way in which postcolonial literature reconstructs postcolonial identity in a way that dismantles the stereotypical images is made evident. Hall (1992) also discusses the origins of the formation of the 'West and the Rest' by highlighting how the West is an ideological, discursive and historical construct rather than a geographical division. It is a system of representation that organizes global power relations by locating the 'West' in the center and the 'Rest' in the margins, while producing a 'regime of truth' that maintains these hegemonic power structures (Hall, 1992). In the novel *Ice Candy Man*, Lenny's physical ailment and her identity as a Parsee locate her in the margins. She also represents postcolonial identities that are constantly pushed to the periphery by hegemonic discourses that locate the Western identity in the center. These factors destabilize the narrative identity of Lenny by making her a character that interrogates the 'center' while remaining in the fringes. This exemplifies how postcolonial literature analyses and deconstructs these hierarchies by redefining the ways in which the 'West and the Rest' are represented. Hence, Sidhwa (1989) is able to provide a relatively unbiased view of the Partition politics through the character of Lenny and provides a more nuanced view of the struggles faced by the Indian subcontinent that ultimately led to the Partition.

Additionally, the way in which identities are formed by individuals based on personal motives and larger political propaganda can be explained through the swift identity changes that the two protagonists in *Ice Candy Man* and *Anil's Ghost* undergo. The revelation of how Anil's name "was her brother's unused second name. She had tried to buy it from him when she was twelve years old" (Ondaatje, 2000, p. 67) highlights the artificiality and fluidity of identity that is constantly subjected to the process of change and reconstruction. The word 'buy' ironically heightens the sense of impermanence or the fluctuating nature of the self. Therefore, as Cook (2004) states, "Ondaatje problematizes notions of either individual or national identity as being fixed and immutable, adopting instead a perspective that considers such boundaries as both flexible and permeable" (p. 7). Furthermore, Anil's desire to embrace this new identity can also be seen as an attempt to resist marginalization based on gender and sexuality. The fact that she is treated as the outsider by locals such as Sarath and Ananda due to her diasporic identity is further intensified due to her identity as a woman. Thus she is in constant conflict with social forces that threaten to discriminate her. The way in which she adopts a name that implies an

androgynous quality as it is considered a masculine name, yet has a "feminine air" (Ondaatje, 2000, p. 67) reflects how she strays from rigid constructions of gender identities and sexuality. Similarly, Lenny's gradual awakening to the atrocities committed by people against each other on the basis of ethno-religious biases paves way for an identity conflict through which Sidhwa (1989) discusses the way in which identity is constructed based on hegemonic discourses. The concept of identity as fixed or stable is dismantled through the way in which Lenny shows how her identity changed instantly based on her geographical location; "I am Pakistani. In a snap. Just like that" (Sidhwa, 1989, p. 108). The politics of the nation enters the personal life of Lenny thereby, forcing her to grapple with the power dynamics associated with ethnicity, religion and caste. With the Partition of the Indian subcontinent that led to the creation of Pakistan, millions of people were forced to migrate and embrace a completely different identity. This reflects the politics associated with the way people construct and reconstruct their own cultural or individual identities. Furthermore, the incident where Hari, the gardener becomes a Muslim and Moti announces that they are "becoming Christians" (Sidhwa, 1989, p. 120) are examples that reinforce the artificiality and fluidity of identity. Therefore, this novel uses the identity conflict experienced by Lenny and her increasing understanding of the society she lives in to provide an intimate exploration of the political violence of the Partition. The way in which identities are constructed based on personal interests is also made evident through the character of Ayah who becomes central to the exploration of how existing power structures are interrogated. Her character can be read as an allegory of the Indian subcontinent. At the beginning of the novel, Lenny records the unity of her community by observing how "the Fallettis Hotel cook, the Government House gardener, and an elegant, compactly muscled head-and body masseur" (Sidhwa, 1989, p. 25) along with Ice-candy-man sit together with Ayah at the park. The way in which Ayah's admirers belonging to different ethnicities, religions and castes were able to co-exist by respecting the differences of each other is symbolic of the possibility of multi-ethnic communities to live in harmony. However, as the Partition riots begin it is made evident that these admirers of Ayah gradually drift apart. These changes of the everyday activities that Lenny is accustomed to mirrors the shifting power structures that ultimately lead to massive destruction. The need to secure the affections of Ayah is metaphorical of the conflicts that arose over the ownership of land. Hence, "her body becomes the symbol of the broken land, desired by all and ravished by those who courted and loved her" (Dhal, 2018, p. 22). Just as the Ayah is destroyed by the violence perpetrated upon her by Ice-candy-man and other men, India was destroyed due to extremist beliefs and political propaganda. Thus, the hegemonic constructions of identity, both national and personal are interrogated in both *Ice Candy Man* and *Anil's Ghost.*

4.2 History

As defined by Jensen (2021), "history is the study of the past in all its forms" (p. 1). It is a source through which an individual can derive a sense of understanding of human nature and the world one inhabits. However, what is recognized as 'history' is affected by processes of construction and reconstruction that function upon hierarchical discourses and dominant ideologies. Similar to how the fluidity and multiplicity of identities dismantle marginalizing power structures, history can also be discussed based on its multifaceted nature. The concepts of memory and truth addressed by Sidhwa (1989) and Ondaatje (2000) in the two novels are interrogated in order to highlight how history is discursively constructed. Ondaatje (2000) constantly stresses the importance of understanding history, memory, truth and its nuances by looking at the fragments of a single story or perspective. The reference to the 73 versions of the National Atlas elucidate how there cannot be a single story and that each version reveals "only one aspect, one obsession" (Ondaatje, 2000, p. 39). This is reflective of how what is presented in history is only a part of a much larger and multifaceted narrative. This can also be linked to the multiple narrative voices employed within the text and the non-linearity of the plot that give insight into

these different versions. The shifting nature of the plotline creates certain gaps in the narrative through which the reader is able to question the different versions, the validity and relevance of what is presented in the novel. The beauty of the narrative lies in its complex structure that remains a puzzle and it is through this ambiguity that meaning is derived. The confusion created as to when history ends and the present begins is used to highlight the flexibility or the multifaceted nature of hierarchical ideologies that construct power structures. Therefore, Ondaatje (2000) brings both history and the present seamlessly together in his discussion of the political violence in Sri Lanka during the 88/89 Insurgency period The non-linearity of the text demonstrates how meaning is not linear or coherent, rather a collection of fragments that are pieced together in different ways to construct meaning. This multiplicity of voices and the lack of a logical development of the narrative support the theme of the multifaceted, fluid nature of concepts such as history, truth and memory that helps to dismantle the notion of a single story. It is on this premise that the political and ethnic violence that Ondaatje (2000) expounds on can be understood. The inability to distinguish between the perpetrators and the victims due to the wide-spread violence is evident when Sarath says that "there's no hope of affixing blame. And no one can tell who the victims are" (Ondaatje, 2000, p. 17). The writer provides an unbiased, intricate representation of the 88/89 Insurgency period in Sri Lanka through the interrogation of power structures that exist in society. Accordingly, the fixity of 'truth' and 'history' is challenged by showing how it is exploited and controlled by the larger discursive powers of society. The text encourages the reader to think about the duplicity or the different versions of history by showing how depending on the location, context and experiences, history becomes different to each individual. History and its multiplicity are unearthed and questioned through the bones of Sailor, the skeleton exhumed from a government protected prehistoric burial ground. Bones become the central motif of the novel and are a repository of memory, history and ancestry. The act of unearthing the bones is in itself a direct interrogation of 'truth'. The archaeological process investigates, constructs and reconstructs the 'truth' based on evidence which shows how it is fluid and changes according to the social context and location. The ambiguity associated with the skeleton can be paralleled with the ambiguity of the concept of truth. The notion of how 'truth' has to be disassembled and reconstructed while focusing on fragments can be explained through the instance where Sarath separates Sailor's bones. He creates fragments out of the larger piece which shows how fragments give a better picture of the central concept. Each fragment brings in a different story which reiterates the idea of how there is no single version of truth, history or memory. It is through these individual stories and memories that the ethnic wars and the political conflicts that occurred in Sri Lanka are revealed.

Furthermore, the multiplicity of memory can be discussed through how it is not fixed, but consists of different fragments that are pieced together to create meaning. The various nuances of trauma and grief are interrogated to redefine power structures that homogenize the concept of memory. The uncertainty and the void one carries as a result of not getting definitive closure addressed in the novel *Anil's Ghost* brings in a different aspect of violence and its effects on the human psyche. The way in which "death, loss, was 'unfinished'" (Ondaatje, 2000, p.56) is highlighted and this understanding of trauma is established from the beginning of the novel itself through Anil's experiences at the archaeological site in Guatemala. It provides a lens through which the life of Gamini who buries himself in work to find order in his chaotic life filled with death and violence, Sarath who is struggling to understand the suicide of his wife and Ananda's inability to come to terms with his wife's disappearance can be understood. Each character has suffered different traumatic experiences and they deal with these memories in their unique ways. The grief one encounters in fragments and how it is intertwined with fear, uncertainty, anxiety, empathy and love provides a nuanced understanding that re-examines the monolithic understanding of trauma and memory. The novel discusses the trauma that one may attempt to disassociate from but is unable to due to the irreversible damage inflicted by

war and violence. Similarly, the character of Ice-candy-man in Bapsi Sidhwa's (1989) novel provides an intricate understanding of memory, trauma, grief, anger and violence. The inhumane rape, slaughter and mutilation of the women travelling on a train from Gurdaspur to Lahore is a traumatic incident that alters the character of Ice-candy-man and drives him to commit atrocities on his loved ones due to his inability to understand his own grief (Gagiano, 2010, p. 26). Thus, the way in which people were driven to violence due to the trauma they had to suffer as a result of larger political propaganda is made evident. His acts of violence cannot be understood in isolation as his trauma becomes an important part of his brutal actions. This is best captured when Lenny says that beneath the violence and misery of Ice-candy-man lays the "pitiless face of love" (Sidhwa, 1989, p. 183). The writer interrogates the homogeneous and generalizing views of ethno-religious violence by providing an intricate exploration of the Partition period. Thus, Ondaatje (2000) and Sidhwa (1989) highlight how history, memory, actions and experiences should be seen in their fragmentary elements to make meaning of the whole. The haunting nature of trauma and the extent of the violence that was generated from ethnic, racial and political turmoil are made evident in both novels as seen through these examples.

5. CONCLUSION

In conclusion, it can be stated that the novel *Ice Candy Man* (1989) by Bapsi Sidhwa and *Anil's Ghost* (2000) by Michael Ondaatje are postcolonial texts that interrogate power structures which construct monolithic ideologies that oppress and discriminate. The existence of a single notion of truth or reality is rejected by showing how identity and history are discursive constructions that operate based on hierarchical ideologies. Postcolonial texts become a source that challenges these dominant perspectives and dismantles marginalizing narratives. The way in which identities are constructed is determined by factors such as gender, sexuality, social class, ethnicity and race. The fluid nature of these aspects deconstructs the fixity associated with the concept of identity. Moreover, the multifaceted and fragmented nature of history is emphasized through the way in which the past is continuously constructed and reconstructed depending on the different forces of power that operate within society. Therefore, both Sidhwa (1989) and Ondaatje (2000) urge the reader to re-evaluate identity and history by analyzing the fragmentary elements that construct dominant representations. Thus, these two postcolonial novels critically interrogate existing power structures by providing a nuanced discussion of the concepts of identity and history.

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CAGING CHAT ROOM PREDATORS: THE LEGISLATIVE ADDRESS OF 'ONLINE CHILD GROOMING', A COMPARATIVE ANALYSIS OF SRI LANKA AND THE UNITED KINGDOM

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ABSTRACT

The most vulnerable sector of people are the minors, and that is a statement which can be pronounced with great confidence. Hence the duty of society to safeguard the offspring of its future cannot be renounced. With the advancement of technology and the access to such advancements readily available to children, sexual exploitation of the innocence of the juvenile via the internet has seen the light of day. Autonomous popularity of the social media and addiction inducing internet games can be identified as the contemporary breeding grounds for child sexual exploitation. This paper seeks to analyze the coherence of the Sri Lankan legal system, comparing it with that of the United Kingdom, in addressing online grooming of children to befall victims to sexual violations. Child grooming is an inchoate offence, upon which this paper elaborates further. The objective of this research is to determine the adequacy of the Sri Lankan legislative initiatives to address this novel form of child exploitation, focused mainly on the Penal Code of Sri Lanka. The methodology utilized for the purpose of this research is the Black Letter approach coupled with comparative research methodology with United Kingdom, and further this paper uses qualitative analysis of legislative enactments and case law as primary data and books and journal articles as secondary data. The research concludes with the view that, in Sri Lanka, legislative enactments are insufficient to address the inchoate offence of child grooming, which warrants amendments to the penal law.

KEYWORDS: *Child grooming, Inchoate Offence, Internet Sexual Exploitation*

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1. INTRODUCTION

The advancement of technology has no doubt been greater than the possibilities of human connection. It has evolved into a stage where for a conversation to take place, the physical presence of the communicators is redundant. This however, affects the norms of communication, and one could tend to behave differently in a virtual conversation compared to one conducted in person. This change of behavior could easily incite immoral conduct. Witness the proceeding passage of conversation;

"caspercock (1:26:46 PM): hello, enjoying yourself?

angelgirl12yo (1:26:53 PM): its ok

angelgirl12yo (1:26:57 PM): kinda quiet

caspercock (1:27:15 PM): what you doing?

angelgirl12yo (1:27:26 PM): just chattin

caspercock (1:27:49 PM): cool,

caspercock (1:28:05 PM): I like your name, got a pic?

angelgirl12yo (1:28:13 PM): no sorry

caspercock (1:28:23 PM): that's ok.

caspercock (1:28:28 PM): u really 12?

angelgirl12yo (1:28:35 PM): ya

caspercock (1:28:50 PM): that's cool

caspercock (1:29:08 PM): I've never chatted with someone 12 on here.

angelgirl12yo (1:29:16 PM): ok, nice meetin u tho

caspercock (1:29:24 PM): nice meeting you too.

caspercock (1:29:30 PM): I'm 21"

- *US v. Wales* (2005) 10th Cir.

The above extraction is an attempt to depict the immorality mentioned, and to venture to endeavour to the essence of grooming. Thimothy Wales was identified as the person behind 'caspercock', who had the stained record of being convicted of illegal sexual activity involving minors. (Clough 2010, p.331) The above extraction indicates an attempt which was curtailed by the coherence of the investigation officers of the police, who patriated as 'angelgirl12yo' to convict the culprit of attempted child sexual exploitation, consequent in imprisoning Timothy Wales for fifteen years. (Clough 2010, p.331)

A specific meaning to the word grooming or online grooming cannot be assigned, though widely appropriated, as of the case per innovations of linguistics prolonged via internet. (Craven, Brown, Gilchrist 2006, p.287) Yet it can be presented as the procedure of the potential abuser to gain acquaintance of the child with the intention of later sexual exploitation. (Gillespie 2002, p.411)

Though it appears in an extraordinary novel nature, the notion of grooming precedes the contemporary era, and with the enhancement of the advanced subtleness via internet, grooming has achieved a contingent prevalence. The child in dictating cultures was socially exposed only to a limited scope of persons, particularly contained from Akins to clergy. Apart from those circumstances, the minor was to be under continuous surveillance of the guardians. In the contemporary society this security to the child has been silently infringed by the internet, which provides private access to a child confined even to a room. (McGrath, Casey 2002, p.81) Yet resorting to advanced methods of communication would aid the prosecution of such offenders due to the digital evidence trailed behind by such offenders. (Clough 2010, p.333)

Grooming of children occurs gradually in most instances, which could be identified as;

1. Friendship forming stage
2. Relationship forming stage
3. Risk assessment stage
4. Exclusivity stage
5. Sexual stage

- (Black et al 2015, p.147)

Friendship forming Stage - This is the stage in which initial steps are taken by the offender to determine the eagerness of the child to engage in conversation at the commencing contact. This could occur in online chat rooms, online interacting games, and mobile phone and social network sites. (Clough 2010, p.333)

Relationship forming stage - Offenders attempt to investigate facts and establish the truth regarding the status of the minor at this stage, particularly children with troubled family support and those who suffer from isolation can be considered relatively effortless victims (Clough 2010, p.333) This vulnerability is the subject of exploitation of the offender coupled with the sexual curiosity to establish a prima facie sincere bond, which would encourage the child to protect the secrecy of the relationship. The wit shared in the force of psychology at this stage would pave the way for later sexual exploitation of the child. (McGrath, Casey 2002, p.87)

Risk-Assessment stage – This stage resembles the assessments the offender conducts in order to determine his own safety whilst proceeding further such as the location of the device, and he may inquire into the facts about the parents or other guardians. (Clough 2010, p.334)

Exclusive stage – The extension of the trust is to occur at this stage particularly with inducements being presented to the child. The victimization of the child at this stage would be subtle, which would render the child unaware of the later intent of exploitation. The communication would expand to more exclusive means such as e-mail, private chat rooms or telephones. As per the facts of the case *R v. Jongsma*, the victim had provided the home address of hers in order to obtain monitory and material incentives in exchange for sexual favours. (Clough 2010, p.334)

Sexual Stage - At this stage the offender would start to depict sexual intimacy in the forms of engaging in conversation regarding kissing to sexual activities. (Clough 2010, p.334)

Conclusion - The conclusion of the grooming would result mostly in meeting the minor and engaging in sexual activities. 74 percent would arrange such meeting and 93 percent of that would engage in sexual activities. (Wolak, Mitchell, Finkelhor 2004)

Each step above referred would be an essential part in the completion of the offence of sexual exploitation of the child. The concluding stage or the meeting of a minor to induce her to engage in sexual activities, and then going forward to participate in or physically commence the act of abuse or rape, can be considered as apparent even in sexual violation of the child throughout jurisdictions, Trans bound. What this paper attempts to emphasise is that the violation of the mind of the child in the process of grooming via the use of modern technological advancements takes place even when the child is, on their parents' opinion, is in the comfort and security of their own household. An underdeveloped mind of a child is at a high risk of succumbing to the persuasion and the inducement of the sexual predator using the modes of texting under presence to deceive the child.

The real threat and the inadequacy of the law of many jurisdictions to adequately address the issue of grooming has been identified as an issue that needs to be addressed for a while now (WoodRoyal report 1997). As exemplified above, the process of grooming the child necessarily precedes the commission of the actual offence of sexual violation, therefore, the nature of the grooming falls within the sphere of inchoate offences. The concept of inchoate offence is not an alien concept to legal systems, and it has been addressed in many ways such as, with the introduction of the concepts of attempt, incitement and conspiracy in more traditional sense. (Gillespie 2001, p.436) The matter at hand regarding the process of online grooming is that the said traditional methods are unsuited to meet the ends of it. Provided further that in some legal systems the offence of conspiracy cannot be established when the sole other party to the conspiracy is the potential and the intended victim. The Section 2(2) (c) of the *Criminal Law Act* 1997 of UK and section 11.5(3) (c) (ii) of Cf *Criminal Code* 1995, can be taken as examples. A similar case can be made regarding the incitement to commit an offence. It is true the child is incited by the defendant to engage in sexual conduct, but the person induced being the victim would negate the effects of the utilization of the concept of incitement, further incitement would require the other party to commit the offence in order to establish incitement. The attempt to commit an offence, as other traditional methods of addressing inchoate offences face a difficulty, for to establish the attempt the alleged act should be sufficiently

proximate to the offence intended to be committed. (Clough 2010, p.335)

Addressing of inchoate offence can be justified or explained under two major approaches, one being the consequentialist and the other retributive approach. (Ashworth 2006, p.471) This paper intends to favour the consequentialist argument, which emphasises on the prevention of the crime, for there is always the uncertainty of the extent the offender would go in such offences, which affects a minor. Therefore, without endangering a child, it is best to equip the law enforcement authority with laws which would enable the enforcement to prevent a child from being endangered rather than waiting for the completion of the offence of sexual exploitation to punish a culprit over the misery of the victim.

2. METHODOLOGY

The paper saliently relies upon the combination of Black- Letter (Doctrinal) methodology and Comparative research methodology through which the Sri Lankan jurisdiction is compared with that of the United Kingdom. The choice of the UK jurisdiction was influenced by the profound fluidity of the English legal system to uprooting technical advancements. As the main focus of this paper is to address the inchoate offence of Child Grooming, prominent attention has been given to the Penal Code of Sri Lanka as it is the piece of legislation which is mostly utilised in addressing criminality. Primary sources to this qualitative study will be the legislations of the countries and the case law which has been discussed covering the topic, as the secondary resources the aid of journal articles and books have been relied on.

3. DISCUSSION AND RESULTS

Inchoate offence

The subject matter of this essay which is grooming would have less qualifications to be considered as a completed offence, yet could be favoured to be recognised as an inchoate offence. Grooming would qualify as the preparatory conduct which is facilitating the incitement. (Clough 2010, p.336) The recognition of inchoate offences has been incorporated in legislature as attempt, conspiracy or incitement. (Ormerod 2011, p.402) Hence the facilitation of the incitement shall be merited in the purview of an inchoate offence. Preparatory incitement of the child for a meeting to advocate the minor to grant sexual favours to be more specific to the conduct as defined by an inchoate offence. (Ormerod 2011, p.402) Yet the highly merited conception that there is an inadequacy of the incorporation of the traditional offences of inchoate supplement the law relevant to grooming, in particular the offences of incitement and attempt. Even the offence conspiracy fails to qualify for such standard in most jurisdictions. (Clough 2010, p.335) If attention is to be advocated to the Sri Lankan legal competence in curtailing the inchoate offences, the penal code of Sri Lanka can be regarded as the prime legislation. Section 490 of the *Penal Code of Sri Lanka No.2 of 1883*, covers the attempt to commit an offence, which is with the pre-condition that an attempt should be made in order to commit an offence. It is a blurred area in the Sri Lankan situation because of the presence of an uncertainty regarding under which offence the grooming can be covered. In the Sri Lankan penal law, the incitement to be applied the requisite is, an act of incitement by one on the other, in order to make the latter commit an offence. The criminal liability should be imposed on the latter person (Peiris 1972, p.384) the matter at curtailing grooming with the use of incitement is that the persons incited are the victims themselves.

In order to address the legal lacuna in sufficiently curtailing the averment of the law regarding grooming, the continuum of the offence to be understood, is of vital importance. Even if there is a failure to bar the culprit from commencing and proceeding the offence, if the continuum of the offence be impeded it would be a virtuous deed in the pursuit of protecting the innocence. The continuum is manifested of the stages;

1. Presentation of the indecent or obscene materials to minors.
2. Grooming
3. Inducing or procuring
4. Traveling with intent (Clough 2010, p.337)

Presentation of the indecent or obscene materials to minors.

This would be an incident at the sexual stage of the communication with the child. The person's attempts to communicate indecent or obscene material to the child is of the nature to pursue such into subjecting the child to exploitation at a later stage. The materials stated could vary from the expressions of sexual gratification of oneself to the use of vulgar language. The communal method would be the expression of sexual desires via vulgar language in writing and transaction of images of exposure of themselves. This was emphasised in *R v. Burdon, ex parte Attorney General* (Qld) [2005] QCA 147. It is opportune to attempt to analyse the curtailing legislations to this stage comparatively with the United Kingdom, which has reached far in advancing through legislations to manage to address contemporary issues in contrast to outdated Sri Lankan legislations.

The United Kingdom had sophisticatedly implemented legislations tailored to the above instance, which is the transmission of the sexual context, most in particular at the instance, transmission via internet. *Sexual offences Act 2003* provided for such instances under section 12. The act might not have been promulgated deliberately to address the grooming of children via internet. Nonetheless, the section is neutral as the technological aspects warranting the admission of the section. As per to the section, it is an offence, if performed by a person of 18 years or above, to a person under 16 years of age or to a person believed to be 16 years of age by the doer, to cause to watch a third person engage in sexual activity or to look at any image of any person engage in sexual activity, provided for the purpose of obtaining sexual gratification. The offence created by the section, though contains sophistication in providing to curtail internet abuse for online grooming, it had failed to address the instances where anyone would expose oneself to a child or masturbate via internet, for the act only provides if photographs are sent, not the livestream of the sexual activity of that particular person.

If the child however retains such offline the offence would be completed. (Clough 2010, p.339) Apart from that blemish, the provision even provides for the comfort of the investigation of such crimes by the words "does not reasonably believe to be over 16" regarding the age of the victim, which abets officers to pose as minors under the anonymity of the internet to gather evidence to apprehend such sexual predators.

Sri Lankan legislations in contrast have failed to take notice of this issue let alone to specifically address it. The amendment which was made to the Penal Code of Sri Lanka in 1995 had somewhat attempted to expand the protection to the child from sexual exploitations to a certain extent. Section 286A inserted by the amendment provides legislation against obscene publications and exhibition relating to children. The section mainly focuses on obscene articles made of children rather than on material transmitted to the minor, hence it would be of little help. However, *Obscene Publication Ordinance No.4 of 1927* can be taken to shed a dim light interpreting the section 2(b) of the section, making or producing obscene cinematograph films for public exhibition. In order to qualify for public exhibition or to be considered as published, storage of data and the transmission of data to another should happen as elaborated in *R v Waddon* (1999) I.T.C.L.R 422. Therefore, the transmission of indecent materials to a minor via the internet would fall within this purview. The problem however arises regarding the predator exposing himself or engaging in masturbation through live feed, for amendment of 1995 of the *Penal Code* defines 'film' as any form of video recording, which would exclude the live feeds, for they are not recorded.

Grooming

This stage effects the offender to win the trust of the child through various methods resorted to. The preparatory conduct needs to be curtailed by law in order to provide convenient results, particularly this stage gives room for the investigators to identify the potential child abuses by the use of language and various incentives provided to the child or to the undercover officer posing as the child. When the trust of the child is secured the offender arranges a meeting with the child providing opportune time to apprehend

the culprit prior to the act of intended child abuse. In the Canadian case of *R v. Randall* [2006] NSJ no 180, where such an offender was apprehended and charged based on the undercover operation in which an officer posed as a child, the defendant argued that he, though wanted to meet the child, had no intention to proceed to sexual activities. The defendant's claim was refused, and it was held that the communication particularly through a computer had a serious intention apparent. It was sufficient to hold the person guilty.

In the United Kingdom again, by resorting to *Sexual Offences Act of 2003,* one could find sufficient means to address the grooming stage. Section 14 of the Act specifies the prohibition of conducts which facilitate or arrange the intent of the offender for the offender, or for someone else, of committing a prohibited act against a minor. This section extends to a vast scope. It not merely covers the conversations that took place through the use of the internet, but it even extends to whatever the preparatory acts offender had conducted with the intent of committing a child sex offence, as buying a ticket or a gift. Therefore, facilitation of the inducement of the child in the stage of grooming has been adequately addressed in the UK jurisdiction.

In contrast, Sri Lankan legislations have turned a blind eye on this matter. The section 360B (1) (f) of *the Penal Code* which provides provisions against sexual assault collaborates with the section 490, which addresses the act of attempt, is the only provision which throws light. Both sections can be utilized to prohibit the offering of incentives in order to pursue the child into performing sexual activities, but if the grooming of the child carried no apparent suggestions of engagement of sexual activity, said sections would not applicable.

Thereby the light casted by the provisions would fade away procuring a blind spot in law. Yet the penal code holds a provision which enables litigation when an offender uses influence over a child to conduct an abuse of the child in the 1995 amendment, Section 360B (1) (d), yet it could be only made relevant as an inchoate offence, while the requirement is to create an offence of the preparatory conduct.

Inducing or procuring

This is the stage in which the inducement occurs of the child to engage in sexual activities. It would be either to send indecent photographs or pursue the child to perform the act of masturbation or to make them watch the offender conducting such act. (Clough 2010, p.354)

United Kingdom has covered this stage of child grooming through the sections 8 and 10 of the *Sexual Offences Act*, which provides penalising intentional inducement of any party of a child to engage in any sexual activity. The phrase, 'sexual activity' has been interpreted to include even the act of masturbation and inducement to watch pornographic material.

In contrast, observing Sri Lankan Legislation's penal code by the amendment of 1995 has been able to adequately address this stage of the offence. Section 286A penalizes the inducement of any child to appear or perform any indecent or obscene exhibition. Technological neutrality of this provision has made this capable of being utilized against child grooming through the internet, particularly unlike in *the Sexual Offences Act* sections 8 and 10, which has caused an ambiguity regarding the term 'engage in sexual activity', which was interpreted to be included inducing a child to masturbate, Sri Lankan legislation has specially specified the nature of the act 'indecent or obscene exhibition', which warrants the application to a larger scope.

4. CONCLUSION

A child vulnerable owing to the absence of care or conflicting parents, particularly in a cultural context as of Sri Lanka where children are taught to trust elders, curtailing online grooming adequately presents a contemporary necessity. Supplemented by the tendency of a child to open up about their problems to a faceless stranger. Strengthening the evidence ordinance to counter such misuse of technology by *the Evidence (Special provisions) Act 1995* is a positive step forward. Yet the requirement of legislations following the structure of *Sexual Offences Act of UK* is apparent, particularly to apprehend an offender before an irreparable damage is caused to a child, by

adequately addressing the offence of online child grooming, strengthening the inchoate offences regarding computer based child sexual exploitation, for prevention is always better than cure.

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ANALYSIS OF LAND SURFACE TEMPERATURE VARIABILITY OVER THE INDUSTRIAL ZONE DURING THE LOCKDOWN PERIOD OF COVID-19 PANDEMIC BY USING SATELLITE REMOTE SENSING AND GIS

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ABSTRACT

Rapid industrialization is one of the concerns that lead to climate change in the current world. With the advancement of industrialization declining, vegetation cover becomes inversely proportional to the rise of built-up areas. Export Processing Zones (EPZ) are playing a vital part in the economy of any country, and there are usually associate with some environmental issues. Due to COVID 19 pandemic, the Sri Lankan government declared a lockdown period from 20th March to 11th May 2020 and the EPZ zones have not functioned during that time. Therefore, the present study concentrates on examining the land surface temperature variation during the lockdown period and the normal working time in Seethawaka EPZ. The long-time record of remote sensing satellite images was beneficial in time series analysis. Consequently, the Landsat 8 satellite images were used for the research, and the processing was accomplished in the ArcMap 10.5 software environment by using the temperature extraction method defined by the NASA and United States Geological Survey. Rendering to the study that reveals there is considerable temperature variation during lockdown time and the normal working day. As an outcome of the study, its illustrations a decrease in the temperature during the non-working day compared to the normal working day. Further, it shows mean temperature increase concerning the NDVI ranges throughout the working day than on the non-working day, which indicates the effect to the air temperature upsurges due to the working condition. In conclusion, it highlights the requirement of careful environmental monitoring over the area for conservation and temperature control. Although we might not proceed with development devoid of proper industrialization, it is vital to revenue necessary actions for the sustainability of these zones. Hence, continuous measuring of climatological parameters over these areas, making green walls in between buildings, using eco-friendly building materials were the possible actions that could take as solutions.

KEYWORDS: *Covid-19, Epz, Remote Sensing, Temperature, UHI,*

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1. INTRODUCTION

The quantity of export processing zones (EPZs) has been expanded in developing countries in recent years (Cling, Razafindrakoto and Roubaud, 2005). These EPZ plays a vital role in the economic expansion in developing countries (Shah and Rivera, 2007). However, EPZs are basically isolated from the internal economy, and useful for developing countries to collaborate with foreign investors freely by obeying the rule and regulations of the country (Jayanthakumaran, 2003).

Even though the EPZs are vital in the economy it may be a threat to the nature due to the misuse of the environment and can cause a negative impact on the nature (Cling, Razafindrakoto and Roubaud, 2005). Several environmental problems can be highlighted in these EPZs such as temperature increases, air and water pollution, collection of solid hazardous trashes, noise radiation, soil infection, and chemical hazards. Sometimes these problems are not associated with a single industry, and it is due to the whole zone. Environment and biodiversity defeat, reduction of water reserves, and terrain disruptions can be highlighted as the major issues in concern. Although, on the other hand when all these industries are together it will be important for providing facilities, reducing transport cost, increasing collaboration among organizations etc. Further, the population growth of the EPZ could be identified as the foremost secondary challenge of these areas which could lead to various associated complications with the environment (Shah and Rivera, 2007).

Under this investigation, it is supposed to analyze the land surface temperature difference of the EPZ on normal working days and non-working days. Due to the COVID-19 pandemic, the Sri Lankan government declared a lockdown period from 20th March to 11th May and all these zones were not occupied in that period. This brought an advantage for this study since it is difficult to find non-working days for these EPZs. As a consequence of the difficulty to access EPZ in the lockdown phase the remote sensing provide the best platform to analyze such scenarios remotely which made this study more flexible compared to manual data collection.

The development of satellite technology enhances the remote sensing analysis in various ways and the monitoring of Land Surface Temperature (LST) highlighted as one of the important phases (Weng, Lu and Schubring, 2004). The Thermal infrared (TIR) remote sensing consents for the compilation, assessment, and modeling of ecological factors. The TIR remote sensing is crucial in measuring LST which is the foremost concerning factor in ecological related approaches, for instance, global warming or Urban Heat Islands (UHI) analysis (Taylor and Kim, 2007). The long-time record and the free availability of Landsat satellite image provide the best tools to assess environmental related problems (Feizizadeh and Blaschke, 2012) and the thermal bands of Landsat 8 satellite provide the best platform for examining the LST variations efficiently and effectively.

2. METHODOLOGY

Study Area

Analyzing the temperature variations requires collecting the data of the industrial zone. Hence due to the availability of the satellite data during the lockdown time the Seethawaka EPZ zone (6.9599° N, 80.2067° E) was selected (Fig. 1).

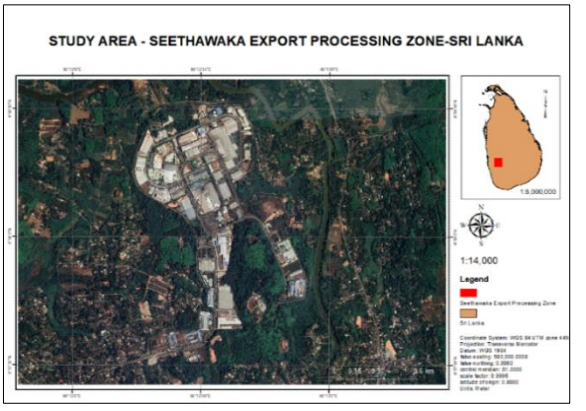

Figure 1: The study area under the investigation, Seethawaka Export Processing Zone-Sri Lanka (6.9599° N, 80.2067° E). Coordinate System: WGS 84 UTM Zone 44N Source: Google earth Image.

Seethawaka EPZ was established in 1999 and it is the only zone located in Colombo District and a 47 Km away from Colombo. Approximately 431 acre area is encompassed and around 21,500 people are employed in Seethawaka EPZ (Karunaratnen and Abayasekara, 2013). There are currently 27 enterprises in commercial operation at the Seethawaka zone that are involved in the manufacture of Apparel & Accessories, Glove Products & Rubber Products, Fabric, Chemical & mineral, Printing, and food processing. Buildings, roads, and barren lands are the primary land use and land cover types in the study area, and further, the surrounding area covers with a vegetative zone.

Data used

The Landsat program is the longest-running innovativeness for the acquisition of satellite imagery of Earth. It delivers a greater platform to remote sensing applications in a medium resolution scale. In this study Landsat-8 data (U.S. Geological Survey, 2019) were used as the main data source which were downloaded from U.S (Table 1). Geological Survey (USGS) using Earth Explorer. The thermal band basically utilized for the temperature extraction and the Near Infrared (NIR) and Red bands were occupied for the correction over the images through Normalized Difference vegetation Index (NDVI) (http://earthexplorer.usgs.gov).

Table 1: Data used for the analysis *Weather Source: https://www.accuweather.com/*

Time Period	**Date**	**Time**	**Weather**
Before the Lockdown	2020-02-23	04:53:55.5011040	Sunny
During the Lockdown	2020-04-11	04:53:33.1560590	Sunny

The Workflow of Investigation

The whole workflow of the study was based on Landsat data processing and statistical analysis in an ArcGIS environment. Under the investigation, two Landsat images that obtain Before the Lockdown (Normal Working Day) and During the Lockdown (Non-Working Day) were processed and analyzed. The overall approach of the study can be described as follows.

Landsat Thermal Band Analysis

The preprocessing of data is a crucial step in the remote-sensing analytical workflow. Therefore, firstly the images were corrected geometrically and radiometrically. Then conversion from DN to radiance and sun angle correction were performed over the images, respectively (U.S. Geological Survey, 2019).

The phases of the analysis are described in Fig. 2.

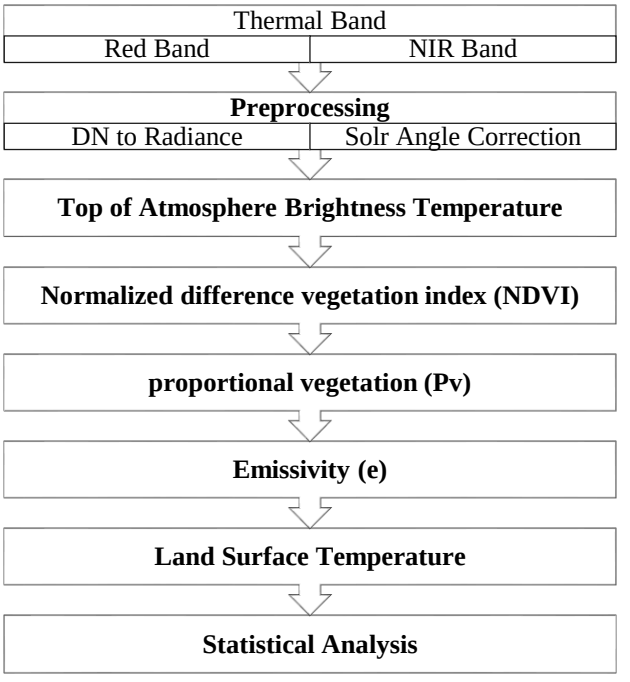

Figure 2:. The overall approach of the experimental analysis

OLI and TIRS at Sensor Spectral Radiance

Images were processed in units of absolute radiance using 32-bit floating-point calculations (Young *et al.*, 2017). These values were converted to 16-bit integer values in the finished Level 1 product. Then converted to spectral radiance using the radiance scaling factors provided in the metadata file of the image (U.S. Geological Survey, 2019):

DN to radiance conversion.

$L\lambda = ML * Qcal + AL$ ----------(1)

Where:

- $L\lambda$ = Spectral radiance (W/(m2 * sr * μm))
- ML = Radiance multiplicative scaling factor for the band (RADIANCE_MULT_BAND_n from the metadata)
- AL = Radiance additive scaling factor for the band (RADIANCE_ADD_BAND_n from the metadata)
- Qcal = Level 1-pixel value in DN 5

Correction for solar elevation angle($P\lambda$)

$P\lambda = L\lambda /Sin$ (Sun Elevation) ----------(2)

Where:

$L\lambda$ = Spectral radiance (W/(m2 * sr * μm)) ------(3)

TIRS Top of Atmosphere Brightness Temperature

The top of atmosphere brightness temperature is a measurement of the radiance of the Thermal Infrared radiation drifting upward from the top of the atmosphere to the satellite, expressed in units of the temperature. Subsequently the top of Atmosphere Brightness Temperature was obtained by using following equation(U.S. Geological Survey, 2019).

$T=K2/\ln (K1/L\lambda + 1)$ ----------(4)

Where:

- T = Top of atmosphere brightness temperature (K)
- $L\lambda$ = TOA spectral radiance (Watts/ (m2 * srad * μm))
- K1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number)
- K2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number)

The resulted temperature value in kelvin and it will be converted to degree by using following equation.

Conversion of degree kelvin into Fahrenheit (TF)

TF=T-273.15 ----------(5)

Where:

- T = Top of atmosphere brightness temperature (K)

Computing the Normalized difference vegetation index (NDVI)

NDVI introduced Tucker in 1979 as an index of vegetation wellbeing and thickness. The NDVI is a simple vegetation index that widely used for vegetation related analysis and in various aspects (Singh, Roy and Kogan, 2003) by using NIR and RED are the reflectance in the close to infrared and red groups. NDVI varies from -1 to +1 and a decent marker of green biomass, leaf region index, and examples of creation. Landsat noticeable and close infrared groups were utilized for ascertaining the NDVI. The significance of assessing the NDVI is fundamental since the measure of vegetation (Li, 2011) present is a significant factor and NDVI can be utilized to induce general vegetation condition. NDVI has become an essential indicator for mapping changes in vegetation spread and investigating natural effects.

NDVI= (NIR-RED)/ (NIR+RED) ----------(6)

Where:

- NIR= Near Infrared Band
- RED= Red Band

Then the Proportional vegetation was calculated by using the maximum and minimum of NDVI result images in each year.

Proportional vegetation (Pv)

This Pv gives the estimation of area under each land cover type (U.S. Geological Survey, 2019).

Pv= ((NDVI-NDVImin)/ (NDVImax-NDVImin)) 2 -------(7)

Emissivity (e)

Then e calculated by using the previous resulted Pv value of each image (U.S. Geological Survey, 2019).

Emissivity

e = 0.004*(Pv) + 0.986 ----------(8)

Land Surface Temperature

Finally, the top of atmosphere brightness temperature was converted to Land Surface Temperature (LST) via following equation by utilizing previously calculated emissivity value (U.S. Geological Survey, 2019).

LST can be retrieved using the equation.

LST=BT/ (1+W*(BT/P) *ln (e)) ----------(9)

Where,

- BT= satellite brightness temperature
- W=wavelength of emitted radiance
- P= 14380
- P= h*c/s
- h= Plank's constant (6.626 x 10-34)
- s= Boltzmann constant (1.38 x 10-23 J/K)
- c=Velocity of light (3 x 108 m/s).

Source of the calculation: (U.S. Geological Survey, 2019).

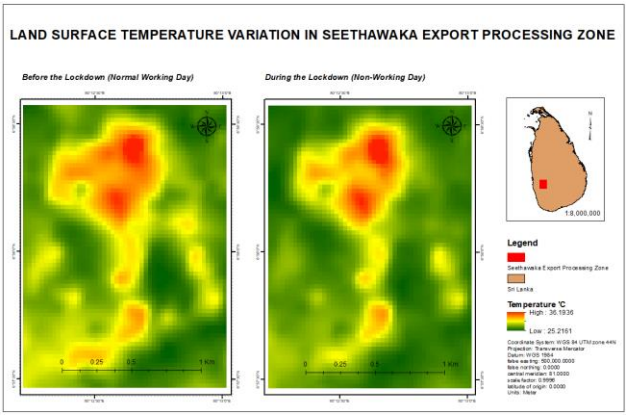

Figure 3: The Land surface temperature variation in Seethawaka EPZ Before the Lockdown (Normal Working Day) and During the Lockdown (Non-Working Day). Coordinate System: WGS 84 UTM Zone 44N. Source: Landsat 8 Satellite Images

3. RESULTS

The variation of temperature before and after the lockdown could be identified as a key finding of the study. The resulted maps show comparative difference of temperature during the two periods as in figure 3. It demonstrates the fluctuation of temperature in Seethawaka EPZ during the normal working day and the lockdown time indicating the fact that during the working day temperature has risen higher than on the non-working day. This reveals that when all the factories are occupied there is a considerable amount of temperature upsurge in the study area. This may be due to factory carbon dioxide emission, fuel consumption, the material of the building, the layout of EPZ, population around and their anthropogenic activities etc.

NDVI is well-known indices in vegetation mapping and evaluation. The investigation highlighted the fluctuation of NDVI value in two different periods with the LULC category. As the temperature variation, the NDVI also highlights the low NDVI for the building and bare earth while there is a rich NDVI value for the vegetation areas. The NDVI indicates the differences between the vegetation cover over the area during the two periods. The highest NDVI values indicate rich

vegetation covers and the smallest NDVI values denote the built-up areas.

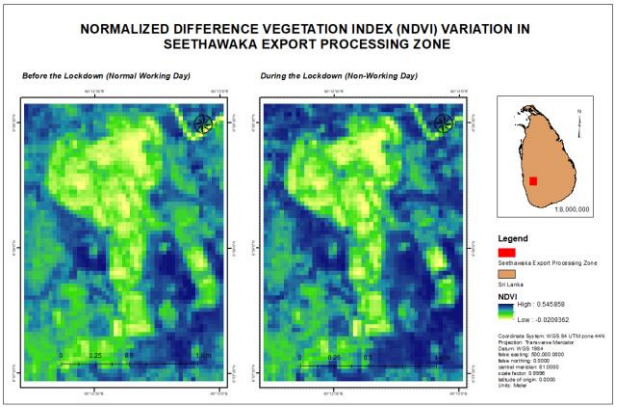

Figure 4**:** The NDVI maps of the Seethawaka EPZ Before the Lockdown (Normal Working Day) and During the Lockdown (Non-Working Day) lockdown
Coordinate System: WGS 84 UTM Zone 44N
Source: Landsat 8 Satellite Images

Bigger NDVI values show that the land surface was secured with thick solid vegetation, while negative qualities demonstrate the nearness of mists, a day off, or a brilliant non-vegetated surface (Chen *et al.*, 2006). Hence the above NDVI map (Fig. 4) of before and after lockdown shows the condition of the land use land cover (LULC) classes since the NDVI analysis is a good indicator of measuring the condition of the vegetation and land.

The LULC forms have strongly correlated with the variation of thermal radiation, for example, the industrial locations and heavy urban regions were warmest, and forest and vegetated areas were coolest (Xian and Crane, 2006). Then the LULC classes of the Seethawaka EPZ were identified and the point sample for the analysis was collected from the Google Earth images. Then, extracted the temperature of each LULC type in the ArcGIS environment from the resulted satellite images. The following figure 5 describes the variation of the temperature of different LULC during the two periods.

The percentage of mean temperate variation in each LULC class is shown in the following table 2.

Table 2: The mean temperatures of each LULC before and after the lockdown

LULC Type	Mean Temperature		Precentage of Difference
	Before Lockdown	During Lockdown	
Building	32.80	32.27	1.60%
Bare earth	29.23	28.31	3.13%
Vegitation	25.86	25.22	2.47%
Water	25.84	25.30	2.09%

Following Figure 5 describes the detailed explanation of the above figure, the temperature variation with regard to the land use land cover type on the ground.

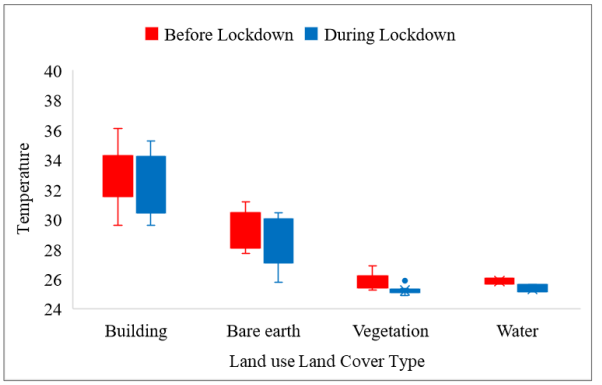

Figure 5: Temperature difference in each LULC in Two periods

Then examined the distinction between NDVI values in the two time periods for each LULC category of the study area in order to identify the comparative variation (Fig. 6). Further, it designates less fluctuation of NDVI values in manmade features against the comparatively high variation in natural features with respect to the temperature fluctuation.

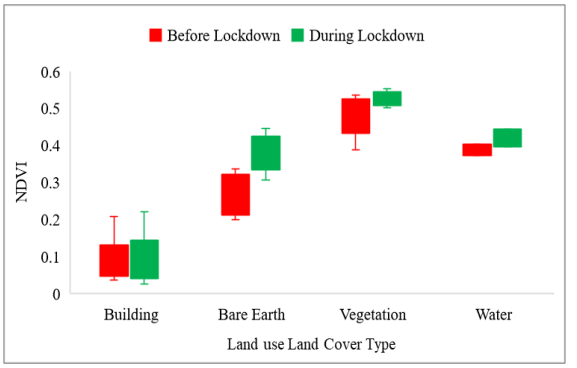

Figure 6: NDVI difference in each LULC in Two periods

4. DISCUSSION

Rendering to the study, it shows the fluctuation of temperature in Seethawaka EPZ during the normal working day and the lockdown time. This indicates when all the factories were occupied there is a considerable amount of temperature upsurge in the study area. This may be due to factory carbon dioxide emission, fuel consumption, the material of the building, the layout of EPZ, etc.

Further, this study indicates that different LULC types have associated a temperature class which varies with the feature type, texture pattern, contamination, etc. In addition, it shows a less amount of temperature variation in Building areas related to other areas even in the lockdown time as the same fluctuation of NDVI values. Further, it highlights the importance of the building materials and the layout of the zone for temperature conservation.

LST and NDVI are two variables that contain interrelationship between them. Then a correlation analysis was performed among the LST and NDVI to examine the interrelationship between the variables. The resulted graph (Figure 7) indicates the positive correlation between the LST and NDVI during the two times.

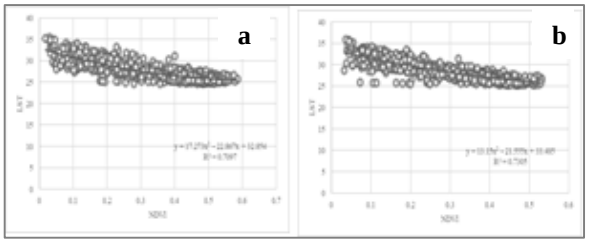

Figure 7: Correlation analysis among the LST and NDVI in two time periods (a) (Normal Working Day) (b) During the Lockdown (Non-Working Day)

NDVI is utilized not just for the exact depiction of land spread, vegetation grouping and vegetation phenology, but on the other hand, it is utilized adequately for observing precipitation and drought, assessing crop development conditions and harvest yields etc. (Singh, Roy and Kogan, 2003). NDVI is well-known indices in vegetation mapping and evaluation. The investigation highlighted the fluctuation of NDVI value in two different time periods with the LULC category. As the temperature variation, the NDVI also highlights the low NDVI for the building and bare earth and a rich NDVI value for the vegetation areas. Further, it designates less fluctuation of NDVI values in manmade feature against the comparatively high variation in natural feature same as the temperature fluctuation.

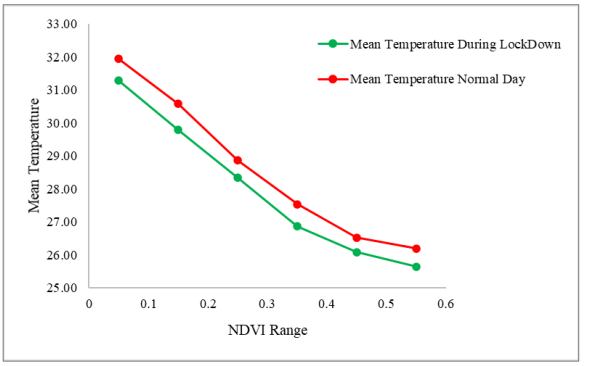

Figure 8: NDVI ranges and respective Mean temperature decreasing in normal working day and non-working day.

Then the fluctuation of temperature with respect to the NDVI ranges were examined during the two times. For both instances, the mean temperature values of the same NDVI range have been varied (Fig 8). Comparatively, lower temperature values could be observed at the non-working day than at the working day as per the Table 3.

Table 3:Mean Temperature fluctuation with respect to the NDVI ranges

NDVI Range	Mean Temperature	
	During Lockdown	Normal Day
0.0-0.1	31.28	31.94
0.1-0.2	29.79	30.58
0.2-0.3	28.34	28.86
0.3-0.4	26.86	27.53
0.4-0.5	26.08	26.52
0.5-0.6	25.64	26.19

The LULC forms have strongly correlated with the variation of thermal radiation, for example, the industrial locations and heavy urban regions were warmest, and forest and vegetated areas were coolest (Xian and Crane, 2006).

Then the LULC classes of the Seethawaka EPZ were identified and the point was selected for the analysis from the Google Earth images. then, extracted the temperature of each LULC type in the ArcGIS environment from the resulted satellite images.

Further, this study indicates that different LULC types have associated a temperature class which varies with the feature type, texture pattern, contamination, etc. In addition, it shows a less amount of temperature variation in Building areas related to other areas even in the lockdown time as the same fluctuation of NDVI values. Further, it highlights the importance of the building materials and the layout of the zone for temperature conservation.

5. CONCLUSION

Freely available medium-resolution Landsat images were beneficial in time series analysis remotely. This study highlights the importance of remote access to the data in such pandemic times since the manual data collection was at high risk.

Further, this study shows the percentage of variation of temperature during the working and non-working time of the industrial area. The UHI could be identified as the foremost swelling issue due to the temperature rises of an area because of the building coverage and the industrial process. It concludes when the industry gets occupied there is considerable temperature fluctuation comparatively. Hence all the environmental authorities should focus on maintaining the conservation of the environment in such industrial zones while balancing the temperature fluctuation. Since the temperature increases directly affect the livelihood of people animals and finally nature. Therefore, any industrial area should maintain a green area ratio among the built-up area, and the vegetation cover and the green wall in between the buildings is also vital. These strategies should come as a policy development of the country. In addition, this study reveals that even the industrial area does not affect the features against the natural temperature variation of manmade features which is low. Hence the occupying of the EPZ is not the only factor that affects the temperature increase. Therefore, we have to consider the building materials, the layout of the EPZ, height, and shape of the buildings etc.

More or less these EPZs are vital to the economy, and we cannot neglect them. As a developing nation, we should go with industrial development and otherwise being a developed nation would only be a dream. Hence, we need proper development for the country while maintaining production. Therefore, the process of development should be sustainable and eco-friendly which caters to the current requirement of the country. After all, the reduction of temperature during the lockdown time in EPZ gives us a silent message that the earth gets recovered during the COVID 19 time.

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IDENTIFICATION PARADES: THE EVIDENTIARY VALUE & THE CREDIBILITY OF THE WITNESS IN IDENTIFYING SUSPECTS FOR CRIMINAL INVESTIGATIONS IN SRI LANKA

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ABSTRACT

The term Identification does not only refer to Fingerprint Identification but also to voice identification, footprint identification and identification parades. However, the present paper focuses only on identification parades. According to the Oxford Learner's Dictionary, the term Identification Parade means "a row of people, including one person who is suspected of a crime, who are shown to a witness to see if he or she can recognize the suspect.". Identification parade is an important criminal investigation tool to catch the real perpetrator. When a person is suspected of committing a particular crime, that person is directed to an identification parade. In an identification parade, there is a line of people including the suspect who stands next to each other while the witness tries to recognize the person who has actually committed the crime. The research problem of this study is whether the evidence provided by the witness in an identification parade is actually accurate, or is there any credibility of the evidence provided by the witness in an identification parade. Also, the study explores the research question, does such evidence actually assist criminal investigations? This is an important question especially in the context of reported misidentifications in many jurisdictions at such identification parades. Therefore, this paper focuses on the evidentiary value of identification parades as it is one of the vital criminal tools in criminal investigations to catch the real offender. Also, it will elaborate on the procedure of identification parades conducted in Sri Lanka in order to make the public more enlightened on this subject. Further, the credibility of the witness on the identification of suspects in the eyes of the court will be discussed. This research was conducted through black letter approach and the critical analysis method. Also, the qualitative research method was used. Data were collected through primary and secondary sources. Primary sources consisted of national laws of Sri Lanka, and the secondary sources were the published books, e-journals, and e-books. One recommendation brought out by the study is that the police must be trained to use new techniques and should not contaminate the evidence obtained from IDPs. Also, updated information and knowledge about the proceedings must be given to the law enforcement officers. Additionally, government too has a responsibility to give facilities when conducting IDPs.

KEYWORDS: *Evidentiary-Value, Credibility, Identification-Parades, Criminal Investigations*

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1. INTRODUCTION

According to Rajamanickam & Kung, identification parade means "a line of people who stand together and the victim tries to recognize the person who has committed the crime." (Rajamanickam and Kung, 2017). Identification of persons plays an important role in the criminal justice system. In a criminal trial, it is difficult to identify the real perpetrator. Sometimes not only the accused but also the victim needs to be identified. This identification of persons is basically determined on visual identification. In an identification parade, the witness will first identify the accused's appearance and thereby recognize the person who was connected to the incident. In some instances, the witness can remember the name of the accused. In Sri Lanka, once a suspect is arrested, an identification parade must be held by the Magistrate or by an Attorney at Law nominated by him. An Identification Parade must be held in instances such as when the witness is unaware of the name of the accused, or when the witness can recognize the particular accused who was connected with the incident.

The law with regard to identification parades was introduced by the English law to our system. In our law, the procedure of the identification parade is not specifically stated. In most other jurisdictions the identification parades are conducted by police officers at the police stations. But in Sri Lanka, there is no any mechanism for a police officer to conduct an identification parade. According to section 124 of the criminal procedure code, a magistrate must guide the police to conduct the identification parade. (Criminal Procedure Code of Sri Lanka, 1979).

Not only the Magistrate and the police but also lawyers, prison officers and members of the court have a duty to conduct the identification parades carefully and responsibly. Generally, a parade will be conducted in the court premises. Therefore, identification parade (hereinafter this term will be used as IDP) plays a very important part of the investigation for the court to determine the credibility of witnesses on the point of identification. (Rajamanickam and Kung, 2017).

2. METHODOLOGY

The study was conducted using the traditional black letter approach and the critical analysis method. Also, the Qualitative research method was used. Data were collected through primary and secondary sources. Primary sources consisted of national laws of Sri Lanka and India; especially from the Evidence Ordinance of Sri Lanka, Code of Criminal Procedure of Sri Lanka and the Indian Criminal Procedure Code. Secondary data were obtained from published books, e-databases, e-journals, e-books and theses and dissertations with special focus on definitions, history, issues, procedures, evidentiary values, case laws and application of the law etc. Validity of the data has been highly taken into consideration. Existing literature on the present topic is extremely sparse, in contrast to other jurisdictions, for which sufficient literature is available (Perera E.M.N, 2019).

3. DISCUSSIONS & FINDINGS

3.1 The Procedure of identification parades in Sri Lanka

First of all, the police officer must submit a report to the magistrate court by requesting to hold an Identification Parade. The witness must be kept outside the court premises and the witness cannot see how the suspects are taken inside the court premises for the identification parades. The magistrate has a duty to examine the prison bus where the suspects are kept for the IDP. Also, he/she must ensure that no outsider can see the suspect in the bus. And also, the windows of the bus must be properly covered. The necessary security must be provided for the bus.

The magistrate must order the police to select six persons to attend the IDP. These six persons must be selected from the public such as those people who came to the court for different purposes. When selecting those persons, the police have a duty to ensure that those people have the same features like the suspect. It is essential to maintain the 6:1 ratio. The magistrate has a duty to ensure that the court is fully covered before the IDP. Then, the Magistrate must order the police to bring the persons to the IDP from the general public. Next, the magistrate must order the police to leave the parade hall. Also, the

magistrate must send a message through prison officers to bring the suspect from the prison bus by fully covering the suspect into the parade hall.

The doors of the Identification Parade Hall are closed once the suspect is taken inside the parade hall. Then the grab cover of the suspect must be removed by the prison officers. Details of the suspect must be handed over to the magistrate by the prison officers and then the magistrate must be satisfied that the particular suspect brought by the prison officers is relevant to this particular case. After that, the magistrate must order the prison officers to leave the parade hall.

The suspect has a right to change his hair, clothes, apparels and footwear, and also, he has a right to stand at any place among the other six persons who have been taken into the court for IDP. They should be in a standing position. There is no harm in giving a number to each person including the suspect who is taking part in the parade. The number should be clearly visible to the magistrate. Then, on the order of the magistrate, witness should be brought inside the parade hall. The moment the message is conveyed and before the witness is brought to the door, the suspect is again entitled to change his clothes and position in the parade before the witness enters the hall. After the witness was taken inside the parade hall, the doors of the parade hall should be closed. Then the witness must establish and prove his identity to the Magistrate. The magistrate must then be satisfied with the identity of the witness. Next, the Magistrate must inquire whether the witness could identify any perpetrator that was involved in the incident. The magistrate shall not put leading questions to the witness.

To understand the role and the behavior of the witness, the magistrate has a duty to go through the brief or the summary of the evidence when submitting the B report by the police. For instance, sometimes the witness only saw the suspect enter the gate of the house. Instead of reminding those details, the magistrate must merely pose a general question whether the witness could identify any person that was involved in the incident. Once the witness gives the answer, he should be allowed to proceed along the parade where the 7 persons are standing. The witness should be told that he must touch the suspect and show to the magistrate if he has identified the suspect. Magistrate cannot force the witness if he cannot touch the suspect. In such an instance, the witness must use the number that is displayed on the garment of the person.

Before the witness enters the hall, his face and body can be covered. Or he could be kept at a covered place in the hall, and requested to identify the suspect from a distance. This type of a procedure is allowed under section 124 as amended. (Evidence Ordinance of Sri Lanka, 1988).

If a witness is brought in a covered position, the magistrate must ensure that he is the witness referred to in the B report and not anyone else. If the magistrate fails to take these precautions, the defense can make accusations later that under the guise of covering, a police officer had come to make the identification. If the witness identifies or recognizes the suspect as the real perpetrator, the magistrate has a duty to ask to explain the acts done by that particular suspect with regard to that incident. Under that explanation, the witness must explain where the suspect and the witness were when the incident was taking place. These precautions are taken with a view to elicit the evidence only from the mouth of the witness and not from the mouth of the magistrate.

Once the witness explains the incident and the role played by the suspect, the witness should be taken out of the hall. After that, once again, the suspect may be given an opportunity to change his appearance such as by changing his hair, dress, and shoes. He may be also given an opportunity to change the place where he stood at the parade. Then the other witness is called upon (witness number 2) to the court. Witnesses who have observed the parade should not be allowed to communicate with the witnesses who have not gone before the parade. The same procedure should be followed with the second witness. The parade can be held for any number of eye witnesses. Once the parade is over, the magistrate shall inquire from the suspect whether he wishes to say anything about the conduct

of the parade. If the suspect responds, the magistrate shall record the same.

During the IDP, no one can enter the parade hall and also no person inside the parade hall can leave the parade hall. Even the lawyers who are involved in the case cannot leave the parade hall before the conclusion of the IDP. Also the lawyers who are not a party or not involved in the case cannot remain inside the parade hall. Even the law students and apprentices are not allowed to remain inside the parade hall. Therefore, they may not get any experience as to how the parade was conducted. All the precautions are taken to minimize the leaking of information regarding the suspect to witnesses.

If the suspect or his lawyer objects to hold the parade, then it should be recorded and the magistrate cannot abandon holding of a parade. Lawyers cannot cross examine the witness. Even the lawyer of the prosecution cannot ask questions from the witness during the IDP. But the prosecuting counsel can assist the magistrate if a request is made. For example, the prosecuting counsel may help the magistrate when formulating the question that should be put to the witness. The prosecuting counsel must assist to hold the parade in a fair manner so that neither party is prejudiced.

If a witness in his statement to the police stated that he had observed some special features like birth marks or cut marks on the face of the suspect, it would be very difficult to select such persons from the general public for the purpose of the parade. Therefore, a magistrate must take necessary precautions to cover such special feature from the face of the suspect and cover the same place of other persons who take part in the parade. This safeguard is taken in order to ensure that the witness identifies the suspect only through the features on the face and not due to any birth mark or any other special mark.

Once the witness points out the suspect, the magistrate should ask from the witness the role played by the suspect during the incident. The magistrate should not refresh the memory of the witness by reminding the contents of the statement the witness had given to the police. At the trial, the Defense can mark contradictions on such utterances. If the magistrate had spoon-fed the witness at the parade in keeping with the statement to the police, at the trial, the defense may not be able to properly test the credibility of the witness. It also has to be borne in mind that no lengthy questioning is to be carried out at the parade. (Meezan, 2011)

3.2 Rights of parties in an Identification Parade

When it comes to the rights of the suspects in an identification parade, according to the procedure of an IDP which was mentioned in the previous subtopic, the suspects have several rights in an identification parade as given below;

- The suspect has a right to change his hair, clothes, apparels and footwear.
- He has a right to stand at any place among the other six persons who have been taken into the court for an IDP.
- The suspect has a right to change his clothes again, and position in the parade before the witness enters the hall.
- Before the second witness is brought to the parade hall, once again the suspect has a right to change his appearance such as by changing his hair, dress, shoes and even has a right to change the place where he stood at the parade.
- After the parade, the judge must give an opportunity for the suspect to ask anything with regard to the conduct of the parade.
- The suspect and his lawyer can object to hold an IDP. Which means the suspect has the right to accept or refuse the request of an IDP.
- Also, the suspect has the right to know about the purpose of the parade.
- The suspect has the right to request the presence of his attorney at the IDP.

Apart from that, Article 13(3) of the Constitution of Sri Lanka states that “any person charged with an offence shall be entitled to be heard, in person or by an attorney-at-law, at a fair trial by a competent court”

(Constitution of Sri Lanka, 1978) because Article 13 (5) of the Constitution of Sri Lanka states that "every person shall be presumed innocent until he is proved guilty." (Constitution of Sri Lanka, 1978)

When it comes to the rights of the witness in an IDP, it can be highlighted as follows;

- The magistrate cannot force the witness if he cannot touch the suspect. Therefore, the witness has the right to point out the suspect by the number displayed on the suspect.
- The witness has the right to take time when making his identification.

3.3 The Evidentiary Value of the Identification Parades

In the procedure of Identification Parade, Magistrate will ask questions from two witnesses, rather than from one. Then, if both the witnesses are saying the same thing such as "this is the person I saw in the incident", and pointed out the same person, then that is a reliable evidence. And that is why in an identification parade, the evidence will be taken from two witnesses. Therefore, an identification parade is a reliable method of collecting evidence. It will be fair for both the suspect and the witness.

Another finding is that, throughout the identification parade procedure there is a strict procedure not to allow people who are not a party to the case to enter the parade hall. Even the lawyers who are not a party to the case would not be permitted and also the law students, or apprentices cannot be in the parade hall. Most scholars have stated that it is a huge disadvantage to them because they do not get an opportunity to learn something as future legal practitioners. But some scholars have mentioned that it is good to have such restrictions to protect the confidential information about the suspect because that person is still a suspect of the incident and not an offender.

Some scholars have mentioned that the suspect should not be covered when he is taken to the parade hall, and the face of the suspect must be shown to the general public. According to the law, the suspect is considered innocent until proven guilty. For instance, supposing 'A' was arrested as a suspect of a murder but that suspect is not the actual killer. Therefore, it can be clearly seen that if the suspect 'A' is taken to the parade hall without covering him, the general public might think that he is the real perpetrator of the murder and after the case that suspect cannot face society. Also, there might be a miscarriage of justice and it will lead to a wrongful conviction.

Through the identification parade procedure, the suspect is given an opportunity to change his appearance. Even if there was any mark on the suspect's face when the incident happened, the suspect is given a chance to cover that mark. So, this literally means that, only a witness of strong evidence can recognize the suspect even that particular suspect covers the mark of his face. For instance, supposing suspect 'B' killed 'C' and that particular suspect has a mark on his face. Think that during the identification parade that particular suspect covered that mark; but if the witness has a strong memory of that day's incident of the murder, even though the suspect covers his mark, that witness can recognize him. According to that, it will be a strong evidence because if the witness could recognize the murderer without the mark but by his appearance, it will eventually become a reliable evidence in an identification parade.

Last but not least, posing questions to the witnesses again and again by the magistrate about the role played by the suspect will protect the suspect from being wrongfully convicted. The reason is, out of seven people, the witness selects the accused by recalling the incident to his mind. If the witness chooses another person who is not the suspect, that evidence is not acceptable and it will be considered as the witness not recognized the suspect or the witness being unable to recognize the suspect in the identification parade.

3.4 Application of Sri Lankan Case Laws and Provisions with regard to IDP

According to Section 124 of the Criminal Procedure Amended Act of Sri Lanka, " Every Magistrate to whom application is made that behalf shall assist the conduct of an investigation by making and issuing appropriate orders and processes of court and may, in

particular hold, or authorize the holding of, an identification parade for the purpose of ascertaining the identity of the offender, and may for such purpose require a suspect or other person to participate in such parade, allow a witness to make his identification from a concealed portion and make or cause to be made a record of the proceedings of such parade."(Criminal Procedure Amended Act, 1988). This was discussed in the recent case of Mahanama Tillakeratne Vs Bandula Weerasinghe and Others (1999) 1 SLLR 372. According to this case, under the provision of this section, police had been requested to arrest a suspect. That person was then produced to the CID for investigations before taking him to the court. According to the opinion of Weeraratne J, suspect could not be arrested under section 124. And also, he stated that, the suspect can be arrested according to the provisions of chapter v of the code and not according to section 124 of the code. He further stated that, a warrant for a suspect can be issued according to the evidence given on oath before a magistrate. Therefore, even though a magistrate is empowered to assist in the conducting of an IDP, he is not empowered to issue a warrant of arrest under this section thereby overriding the requirements of chapter v of this code.

The case of Perera Vs the Republic (1969) 77 NLR 224: This is a case with regard to a murder which has been committed in the magazine prison. In this case, 11 prison guards were the suspects of causing the murder of a prisoner. 53 prison guards and 23 outsiders were lined up at the IDP. The ratio of guards to outsiders was 2:1. And this was criticized by the judge Walgampaya.

Also, in the case of Weeraratne joseph Aloysius Vs AG (1992) 2 SLLR 265, justice Sarath Silva stated that in an IDP, the witness can be questioned with regard to that incident and also about the role played by the suspect in that incident. There are no expressed provisions with regard to identification parades in Sri Lanka, but it should be conducted in a proper manner for the interests of justice. Section 9 of the Evidence Ordinance stated that, "Facts necessary to explain or introduce a fact in issue or relevant fact, or which support or rebut an inference suggested by a fact in issue or relevant fact, or which establish the identity of anything or person whose identity is relevant, or fix the time or place at which any fact in issue or relevant fact happened, or which show the relation of parties by whom any such fact was transacted, are relevant in so far as they are necessary for that purpose." (Evidence Ordinance, 1896). The identification of a person is logically relevant. Therefore, the suspect must be produced under section 9 of this ordinance when the witness identifies the suspect at an IDP. But if the witness gives direct evidence, then there is no need of an IDP. Therefore, it can be stated that IDP is logically relevant as well as legally relevant too.

3.5 Application of Indian Case Laws and Provisions with regard to IDP

Section 54A of the Indian Criminal Procedure Code states that the suspect should be sent for a test identification parade and this test identification parade means, when the victim had never seen the suspect in his life before the incident, then the suspect is produced before a test identification parade; but when both witness and the suspect are known to each other then there is no need to conduct a test identification. And the parade must be conducted as soon as possible due to the fact that the victim does not forget the details. (Gundu and Tirunagiri, 2020) This Indian procedure regarding identification parades is much similar to the Sri Lankan procedure.

An Indian case, Raju Manjhi v. State of Biharx 2018 SCC Online SC 778 stated that the test identification parade is no way a substantial evidence, but this test identification helps the investigation agencies. It means that this identification parade evidence helps the investigation process but this IDP evidence is not produced to the court as evidence. It is only produced for the investigation process. Gundu and Tirunagiri in their journal paper further stated that these kinds of identifications are needed to convict the suspect.

3.6 Credibility of the witness on the identification of the suspect

When it comes to the credibility of witness, it can be stated that for instance, think that the witness gives evidence at the trial that the suspect is dark in complexion and tall. But the witness in the statement

to the police stated before that the suspect was fair in complexion and short. In this example it can be seen that there is a contradiction about the statements given by the witness. Therefore, this contradiction is important when concerning about the credibility of the witness. (Meezan, 2011)

In the celebrated case of Rex Vs Turnbull (1977) QB 224. The following guidelines have been laid down for the judges to consider when evaluating the credibility of the witness on the identification of suspects.

- What is the duration/How long did the witness observe the suspect?
- At what distance did he (witness) see the suspect?
- What is the light that was available at the time of the incident?
- Were there any obstructions between the perpetrator and the witness?
- Had the witness seen the perpetrator in the past and recollected his features?
- How long after the incident did the witness identify the suspect at the parade?
- Whether there is any material discrepancy between the evidence given by the witness in court and his statement given to the police.

3.7 Issues relating to Identification Parades

Existing research has proved that human mind cannot record incidents as a tape recorder. On the other hand, human mind is unable to recall incidents like a tape recorder and exactly as we see them. Therefore, it is important to preserve witness memory carefully and retrieve it methodically without giving any chance to contaminate it (Perera E.M.N, 2018). Mistaken eyewitness identification accounts for over three-quarters of wrongful convictions (Gould and Leo, 2010) and nearly 75 percent of the 250 convictions overturned by DNA evidence between 1989 and 2010 have been due to eyewitness misidentifications. (Bazelon, 2013). Eyewitness evidence is the main cause of wrongful conviction in the United States. It is essential to study the effect of eyewitness evidence on individual cases. (Morgan, 2014). There are many factors that can affect the trustworthiness of an identification, mainly the simple weakness of human memory (Perera 2018).

4. RECOMMENDATIONS

Therefore, it can be recommended that,

- Police must be trained to use new techniques and investigate cases without contaminating the evidence obtained from IDPs.
- Also, updated information and knowledge about the proceedings must be given to the law enforcement officers. Because officers who carry out the IDPs have a very little knowledge about this procedure (Rajamanickam and Kung, 2017). Dock identification is being applied together with identification parade to support the reliability of an identification.
- Additionally, government too has a responsibility to give facilities when conducting IDPs since the quality and the accuracy of the information obtained from the IDPs are based on the reliability of evidence.

These recommendations will help to get more accurate and credible evidence from the witness when identifying the suspect at IDPs.

5. CONCLUSIONS

This study explained the term Identification Parade, gave a brief introduction about Identification Parades, explained the procedure followed in conducting an IDP, discussed the evidentiary value of IDPs, the application of the Sri Lankan case laws and provisions, the Indian case laws and provisions, the credibility of the witness when identifying the suspect at an IDP, some issues relating to IDPs, and finally gave the recommendations and conclusions. Therefore, by going through this research study and considering about the analysis of this study, it is evident that the identification parade is part and parcel of a criminal investigation. (Rajamanickam and Kung, 2017). By going through the analysis, it was revealed that the IDP evidence plays an important role to catch

the real offender and has an evidentiary value. If the identification parades are conducted according to the correct procedure, evidence obtained from the IDPs can be considered as credible and accurate.

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7. ABBREVIATIONS

IDP– Identification Parade

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9. STATUTES

(a) Code of Criminal Procedure Act 1979
(b) Code of Criminal Procedure (Amendment) Act 1988
(c) Constitution of the Democratic Socialist Republic of Sri Lanka 1978
(d) Evidence Ordinance 1896

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FLOOD HAZARD ASSESSMENT USING GIS-BASED MULTI-CRITERIA ANALYSIS: A CASE STUDY FROM DOWNSTREAM OF KELANI RIVER BASIN, SRI LANKA

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ABSTRACT

Increasing the occurrence of extreme rainfalls due to climate change has become a common feature of the climate in Sri Lanka during the past decades. According to the study on national climate change adaptation strategy for Sri Lanka - 2011 to 2016 undertaken by the Environmental Ministry of Sri Lanka, increase in the intensity of rainfall in the wet-zone is expected to increase the propensity for flooding of the flood-prone rivers. Accordingly, the Kelani and Kalu rivers are recorded the highest flood frequencies and the accompanying flood damages among the river basins in the wet zone. In this respect, it is important to assess flood hazard in Sri Lanka.

Therefore, the aim of the study is to assess and map the spatial distribution of flood hazard in downstream of the Kelani River basin. Both primary and secondary data have been used for the study. As primary data, experts' and residents' opinions were collected to decide the important flood causative factors in the study area. As secondary data, rainfall data, GIS data layers such as land use, drainage network, contour data and soil type were used. GIS-based spatial multi-criteria analysis method was used for the study. Accordingly, the study mainly revealed that land use of the study area is the main flood hazard contributing factor among considered factors. The flood hazard assessment map illustrates that high and very high hazard zones are concentrated in the western side and low and very low flood hazard zones in the eastern and southern parts of the study area. The study identified that the spatial distribution of flood-affected areas in the inundation map of the 2016 flood and flood hazard zones of the study area are quite similar. This study suggests that the GIS-based MCDA method can be very effective for mapping flood hazards and may be beneficial for decision-making in flood management.

KEYWORDS: *Floods, Natural disaster, Multi-Criteria analysis, Hazardous area, Causative factors, Downstream*

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1. INTRODUCTION

The world is becoming increasingly susceptible to unexpected events due to climate change. As a result, these extreme weather or climate events leads to change in the magnitude, frequency, intensity, spatial extent, duration and timing of various natural disasters (Perera, 2017; Phillips, Cinderich, Burrell, Ruper, Will and Sheridan, 2015: Seneviratne, Nicholls, Easterling, Goodess, Kanae, Kossin, Luo, Marengo, McInnes, Rahimi, Reichstein, Sorteberg, Vera and Zhang, 2012). Accordingly, the frequency of the hydro-meteorological events has shown an increasing trend (Thomas & López, 2015). Among various hydro-meteorological hazards, flood hazard is one of the consequences of climate change-induced extreme events (Mirza, 2011).

Many scientific studies have revealed that the risk of floods in most humid Asian monsoon regions, tropical Africa and tropical South America have increased whereas the risk of floods in non-negligible areas of the world such as most parts of northern North America been decreased (Seneviratne et al., 2012: Dankers and Feyen, 2009: Hirabayashi, Kanae, Motoya, Masuda and Doll, 2008). However, according to Mirza (2011), South Asia is considered one of the world's most vulnerable regions to floods because the frequency, magnitude and extent of extreme floods have been increasing in South Asian countries.

Therefore, as a South Asian country, Sri Lanka is also frequently affected by natural disasters. Especially, floods and landslides are the most common and hazardous natural events in Sri Lanka. According to International Water Management Institute (IWMI, 2018), the frequency of floods in Sri Lanka has steadily risen over the past two decades. Therefore, the occurrence of flood events portrays an increasing trend in most regions of Sri Lanka. Especially, there is a significant spatial and temporal pattern of river floods in Sri Lanka. With an increase in the number of flood events, the associated flood damages such as loss of human lives, property, crops and infrastructure damages have been also increased (Perera, 2017; Consortium of Humanitarian Agencies, 2016). However, there is a significant decline in loss of lives due to flooding since 2003 (Consortium of Humanitarian Agencies, 2016).

When considering the annual flood pattern in Sri Lanka, it can be characterized by two distinct monsoon seasons, specifically the South-west monsoon (SWM) from May to September, and the North-east monsoon (NEM) from December to February. The SWM brings heavy rains to the western and southern slopes of the central highlands while the NEM brings rains to the eastern side of the central hills and lowlands. Therefore, the country can be subjected to floods twice a year when receiving extreme rainfall in both seasons. In addition to these monsoon seasons, the country receives torrential rainfalls because of the development of low-pressure systems or tropical cyclones frequently formed in the Bay of Bengal. Accordingly, most of the cyclonic floods occur from October to December (Basnayake et al., 2019). As well, historical records prove that most cyclones hit the east, north, and north-central areas of the island (Yoshitani et al., 2007).

Among 103 river basins in Sri Lanka, the Kelani, Kalu, Nilwala, Gin, Walawe and Mahaweli rivers are vulnerable to floods (Gunasekara, 2008). These rivers are frequently subjected to floods triggered by the SWM that arrive in late May. Thus, only some parts of the districts such as Kalutara, Kegalle, Gampaha, Ratnapura, Colombo and Galle can be inundated (DMC, 1999). However, the Kelani and Kalu rivers have recorded the highest flood frequencies and the accompanying flood damages among the river basins in the wet zone (UNDP, 2011).

Kelani River basin has experienced several notable flood events in recent years (Ministry of Irrigation & Water Resource Management, 2018). Consequently, the Kelani River basin experienced a total of 350 mm of rainfall across three days from 15th to 17th May in 2016 after the devastating flood in 1989. Accordingly, 23 out of 37 Divisional Secretariat (DS) divisions in the Kelani River basin were affected by the 2016 Flood. Out of them, 15 DS divisions were affected significantly (Ministry of Disaster Management in Sri Lanka, 2016). Therefore, a large area is inundated almost

annually due to floods in the Kelani River. Especially, the gentle gradients encountered in lower parts of the river mainly cause the floods in the Kelani River basin due to the extremely heavy and prolonged rainfall in the upper catchment areas (UNDP, 2011).

In addition to that, other indirect causes of flooding in the Kelani River basin are lack of investment for drainage projects, unplanned town development, lack of coordination among Agencies, and lack of public awareness. With this brief background, the main objective of the present study is to analyze the flood hazard and map the spatial distribution of hazardous areas in downstream of the Kelani River basin. Accordingly, hazard assessment using GIS-based multi-criteria analysis was conducted to identify the magnitude and spatial distribution of flood hazard.

2. METHODOLOGY

Description of study area

The Kelani River is the second largest river and the third largest watershed in Sri Lanka. It is also the fourth-longest river in Sri Lanka (Mallawatantri et al., 2016). This river basin is located totally in the wet zone of the country. The Kelani River starts from the Adams Peak and the Kirigalpotta areas, which is an elevation 2,200 m above MSL in the Central Hills. The Kelani River basin receives an average annual rainfall of 3,450 mm and corresponding to a volume of about 7860 MCM out of which nearly 43% discharges into the sea (Ministry of Irrigation & Water Resource Management, 2018). The river carries a peak flow of about 800-1500 m^3/s during monsoons to the sea (De Silva et al., 2016). The Kelani River basin is located at the coordinates between Northern latitudes 6° 46/ & 7° 05/ and Eastern longitudes 79° 52/ & 80° 13/ (De Silva et al., 2016). Administratively, the Kelani River spreads over three provinces, namely, Western, Sabaragamuwa, and Central.

Topographically, the Kelani River basin consists of two types of landscapes as a mountainous upper region and a flat coastal plain/ lower basin (Figure 1). The upper basin is mainly covered with the vegetation types such as tea, rubber, grass, and forest. The downstream of the Kelani River basin is highly urbanized. The lower basin is a flat terrain about 100 m MSL and about 500 km^2. Accordingly, this study is mainly focused on downstream of the Kelani River basin (Figure 2).

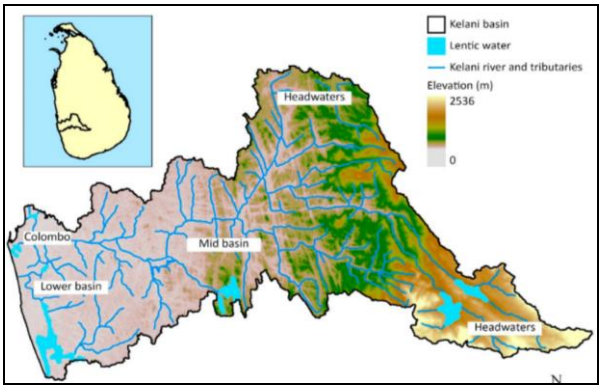

Figure 1: Topographic map of the Kelani River basin
Source: Mallawatantri et al., 2016

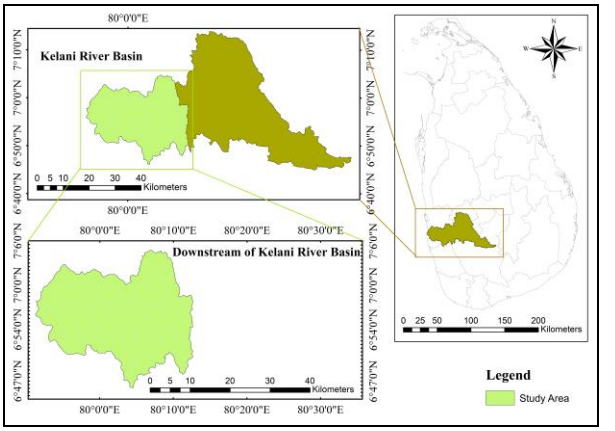

Figure 2: Absolute and Relative location of the study area

With the experience of the previous flood records of the Kelani River basin, the lower reach of the Kelani River basin was selected for the study area as mentioned before. The selected study area is in the Western and Sabaragamuwa provinces of Sri Lanka and located at the coordinates between Northern latitudes 6° 46/ & 7° 05/ and Eastern longitudes 79° 52/ & 80° 13/. When focused on the relative location, the study area is covered by four

administrative districts. It is bounded by the Gampaha district in the North and the Kalutara district in the South. Kegalle and Ratnapura district lie in the East and the Indian Ocean lies in the West of the study area.

Accordingly, the study area covers the flood plains below Glencourse gauging station in Kegalle district up to the Nagalagam Street gauging station in Colombo district. The total length of the Kelani River in the study area is about 55 km. The total land area of the study area is about 810 km^2.

As mentioned before, the study area includes a part of two provinces out of three provinces in the Kelani River basin. Mainly, the western province covers 34% of the Kelani River basin with about 789 km^2. Sabaragamuwa province covers only 21 km^2 of the study area. Further, four out of the seven districts in the Kelani River basin are represented within the study area. The Colombo district represents the largest area with about 19% of downstream of the Kelani River basin, which is located within the district.

The study area is in the wet zone of Sri Lanka and it receives an annual rainfall varying from 500 mm to 4,000 mm with an average mean annual rainfall of around 2,440 mm over the elevation range of the basin. This large amount of annual rainfall becomes the main reason for flooding, as much of the total rainfall comes from intense storms or cyclones. Further, there is a significant variation in rainfall over the year. The highest rainfall in the study area has been recorded in October and May. The peak rainfall period coincides with the highest rainfall period in the main river. Since the study area is located within the wet zone, the flow of the main river, as well as its tributaries are significantly influenced by the rainfall and it tends to be torrential during the monsoonal periods (Ministry of Irrigation & Water Resource Management, 2018).

Data collection

The study was mainly based on primary and secondary data. As primary data, the opinions of experts and residents on flood factors regarding the study area were collected to decide the important flood causative factors in the study area. Therefore, primary data were collected by conducting structured interviews and a survey. The sampling method in data collection was the snowball sampling method and the sample size was 55. As the concerned key informants, 15 experts and 40 residents were interviewed and surveyed over the phone and conducting face-to-face interviews were also conducted.

In addition to that, the following secondary data were used for the study and they were collected from different departments and institutes.

1. Meteorological data

Monthly rainfall data were obtained from the Department of Meteorology and Department of Agrarian Development of Sri Lanka. The rainfall data were collected for a period of 30-years from 1990 to 2019 at five rain gauge stations within the study area, namely Hanwella Group, Colombo, Kalatuwawa, Padukka Estate, and Angoda Mental Hospital to create the rainfall distribution map of the study area.

2. GIS data

GIS data layers were also used for the study. The flood hazard map was generated by using selected hazard factors. Therefore, vector datasets namely, land use, soil types, drainage network and sub-basins/watershed were obtained from the Department of Agrarian Development, Sri Lanka to generate basic thematic maps and hazard map for the study area. Further, 1: 10,000 scale contour data with a contour interval of 5 m were obtained from the Department of Survey, Sri Lanka to create elevation and slope maps of the study area.

Data analysis

To assess and map the spatial distribution of flood hazard in the study area, Spatial Multi-Criteria Decision Analysis (MCDA), image classification, Analytical Hierarchy Process (AHP) and weighted overlay analysis using pairwise comparisons were utilized as methods of analysis. Accordingly, the result of GIS-based multi-criteria hazard analysis was a map which allowed a ranking of hazard areas.

In this case, different areas were compared and evaluated with regard to different hazard criteria. Therefore, a new analysis method for flood hazard assessment was introduced by the current study. There are no widespread guidelines regarding the selection and ranked factors in flood hazard mapping. Therefore, the flood hazard factors related to the study area were determined by discussion with experts and residents, literature review, and personal observation (Ogato et al., 2020). Accordingly, the selected flood causative factors for this study were slope, elevation, soil type, land use, drainage density, and rainfall due to the nature of the study area.

The flood hazard analysis processes were employed with weighting flood causative factors according to their relative contribution to trigger the flood using the GIS-based MCDA method of AHP. MCDA is a commonly used approach for evaluating causative factors to determine and classify the flood hazard zonation (Wang, Tang, and Zeng, 2011; Zou, Zhou, Zhou, Song and Guo, 2013; Gigovi´c, Pamu´car, Bajic and Drobnjak, 2017; Rimba, Setiawati, Sambah and Miura, 2017; Ogato, Bantider, Abebe and Geneletti, 2020). AHP is applied to a wide variety of decisions (Saaty, 1980; Perera et al., 2018), and to solve multi-criteria decision problems by setting their priorities (Ogato et al., 2020).

In this study, flood causative factors exposed to series of pairwise comparisons using the existing literature and opinions of experts consist of academics, engineering experts, professionals, and residents concerning the above mentioned 9-point intensity of relative importance scale (Table 1) proposed by previous studies (Perera et al., 2018; Ogato et al., 2020).

The AHP in this study was mainly done in four steps: construct the decision hierarchy; determine the relative importance of attributes and sub-attributes; evaluate each alternative and calculate its overall weight regarding each attribute and check the consistency of the subjective evaluations (Ouma and Tateishi, 2014; Perera et al., 2018; Ogato et al., 2020).

Accordingly, the pair-wise comparison matrix (Table 2) was normalized by Equation 1 (Perera et al., 2018; Ogato et al., 2020).

$$a_{ij} = \frac{1}{\sum_{i=1}^{n} a_{itj}} \quad \text{For all j = 1, 2, 3..... n}$$

……. Equation (1)

To generate a weighted matrix (*W*), divide the sum of the normalized column of the matrix by the number of criteria used (*n*) based on Saaty's eigenvalue (*v*) using Equation 2 (Perera et al., 2018; Ogato et al., 2020).

$$W_{ij} = \frac{\sum_{j=1}^{n} a_{ij}}{n} \quad \text{For all i = 1, 2, 3..... n}$$

……. Equation (2)

Table 1: Nine-point pairwise comparison scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one parameter over another
5	Strong importance	Experience and judgment strongly favor one parameter over another
7	Very strong importance	One parameter is favored very strongly and is considered superior to another: its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one parameter as superior to another is of the highest possible order of affirmation

Note: 2,4,6,8 can be used to express intermediate values for parameters that are very close in importance

Source: Ogato et al., 2020

Table 2: Pairwise comparison matrix of the flood hazard contributing

Flood Hazard Factors	Land use	Rainfall	Drainage Density	Elevation	Slope	Soil Type
Land use	1	5	2	2	2	2
Rainfall	1/5	1	2	2	2	2
Drainage Density	1/2	1/2	1	2	2	2
Elevation	1/2	1/2	1/2	1	2	2
Slope	1/2	1/2	1/2	1/2	1	2
Soil Type	1/2	1/2	1/2	1/2	1/2	1
Total	**3.20**	**8.00**	**6.50**	**8.50**	**8.50**	**11.00**

Note: λ_{max} represents the sum of the products between the sum of each column of the comparison matrix and the relative weights Source: Ogato et al., 2020

Table 3: Normalized pairwise comparison matrix (Judgment matrix)

Flood Hazard Factors	Land use	Rainfall	Drainage Density	Elevation	Slope	Soil Type	Weight	Priority (%)
Land use	0.31	0.63	0.31	0.24	0.24	0.18	**0.32**	**31.6**
Rainfall	0.06	0.13	0.31	0.24	0.24	0.18	**0.19**	**19.1**
Drainage Density	0.16	0.06	0.15	0.24	0.24	0.18	**0.17**	**17.1**
Elevation	0.16	0.06	0.08	0.12	0.12	0.18	**0.12**	**11.9**
Slope	0.16	0.06	0.08	0.12	0.12	0.18	**0.12**	**11.9**
Soil Type	0.16	0.06	0.08	0.06	0.06	0.09	**0.08**	**8.4**
Total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**100**

Note: The natural values were normalized by adding the column values and dividing the value of each cell by the total of column values Source: Ogato et al., 2020

Weight computed normalized pairwise comparison matrix is known as the Judgment matrix (Table 3). $[A]_{6\times6}$ is the judgment matrix. A relationship exists between the vector weights (*W*) and the judgment matrix $[A]_{6\times6}$ as shown in Equation 3 (Perera et al., 2018; Ogato et al., 2020).

$$AW = \lambda_{max} W \quad \text{..... Equation (3)}$$

The λ_{max} value is an important validating parameter (Perera et al., 2018) in the pairwise comparisons in

AHP. The quality of the output of the AHP is demanded to be severely related to the consistency of the pairwise comparison judgments (Ouma and Tateishi, 2014). In this situation, it is important to calculate the consistency ratio (*CR*) of the estimated vector (Perera et al., 2018; Ogato et al., 2020). To calculate the *CR*, the consistency index (*CI*) for each matrix of order *n* was obtained from Equation 4 (Perera et al., 2018; Ogato et al., 2020). The maximum threshold of *CI* is < 0.1 and *CR* < 10%.

$$CI = (\lambda_{max} - n) / (n - 1) \quad \text{..... Equation (4)}$$

The final calculation was the consistency ratio (*CR*) which is the ratio of the *CI* and random index (*RI*) as shown in Equation 5 (Perera et al., 2018; Ogato et al., 2020).

$$CR = \frac{CI}{RI} \quad \text{..... Equation (5)}$$

The value of *RI* was suggested by Saaty (1980) which presents the value of the *RI* from matrices of order 1 to 10 (Table 4). Accordingly, the *RI* value for six parameters was 1.24 as suggested by Saaty.

Table 4: Random index (RI)

N	RI
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

Source: Ogato et al., 2020; Perera et al., 2018

In this study,

λ_{max} = (3.20*0.32) + (8.00*0.19) + (6.50*0.17) + (8.50*0.12) + (8.50*0.12) + (11*0.08)
= 6.60
n = 6
CI = (6.60 – 6) / (6 – 1) = 0.129
RI = 1.24
CR = (0.129 / 1.24) = 0.096 (9.6 %)

Accordingly, *CR* for the flood contributing factors in downstream of the Kelani River basin is 0.096 which is less than the standard 0.1 and 10%.

Hence, the pairwise matrix ranking is accepted. The order of normalized weight was land use (31.6%), rainfall (19.1%), drainage density (17.1%), elevation (11.9%), slope (11.9%), and soil type (8.4%).

Accordingly, the selected flood generating factors such as drainage density, elevation, land use, soil type, rainfall, and slope were combined for flood hazard assessment using ArcGIS/ ArcMap 10.4 software. Hence, the contour data converted into digital elevation model (DEM) and slope raster layers using the spatial Analyst tools in ArcGIS software. In this study, a drainage density map also created using the line density tool in ArcGIS software. The drainage density was calculated using the equation 6 (Ogato et al., 2020).

$$D = L/A \quad \text{..... Equation (6)}$$

Where,
D = Drainage density of watershed
L = Total length of the drainage channel in the watershed
A = Total area of the watershed

Further, the rainfall distribution map was generated using Inverse Distance Weighted (IDW) tool in ArcGIS. The selected factors were converted into the raster format and transformed to GCS Kandawala geographic coordinate system. To run MCDA and generate the final flood hazard map, the selected factors were developed using the weighted overlay tool in ArcGIS. Moreover, the main calculations in AHP have mainly been done using Microsoft Excel 2010.

3. RESULTS AND DISCUSSION

In flood hazard assessment, slope, elevation, rainfall, drainage density, land use, and soil type were selected as the major flood-generating factors in the study area. The flood-generating raster layers have been classified based on the flooding capacity of the area. Accordingly, based on the susceptibility to flooding, all factors have been classified into five classes as very low, low, moderate, high and very high; and ranked from 1 to 5 respectively. The results of the flood hazard factor analysis can be summarized as follows.

Table 5: Scaled and weighted flooding hazard induced factors for the river basin

Parameter	Relative Weight (%)	Reclassified Parameter	Ranking	Hazard
Land use (based on water absorption level)	**31.6**	Forest/ Forest Plantation/ Scrub land	1	Very Low
		Barren land	2	low
		Coconut/ Rubber/ Tea/ Cinnamon/ Chena/ Home Garden/ Keera Vagawa/ Paddy	3	Moderate
		Residential Area/ Built up area	4	High
		Marsh/ Water Bodies	5	Very High
Rainfall (mm)	**19.1**	2392 – 2750	1	Very High
		2750 – 3138	2	High
		3138 – 3453	3	Moderate
		3453 – 3747	4	Low
		3747 – 4220	5	Very Low
Drainage Density (Sq. Km.)	**17.1**	2.5 – 4.4	1	Very Low
		1.7 – 2.5	2	Low
		1 – 1.7	3	Moderate
		0.5 – 1	4	High
		0 – 0.5	5	Very High
Elevation (m)	**11.9**	> 20	1	Very Low
		15 – 20	2	Low
		10 – 15	3	Moderate
		5 – 10	4	High
		3 – 5	5	Very High
Slope (percent)	**11.9**	> 12	1	Very Low
		9 – 12	2	Low
		6 – 9	3	Moderate
		3 – 6	4	High
		0 – 3	5	Very High
Soil Type (based on drainage capacity)	**8.4**	Bog and Half-Bog soils: high terrain	1	Very Low
		Red-Yellow Podzolic soils-steeply dissected	2	Low
		Red-Yellow Podzolic soils with strongly mottled subsoil & low Humic Gley soils	3	Moderate
		Red-Yellow Podzolic soils with soft or hard laterite: rolling and undulating terrain	4	High
		Alluvial soils of variable drainage and texture/ Bog and Half-Bog soils: flat terrain/ Regosols on the recent beach and dune sands	5	Very High

Analysis of Land use factor for flood hazard

The study mainly revealed that land use was the main flood hazard contributing factor in the study area. Land-use types of the study area were forests, forest plantation, coconut lands, rubber lands, tea lands, cinnamon lands, scrublands, residential areas, built-up areas, chena, home-gardens, Keera *vagawa*, paddy lands, barren lands, marshy lands and water bodies.

Accordingly, those land-use types were rated as very low, low, moderate, high and very high flood hazard areas in order of their capacity to increase or decrease the rate of flooding (Table 5). The spatial distribution of different flood hazard zones portrayed that the Western portion of the study area and areas along the Kelani River basin belong to high and very high flood hazard zones (Figure 3). The map also depicts that the middle part and most of the eastern part of the study area were in the moderate hazard zone.

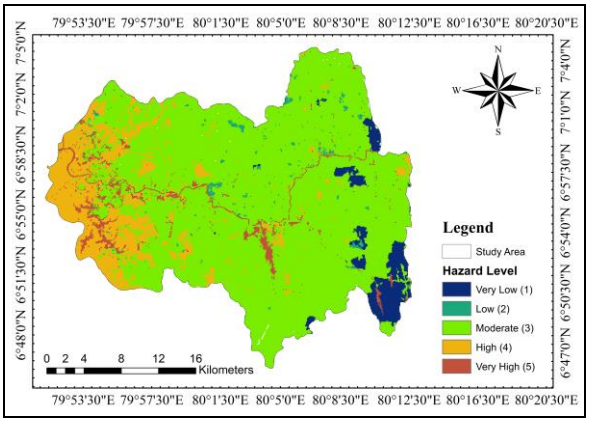

Figure 3: Susceptibility to flooding: rating of land use types

Many studies have revealed that a high rate of surface runoff is more likely on residential areas than on vegetated grounds (Fura, 2013; Mngutyo and Ogwuche, 2013). Especially, forest and scrublands highly reduce the impact of rainfall and the amount of water that ends up in the form of surface runoff. Water-resistant surfaces in the settlement areas such as buildings, concrete, paved areas, and roads decrease the infiltration of water into the soil and increase the amount of surface runoff (Tucci, 2007; Jha, Bloch and Lamond, 2012; Fura, 2013; Mngutyo and Ogwuche, 2013; Hall et al., 2014; Ogato et al., 2020). Hence, land use characteristics were significant parameters in evaluating the probable areas to flood hazard as well as vulnerability to flood risk (Ogato et al., 2020). Therefore, it can be identified that there is a significant change in the downstream of the Kelani River basin of which land-use type is the main flood hazard contributing factor in the study area based on their influence on floods.

The analysis also revealed that 4.17% (33.75 km^2), 1.19% (9.66 km^2), 77.25% (625.52 km^2), 13.86% (112.17 km^2), and 3.53% (28.62 km^2) of total land area in the study area falls under very low to very high flood hazard level respectively (Table 6). Therefore, it can be concluded that about 18% of the study area lies in high to a very high hazard zone of which residential/built-up areas and marsh/water bodies are most vulnerable to floods. The highest proportion (77%) of the study area was a moderate probability of flood hazard of which agricultural lands are more vulnerable to floods. However, the map of susceptibility to flooding also depicted that about 5% of the study area belongs to low and very low hazard zone of which forests and bare lands are least vulnerable to floods.

Table 6: The area covered by different flood hazardous levels subject to land use factor.

Hazard Level	Area (sq. km.)	Percentage (%)
Very Low	33.75	4.17
Low	9.66	1.19
Moderate	625.52	77.25
High	112.17	13.86
Very High	28.62	3.53
Total	**809.76**	**100.00**

Analysis of Rainfall factor for flood hazard

The amount of runoff is correlated with the amount of rainfall experienced in an area. When the area receives heavy rainfall, the water level rises above riverbanks and commences overflowing leading to flooding (KRCS, 2013; Few, Ahern, Matthies and Kovats,

2004). The Kelani River floods are mainly due to the high flow rate and rainfall in upper catchment areas. Especially, the flood is mainly dominated by the rainfalls of the middle parts of the catchment and the areas on lower basin catchments are highly affected to floods (Hettiarachchi, 2020).

In this study, the average annual rainfall between 1990 and 2019 was ranged from 2392 mm to 4220 mm. According to the characteristics of the Kelani River basin, the lowest rainfall category (2392 mm – 2750 mm) of the study area was ranked as a very high flood hazard whereas the highest rainfall category (3747 mm – 4220 mm) was ranked as a very low flood hazard class (Table 5).

Accordingly, the highest proportion of the study area (34.31% and 277.80 km^2) was experienced moderate flood hazards of which these areas are close to the upper catchment area (Table 7).

Table 7: The area covered by different flood hazardous levels subject to rainfall factor

Hazard Level	Area (sq. km.)	Percentage (%)
Very Low	107.54	13.28
Low	132.02	16.30
Moderate	277.80	34.31
High	115.38	14.25
Very High	177.02	21.86
Total	**809.76**	**100.00**

The analysis also showed that about 30% of the study area belongs to low and very low hazard zone. Only 36% of the study area was in high to a very high hazard zone of which lower basin is most vulnerable to floods due to the behavior of water flow.

The spatial distribution of flood hazard levels by receiving the amount of rainfall indicated that the Eastern and Southern portions of the study area are lower hazard levels while the areas in the Western part is high hazardous levels (Figure 4). Because of the low-lying areas in the study area are inundated due to heavy rainfall which receives to the middle reach of the Kelani River. According to the opinions of experts and residents, the floods in the lower reach (below Avissawella) are more critical due to large areas of spread and longer durations of inundation. Those areas are highly developed, populated and susceptible to heavy damages during floods.

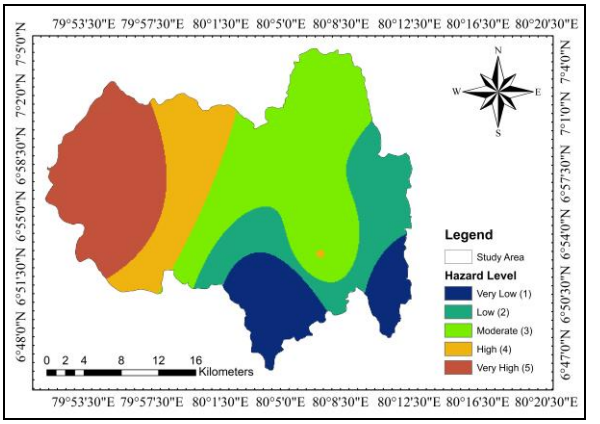

Figure 4: Susceptibility to flooding: rating of rainfall distribution.

Analysis of Drainage density factor for flood hazard

Analysis of drainage density in the study area was indicated that the highest drainage density is 4.42 km^2 while the lowest drainage density is 0 km^2. Accordingly, the lowest drainage density category (0 – 0.5 km^2) was ranked as a very high flood hazard drainage density category, while the highest drainage density category (2.5 – 4.4 km^2) was rated as a very low flood hazard category (Table 5).

Frequently, the drainage system is related to the nature of the soil, rainfall amount, evapotranspiration rates, rock structure, and properties of the area (Ogato et al., 2020). Therefore, low drainage density areas have few channels to drain water and could end up as floodwater (McKnight & Hess, 2007; Ritter, 2010).

The results of the density analysis indicated that the poorly drained areas are highly affected to flood hazards whereas well-drained areas are less influence on flood hazards (Chibssa, 2007; Wondim, 2016; Ogato et al., 2020). The map on flood hazard zones under different drainage density was also indicated that the highest flood hazard areas in the study area are

not mainly located along the river lines, and they are located at the periphery of the study area (Figure 5).

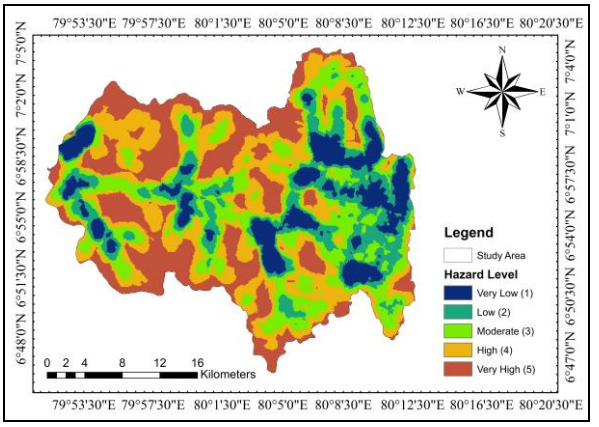

Figure 5: Susceptibility to flooding: rating of drainage density.

Especially, 25.72% (208.26 km^2) of the total land cover in the study area was under the high hazard zones of floods while 25.36% (205.38 km^2) of the total land cover was under the very high probability of floods due to the low drainage densities (Table 8). Accordingly, only half of the study area (50%) was highly affected to flood hazards due to the poorly drained of the study area. However, high drainage density areas are well-drained as more permeable rock structures and soil allow more drainage and thus reduced the possibility of flooding (Waugh, 2009). Accordingly, only a quarter of the study area that is 12.12% (98.17 km^2), and 15.16% (122.79 km^2) of the total land area, were a very low and low probability of floods respectively.

Table 8: The area covered by different flood hazardous levels subject to drainage density factor

Hazard Level	Area (sq. km.)	Percentage (%)
Very Low	98.17	12.12
Low	122.79	15.16
Moderate	175.16	21.63
High	208.26	25.72
Very High	205.38	25.36
Total	**809.76**	**100.00**

Analysis of Elevation factor for flood hazard

Elevation has a significant role in controlling the movement of runoff direction and depth of the water level (Ogato et al., 2020; Gigovi´c et al., 2017). The highest elevation of the study area is 399 m while the lowest elevation is 3 m. Consequently, the lowest elevation class (3 m – 5 m) was ranked as a very high flood hazard elevation category while the highest elevation category (> 20 m) was ranked as a very low flood hazard elevation category according to their influence on flood hazard (Table 5).

Accordingly, the study area represented a high flood hazard level in the western and some middle parts of the study area due to the low elevation of those areas (Figure 6). Therefore, it can be identified that the elevation is also an important flood hazard contributing factor in the study area.

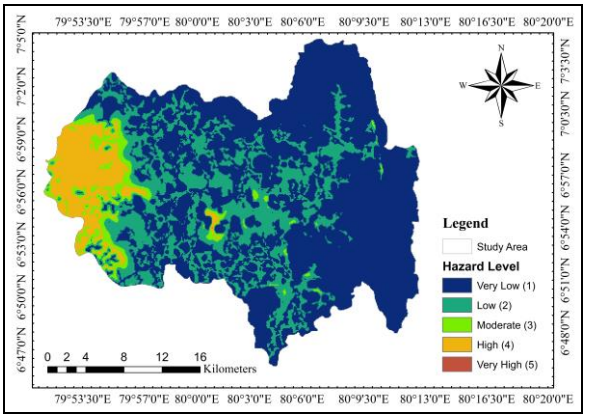

Figure 6: Susceptibility to flooding: rating of elevation.

Further, the area covered by the highest elevation class (> 20 m) was under the very low hazard zone and that was 63.14% (511.28 km^2) of the study area (Table 9). The area covered by the lowest elevation (3 – 5 m) of the study area was under the highest probability of floods. Therefore, 0.01% of the study area was under the highest probability of floods. Accordingly, the study revealed that only 8% of the study area is highly susceptible to flooding.

Table 9: The area covered by different flood hazardous levels subject to elevation factor

Hazard Level	Area (sq. km.)	Percentage (%)
Very Low	511.28	63.14
Low	201.97	24.94
Moderate	34.43	4.25
High	62.07	7.66
Very High	0.01	0.01
Total	**809.76**	**100.00**

Analysis of Slope factor for flood hazard

The slope was also considered one of the main flood hazards contributing factors in the study area because the slope is a key factor in determining the rate and duration of water flow. For example, flat surface areas are more hazardous concerning the occurrence of floods with steeper surfaces (Gigovi´c et al., 2017; Ogato et al., 2020; Rimba et al., 2017).

The percent of the slope in the study area has displayed the range between the highest slope of 63% and the lowest slope of 0%. Therefore, in the classification process, the areas with the lowest slope values (0 - 3%) were considered as a very high flood hazard slope angle category and then ranked to class 5. In the case of the slope, the areas with the highest slope values (> 12%) were considered as a very low flood hazard slope angle category and then ranked as class 1 (Table 5).

The areas of a low percent of the slope were assigned to flat plains because of their ability to hold water and water spreads out in the wide area. Thus, such areas are more susceptible to flooding due to the intensive rainfall (Van Westen et al., 2011). However, the areas of high percent of the slope were assigned to the steep hill slopes because they have soils with low infiltration capacities and high speed of surface runoff. Thus, in such areas. The probability of flooding is less (Hill & Verjee, 2010; Smithson, Addison & Atkinson, 2002).

Accordingly, the study area represented that a very low flood hazard level is in the eastern part due to the high slope angle in that area (Figure 7). However, a very high flood hazard zone was identified in the western and middle part of the study area due to the distribution of fewer slopes. Accordingly, the fewer slope areas lead to flooding due to the inundation with the influence of high-intensity rainfall (Gigovi´c et al., 2017; Rimba et al., 2017).

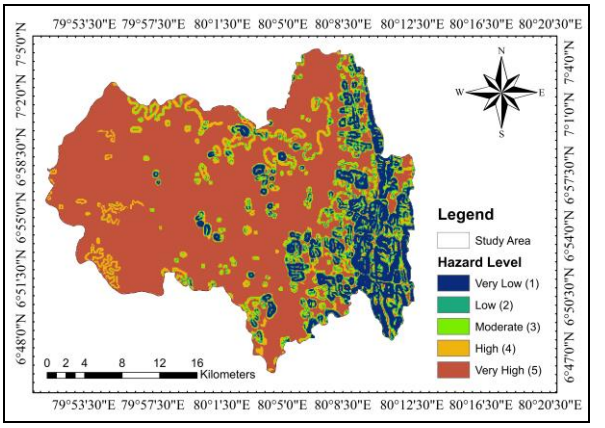

Figure 7: Susceptibility to flooding: rating of slope.

On the other hand, 12.25% (99.20 km^2) of the total extent of downstream of the Kelani River basin had a very low likelihood of floods and 67.41% (545.85 km^2) of the total land area had a very high likelihood of floods (Table 10). However, 4.29% (34.75 km^2), 6.77% (54.79 km^2), and 9.28% (75.17 km^2) of land areas could be considered low, moderate, and high hazardous areas in the study area respectively.

Table 10: The area covered by different flood hazardous levels subject to slope factor

Hazard Level	Area (sq. km.)	Percentage (%)
Very Low	99.20	12.25
Low	34.75	4.29
Moderate	54.79	6.77
High	75.17	9.28
Very High	545.85	67.41
Total	**809.76**	**100.00**

However, the study indicated that the influence of slope and elevation factor to flood hazard of the study area are quite similar.

Analysis of Soil factor for flood hazard

The study also revealed that influence of soil type to flood hazard of the study area is the lowest contribution among all flood causative factors. Especially, floods are more likely to occur over saturated soils, which means that both soil moisture status and precipitation intensity play a significant role (Seneviratne et al., 2012).

The study revealed that the study area is mainly covered by the Red-Yellow Podzolic soils with soft or hard laterite: rolling and undulating terrain. This soil type was covered by 64% (522.03 km^2) of the total extent of downstream of the Kelani River basin. The study also revealed that this soil type lied in high (class 4) probability of occurrence of floods (Table 5 & Figure 8) of which surface runoff was more dominant in the hard laterite than the water infiltration (Ministry of Irrigation & Water Resource Management, 2018).

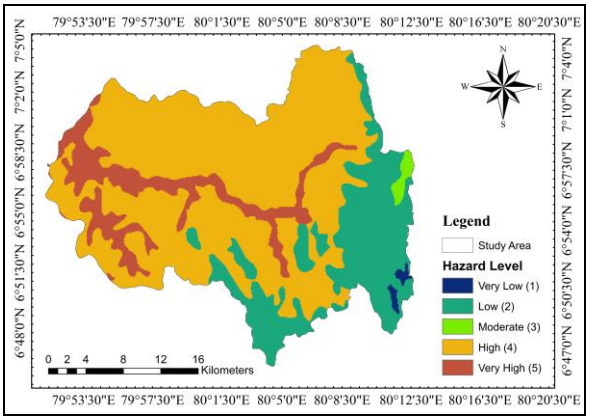

Figure 8: Susceptibility to flooding: rating of soil types

However, 12.12% (98.12 km^2) of the total land area had a very high likelihood of floods of which Bog and Half-Bog soils in flat terrain, Alluvial soils, and sandy Regosols of the dunes and elevated beach were dominant along the Kelani River banks and the river mouth. These soils mostly consist of fine-grained clay soils. Especially, alluvial soils are well developed in the lower regions of the river basin, especially from Kaduwela to Colombo by the previous floods (Ministry of Irrigation & Water Resource Management, 2018). Therefore, since clay soils have fine particles, these areas are more prone to the accumulation of surface runoff for a longer period (Ogato et al., 2020) because floods occur in areas where soils have low infiltration capacity (Ouma and Tateishi, 2014). However, sand deposits can be identified in the middle regions of the Kelani River and these sands are extensively developed in the river basin throughout the year (Ministry of Irrigation & Water Resource Management, 2018). Most of the finer sands also reach up to the Kelani River mouth. Especially, the alluvial and sand aquifers in the river basin are recharged by rainfall and seepage from the river. However, since groundwater levels of the above-mentioned soils are at a shallow depth, infiltration is limited. Therefore, these areas can be highly hazardous to flooding during extreme rainfall events.

Table 11: The area covered by different flood hazardous levels subject to soil factor

Hazard Level	Area (sq. km.)	Percentage (%)
Very Low	3.91	0.48
Low	179.39	22.15
Moderate	6.31	0.78
High	522.03	64.47
Very High	98.12	12.12
Total	**809.76**	**100.00**

It is also indicated that 0.48% (3.91 km^2) of the total extent of the study area is very low (class 1) likelihood of floods (Table 11). Only 22.15% (179.39 km^2) of land areas were low flood hazard of which saturation of Red-Yellow Podzolic soils (steeply dissected) are very low (Moormann and Panabokke, 1961). However, saturation of Red-Yellow Podzolic soils with strongly mottled subsoil and low Humic Gley soils are higher than Red-Yellow Podzolic soils with steeply dissected (Moormann and Panabokke, 1961).

Accordingly, only 0.78% (6.31 km^2) of the land area was identified as moderate flood hazardous areas.

Analysis of Flood hazard

Weighted overlay analysis was used as a Multi-criteria evaluation technique to assess the flood hazard or the probability of the occurrence of floods (Saaty, 1980; Perera et al., 2018) in the study area. From this analysis, the above-mentioned six factors were compared to each other in the contribution of flood hazard (Ouma and Tateishi, 2014; Gigovi´c et al., 2017; Ogato et al., 2020). In other words, the flood hazard assessment map was produced by flood generating factors such as slope, elevation, rainfall, drainage density, land use, and soil type in the downstream of the Kelani River basin using GIS along with multi-criteria AHP techniques and a weighted overlay.

Accordingly, the flood hazard assessment map shows that only 30% of the study area was under high and very high hazard zones (Table 12). The study also revealed that the highest proportion of the study area (53.94%) lies in moderate hazard zone. Only 1.75% (14.20 km^2) of the study area had a very low probability to the occurrence of flood hazard.

Table 12: The area covered by flood hazardous levels subject to all causative factors

Hazard Level	Area (sq. km.)	Percentage (%)
Very Low	14.20	1.75
Low	114.66	14.16
Moderate	436.79	53.94
High	237.23	29.30
Very High	6.88	0.85
Total	**809.76**	**100.00**

Therefore, the non-flooded extent of the study area was relatively small (only 16%) and thus most of the study area was relatively more flooded due to the contribution of above-mentioned six parameters.

When considering to the spatial distribution of flood hazard in the downstream of the Kelani River basin, the flood hazard map indicated that the very high flood hazard areas are concentrated in the western side of the downstream of the Kelani River basin of which build up/ residential and low-lying flat areas are most vulnerable to floods (Figure 9).

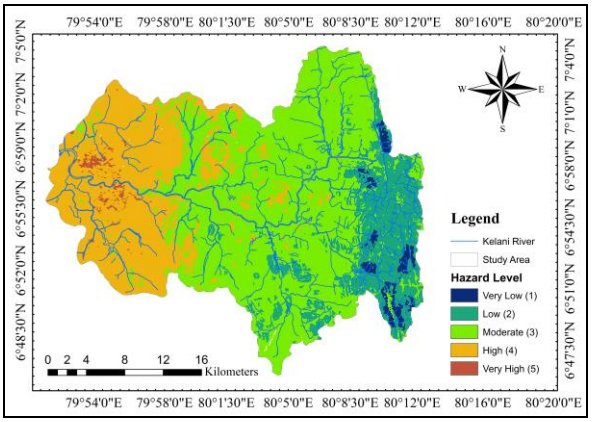

Figure 9: Flood hazard map of downstream of the Kelani River basin.

Further, high hazardous areas are also concentrated in the western side and some areas in the middle part of the study area. However, the study revealed that many areas in the middle part of the study area are at moderate hazard level.

Moreover, the flood hazard map presents that there was low and very low flood hazard probability in the highlands in the eastern and southern parts of the study area. Therefore, it can be identified that slope angle less than 6% with terrain elevations less than 10 meters; low infiltration capacity of soils; low infiltration of water into the soil and high rate of surface runoff of land uses; drainage density less than 1 km^2 plus less than 2750 mm of average annual rainfall in the study area is considered highly hazardous. Accordingly, the flood hazard map of the study area represented the magnitude of flood events of downstream of the Kelani River basin.

In this study, an actual inundated map of recent flooding event in the Kelani River basin was used to validate the flood hazard map of downstream of the Kelani River basin. Accordingly, the inundation map of the 2016 flood shows that some parts of Colombo, Kelaniya, Kolonnawa, Sri Jayewardenepura Kotte,

Biyagama, Kaduwela, Homagama, Hanwella, Padukka and Dompe DS divisions were inundated (Figure 10). When comparing these inundated areas with flood hazard map of downstream of the Kelani River basin, the flood hazard map of the study area revealed that some parts of Kelaniya, Sri Jayewardenepura Kotte, Kaduwela and Kolonnawa belong to high and very high hazard zones. The flood hazard map also shows that some parts of Biyagama, Kaduwela, Homagama, Hanwella, and Dompe were moderately hazardous. Therefore, the study identified that the distribution of flood-affected areas in the inundation map of the 2016 flood and flood hazard zones of the study area are quite similar.

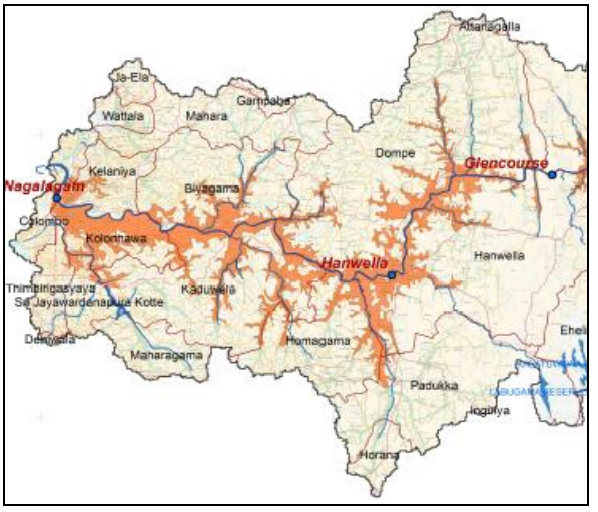

Figure 10: Flood inundation areas in 2016 Flood (Source: Irrigation Department, 2020)

Hence, the present study suggests that flood hazard map of the study area can be fundamental to the entire mapping process particularly in the beginning and also flood hazard map forms the basis for flood emergency maps and other related maps for the downstream of the Kelani River basin. The study also suggests that the GIS-based MCDA method can be very effective for mapping flood hazards that may be beneficial for decision-making in flood management. The methodology employed here can also be applied for data-limited areas anywhere in the world. Furthermore, the study recommends to conduct a flood risk assessment for identifying the exposure and vulnerability of different types of element-at-risks.

4. CONCLUSIONS

The study was carried out to identify the spatial distribution of flood hazard in downstream of the Kelani River basin using the GIS-based spatial multi-criteria analysis method. The study tried to incorporate AHP-based criteria weights and parameter rankings for decision-making in complex relations. Six parameters related to hydro-geomorphological characteristics were prepared in ArcGIS software and clustered into five classes as very low, low, moderate, high and very high for assigning ratings based on their influence on floods. The criteria and their weights were combined linearly to obtain the final hazard map.

The study mainly revealed that land-use is the main flood hazard contributing factor among the considered flood causative factors in the study. The analysis also presented that around 18% of the study area lies in high to a very high hazard zone of which residential/built-up areas and marsh/water bodies are most vulnerable to floods.

According to the perceptions of the experts, the Kelani River floods are mainly due to the high flow rate and rainfall in the upper catchment areas. Especially, the flood is mainly dominated by the rainfalls of the middle parts of the catchment and the areas on lower basin catchments are highly affected by floods. The spatial distribution of flood hazard levels by rainfall distribution of the area showed that the eastern and southern portions of the study area have low hazard levels while the areas in the western part have high hazardous levels. According to the experts and residents, the floods in the lower reach (below Avissawella) are more critical due to large areas of spread and longer durations of inundation. Those areas are highly developed, populated and susceptible to heavy damages during floods.

The results of the density analysis have indicated that the poorly drained areas are highly affected to flood hazards whereas well-drained areas are less influence by flood hazards. The map on flood hazard zones

under different drainage densities has also indicated that the highest flood hazard areas in the study area are not mainly located along the river lines, and they are located at the periphery of the study area. Accordingly, only half of the study area (50%) was highly affected to flood hazards due to the poor draining of the study area.

The study identified that elevation is one of the less important flood hazard contributing factors in the study area. Accordingly, the study revealed that only 8% of the study area is highly susceptible to flooding. The study also indicated that there is a similar contribution of slope and elevation factors to the flood hazard of the study area. Besides, the study also revealed that influence of soil type to flood hazard of the study area is the lowest contribution among all considered flood causative factors.

The flood hazard assessment map shows that the highest proportion of the study area (53.94% or 436.79 km^2) lies in the moderate hazard zone. Only 16% (129 km^2) of the study area was a very low and low probability of the occurrence of flood hazard. Therefore, the non-flooded extent of the study area was relatively small and most of the study area was relatively more flooded due to the contribution of the above-mentioned six parameters.

The flood hazard map also indicated that the very high flood hazard areas are concentrated in the western side of the downstream of the Kelani River basin of which build-up/residential and low-lying flat areas are most vulnerable to floods. Further, high hazardous areas were also concentrated in the western side and some areas in the middle part of the study area. There was low and very low flood hazard probability in the highlands which is in the eastern and southern parts of the study area. Further, the study has identified that the distribution of flood affected areas in the inundation map in the 2016 and flood hazard zones of the study area are quite similar.

Hence, the present study suggests that the GIS-based MCDA method can be very effective for mapping flood hazards that may be beneficial for decision-making in flood management. Furthermore, the study recommends to conduct a flood risk assessment for identifying the exposure and vulnerability of different types of element-at-risks.

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AN ANALYSIS OF CAUSES OF COASTAL EROSION IN CALIDO BEACH, KALUTARA, WEST COAST OF SRI LANKA

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ABSTRACT

The coastal zone is key to sustainable development of a country. However, coastal erosion has been identified as a major natural hazard in the world for a long time. Coastal erosion is mainly affected to damage or destroy the various structures along the coast. This can also be a huge problem for the tourism industry of the country because the beaches play a vital role in attraction of tourists. In Sri Lanka, Kalutara is one of the most critically eroded coastal areas of the country. Therefore, it is needed to identify the spatial distribution of the eroded areas, causes and impacts of coastal erosion as well as suitable protection and mitigation measures. Therefore, the aim of the study is to analyze the coastal erosion of Calido beach in Kalutara. The specific objectives of the study are mainly two fold' identification of spatial distribution of beach erosion in Calido beach, and the causes for coastal erosion in Calido beach. The study is based on qualitative analysis. Google Earth Pro is used for the completion of research objectives. Rainfall, wave climate, river flow, shoreline changes and sediment transport are the main data that was collected. The spatial distribution of eroded area could be classified as high, medium, and low by the direct observation method. The results of the study revealed that the cut of sand bar in May, 2017 is the main cause of coastal erosion in Calido beach. Accordingly, the total extent of the eroded area of the beach was approximately 0.45 km^2. Further, the results of the study revealed that the length of the eroded area was approximately 3 km and the perimeter was about 5.52 km. Therefore, this study was recommended to identify suitable protection and mitigation measures for the coastal erosion in Calido beach.

KEYWORDS: *Coastal Erosion, Calido Beach, Spatial Distribution, Shoreline, Sustainable Development, Google Earth*

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1. INTRODUCTION

The coastal area is subjected to an increased pressure by regional alterations and global changes. The shoreline also called as the coastline is a boundary in between the land and the sea. Due to the dynamic environmental circumstances, coastline being carried out in the coastal areas is constantly changing its location and shape. Diverse development projects have been set up along the coast, putting a great deal of pressure on them, leading to various coastal threats such as seawater intrusion, coastal erosion, and coral bleaching. Among them, coastal erosion is a critical problem affecting all the countries in the world having a shoreline.

Particularly, coastal erosion can be defined as a natural process that breaks down the rocks and the sediments at the shoreline. Taranaki Regional Council (2009) defines coastal erosion as "the process of episodic removal of material at the coastline leading to a loss of land as the coastline retreats landward". Coastal erosion happens due to a result of the action of waves, tidal action, wind, storm surge, ice, rain, and surface runoff (Centers for Disease Control and Prevention, 2016; Atlantic Climate Adaptation Solutions Association, 2011). In addition to that, there are three possible factors to affect coastal erosion, such as Sea Level Rise (SLR), change of monsoon/ storm climate, and human interference (Taranaki Regional Council, 2009).

Beach erosion involves a redistribution of sand from the beach face to offshore. Stormy waves have higher energy. Therefore, the backwash is stronger leading to erosion of beach. Whereas during the calm weather, beaches are not eroded since weaves have lower energy and therefore backwash is not stronger. This phenomenon suggests that wave energy plays an important role in beach erosion (Braatz, Fortuna, Broadhead and Leslie, 2007; Kennedy, Mcinnes and Ierodiaconou, 2010; Short, 2012). Certainly, strong wind is necessary to generate stormy waves that lead to erosion (Lindgreen and Lindgreen, 2004).

There are many methods to study the coastal erosion. As an example, to analyze the coastal/ beach erosion, Synthetic Aperture Radar (SAR) is used as satellite radar to capture shoreline details, while aerial digital photography is used to get three-dimensional (3D) details through photogrammetric study (Jena, Kumar and Kintada, 2017).

Especially, soft and hard engineering structures are developed to mitigate coastal erosion. According to Hunt, Sample and Carlson (2014), the previous attempts in the 1950s and 60s to prevent sea erosion is mainly focused on "hard" engineering measures but more recently consideration has moved to apply "soft" engineering measures that are regarded to be more effective on coastal erosion control. Some of the soft measures can be identified as beach nourishment, stabilizing coastal beaches, planting coastal vegetation (i.e. littoral plants), planting mangroves, maintaining healthy fringing reefs and barrier coral reefs, protection and restoration of sea grass and algal ecosystems, and maintaining a healthy reef island and islets.

When focused on Sri Lanka, the coastal belts are one of the important elements for the sustainable development. There is approximately 1600 km of coastline across the country. The coastal region is gorgeous, and it is rich in biodiversity and wide diverse natural resources. However, coastal erosion has become a problem. With population growth, the pressure on the resource base of the coastal zone has also proportionately increased. It creates new stresses on the coastal environment, and it can become a hazard in the future. Further, the lack of understanding of the dynamic nature and complex interrelationship among ecosystems and human activities in the coastal zone result in an escalation of coastal problems (Senevirathna, Edirisooriya, Uluwaduge and Wijerathna, 2018). Especially, there is a high concentration of population in the southwest coast and western coastal areas, which will expand the coastal erosion in specific areas.

However, coastal erosion is an acute problem today. Accordingly, many coastal areas in the southwest coastal zone in Sri Lanka are highly vulnerable to coastal erosion. In this zone, coastal erosion of Calido beach in Kalutara is a very huge problem today. Especially, the main effect of coastal erosion is to damage or destroy various structures along the coast. Therefore, the buildings along the coastline are highly

vulnerable to coastal erosion in this area. This can also be a huge problem for the tourism industry because the Calido beach in Kalutara plays a vital role in attraction of tourists. Hence, the coastal region has been very popular among foreigners. The economic and social demand previously received from this area has been reduced today due to this situation. Therefore, understanding this issue and contributing to mitigate coastal erosion will be useful in the future.

Present study is focused on analyzing the coastal erosion and identifying the causes of coastal erosion in Calido beach, Kalutara. The specific objectives of the study are mainly two folds; 1) to identify spatial distribution of beach erosion in Calido, and 2) to identify the causes for coastal erosion in Calido beach.

2. METHODOLOGY

Description of study area

Kalutara is located in the Western province and it covers an area of 1,598 square kilometers in Sri Lanka. It is situated on the coast at the estuary of Kalu River. Accordingly, this study is mainly focused on Calido beach in Kalutara.

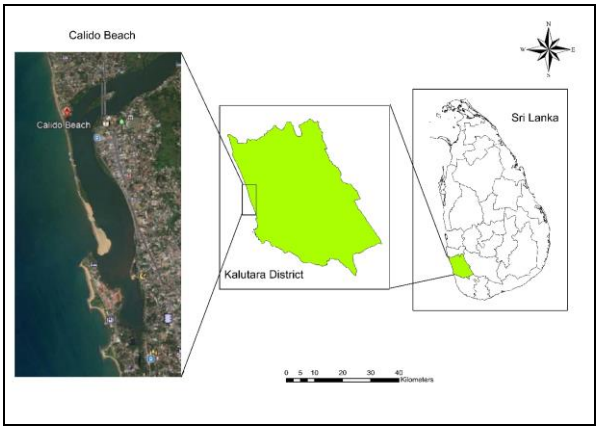

Figure 1: Location of the study area

Calido beach locates in Kalutara district in the Western province of Sri Lanka (Figure 1). It is also located in the wet zone and the Southwest coastal belt of Sri Lanka. The study area is located at the coordinates between 6° 34′ 59.16″ N and 79° 57′ 33.48″ E. The average annual temperature of the coastal zone is around 24 °C - 30.5 °C. Calido beach is the belt of beach that lies between the Kalu River estuary and the Indian Ocean. It is a usually straight beach extending in the south direction.

There are two main monsoon periods in Sri Lanka, namely Southwest monsoon (from May to September) and Northeast monsoon (from December to February). Accordingly, rainfall in the study area is mainly received during the southwest monsoon. High energy steep waves are produced by the southwest monsoon along the south to northwest coastlines of Sri Lanka. The high-energy steep waves decrease the beach breadth and flatten the intertidal shore face during the southwest monsoon (Ratnayake, Ratnayake, Azoor, Weththasinghe, Seneviratne, Senarathne, Premasiri and Dushyantha, 2019).

Especially, sediments are carried with the water to the face of the beach until it consumes its energy and it begins to rush back offshore. Water carries offshore due to gravity, and therefore, it usually does not follow the same path to the beach unless it is moving towards the shore. Hence, sediment is transported downdrift in a zig-zag pattern, not backward and forward. Along shore current is generated in the breaker zone by waves breaking at an angle to the shoreline (O'Neill, 1985; National Oceanic Atmospheric Administration, 2015). Longshore and onshore-offshore sediment transport is based on wave direction and strength (Figure 2).

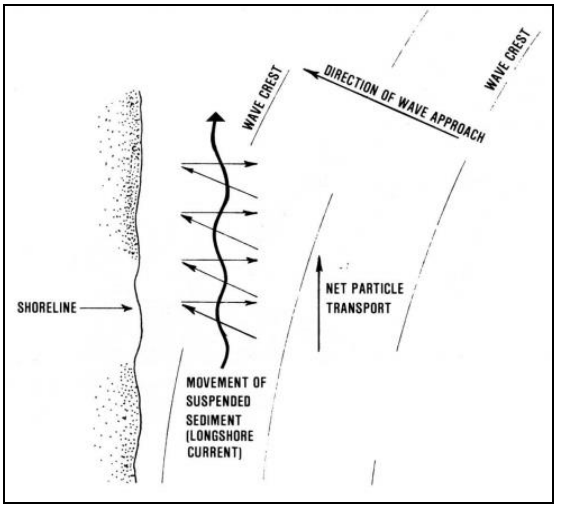

Figure 2: Sediment Transports phenomenon
Source: O'Neill, 1985

Wind waves are set up as a consequence of the wind action on the surface of the water. Wind waves depend on the height, length, period, and direction at which they are striking the shore (Figure 3).

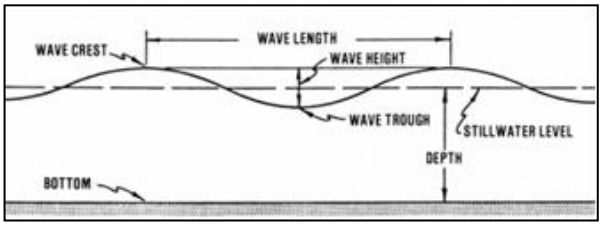

Figure 3: Wave characteristics (Source: O'Neill, 1985)

Data collection

The study was mainly based on secondary data. Wave climate, river flow, rainfall, shoreline changes, and sediment transport data were collected for analyzing the coastal erosion in the Calido beach, Kalutara. Monthly river flow and rainfall data were obtained from the Department of Irrigation and the Department of Meteorology, Sri Lanka. Monthly river flow data were collected for a period of 30 years from 1990 to 2020 at Putupaula gauge station. Monthly rainfall data were also collected for a period of 30 years from 1990 to 2020 at Kalutara rain gauge station.

Further, 22 historical Google earth images were collected for the study during the period from 2004 to 2020. Those images were collected for the months of January, February, March, April, May, August, October, November, and December.

Cross-shore profiles were used for Sediment transport calculations. Further, wave data were obtained from Beruwela. Other sources of data including video, newspapers, and journals were also collected to gather information related to the study.

Data analysis

This study was based on qualitative analysis. A sediment transport map was created using LITPACK model. Rose plot diagrams were generated by MIKE Zero. Furthermore, the past and recent Google earth satellite images were used to examine the spatial distribution of beach erosion and accretion trends in the study area. Accordingly, satellite images in 2004, 2005, 2009, 2010, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, and 2020 were used to identify the shoreline changes for analyzing the level of eroded coastal area as high, medium, and low.

To examine the behavior of the coastline and to identify the land use patterns of the study area, satellite imagery by using Google Earth Pro were used. MS Excel was used to analyze the collected rainfall and discharge data.

3. RESULTS AND DISCUSSION

Analysis of the spatial distribution of beach erosion

According to the analysis of shoreline changes between 2004 and 2020, the eroded area has been classified as high, medium, and low (Figure 4).

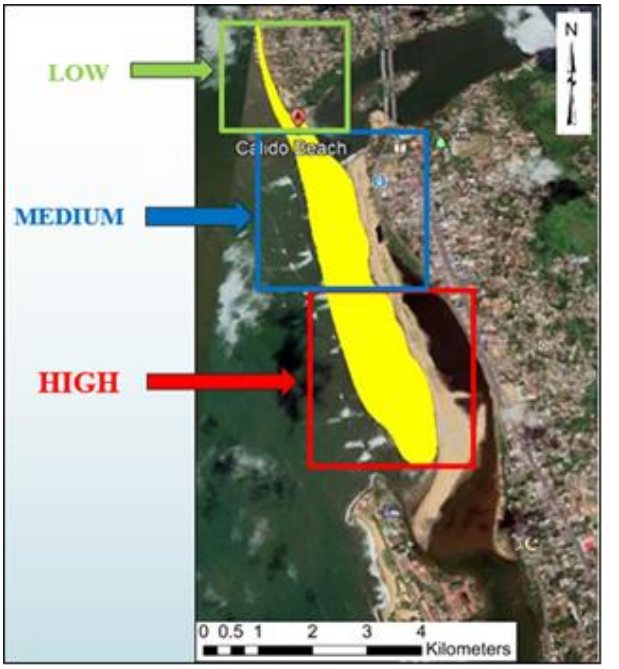

Figure 4: Spatial distribution of beach erosion in Calido

Therefore, the study revealed that the total extent of the eroded area of the Calido beach was approximately 0.45 km^2. Also, the length of the eroded area was approximately 3 km, while the perimeter was about 5.52 km.

Identify the causes of coastal erosion

1. Removal of the sand bar

The sand bar in Calido beach has been cut off to widen the river mouth as a solution to drain the water during the heavy flood situation of May in 2017. When considering the condition of the Calido beach before the sand bar was cut and after the sand bar was cut (Figure 5), it could be identified that the Calido beach has continued to erode by December, 2017. It was a serious problem for the people who live in this area.

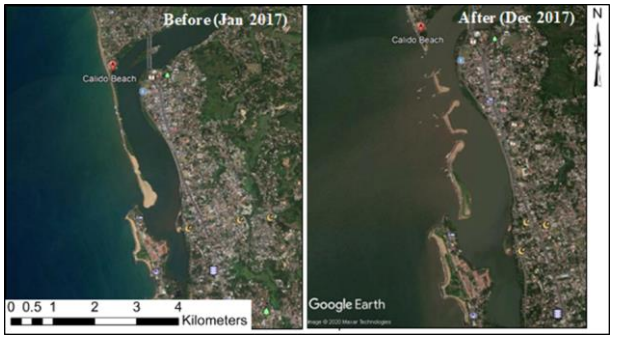

Figure 5: Satellite images of sand bar in Calido beach in January 2017 and December 2017

2. Changes in rainfall pattern & river flow

The climate is one of the facts that influence coastal erosion. There were variations between rainfall and discharge of the study area at the Putupaula gauge station over about 20 years (Figure 6). Although, there was no significant change from 1995 to 2016, however, there was a significant increase in rainfall and discharge by 2017 and 2019.

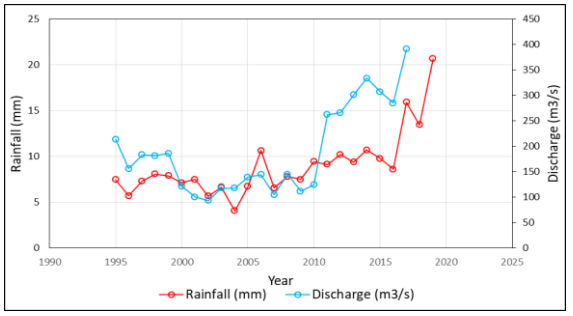

Figure 6: Variation of annual rainfall and river flow at Putupaula

Furthermore, it could be identified that there were significant variations of monthly rainfall at Kalutara from 2016 to 2020 (Figure 7) by considering the rainfall seasons as Northeast (NE) monsoon, First-inter monsoon (IM1), Southwest (SW) monsoon and Second-inter monsoon (IM2). According to those variations, a significant increase in rainfall has occurred during the southwest monsoon.

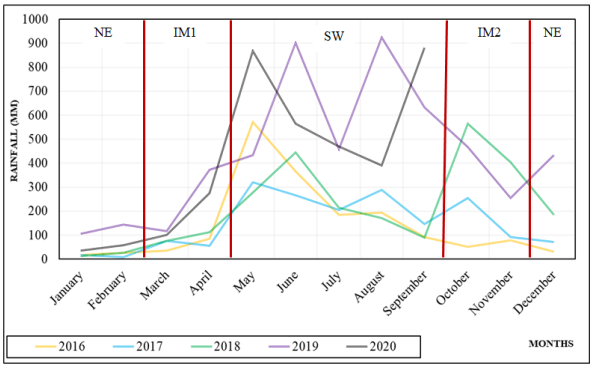

Figure 7: Monthly rainfall variation at Kalutara

3. Sediment Transport

Sediment transport can be identified as the movement of sediments due to wave action and currents in the nearshore area. There are two ways of sediment transport. They are longshore transport (which is parallel to the shore) and onshore-offshore transport (which is perpendicular to the shore). These two types of sediment transport cause either erosion or deposition according to the physical characteristics of the shore and the waves. Generally, less steep, long-period waves move sediment onshore, while steep waves with shorter periods tend to transport sediment offshore (O'Neill, 1985). In addition to that, water stirs bottom sediments at the break of the waves.

Accordingly, at Kalutara coastal area, Longshore and cross-shore sediment transport directions can be identified (Figure 8). The longshore drift and its direction are mainly controlled by the southwest and northeast monsoon wind and waves of Sri Lanka. The cross-shore transport of the coastal profile consists of onshore and offshore sediment transport components and is generated by a variation of waves and water level conditions along the adjacent coast. According to the study, longshore transport of sediment value is

greater than the cross-shore transport of sediment value from Kalu River. A careful study of this map shows that the supply of sediment from the Kalu River is higher than those of the other rivers around Sri Lanka. Although, sand deposition in other river estuaries is a problem, sand deposition at this location is very advantageous. According to that, it can be assumed that the coast will develop at a higher rate.

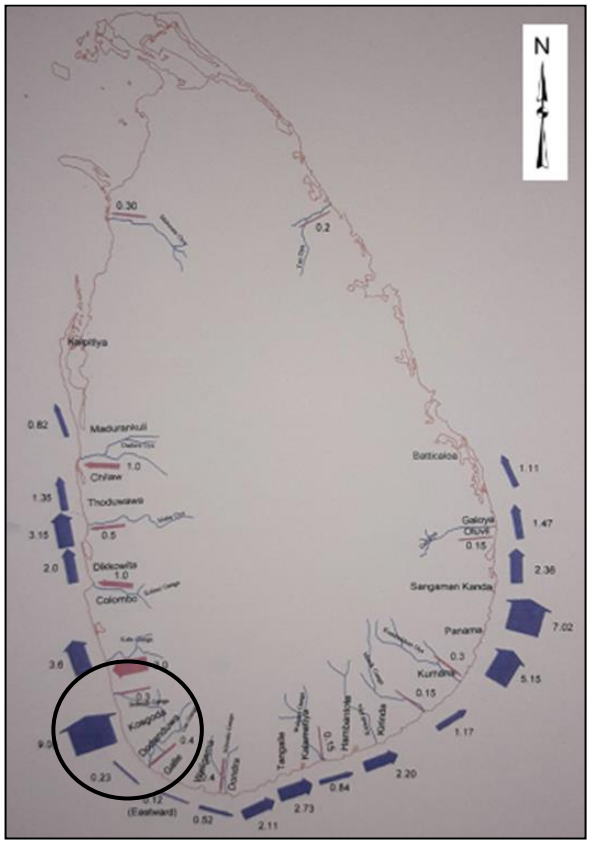

Figure 8: Annual net sediment drift along the shoreline and River discharges (Values are in 100,000 m3/ yr)

4. Wave Climate

Waves are two types as short waves in which the wave periods are less than nearly 20s and long waves in which the wave periods are between 20-30s and 40 min. Furthermore, short waves can be divided into two as sea waves and swell waves. In general, sea waves are steep and are often both irregular and directional and they are generated and conducted by the local wind field. Sea waves can be destructive for the coastal zone because they generate an offshore motion of sediments, which effects a normally flat shoreface and a steep foreshore. Swell waves can be identified as waves that are generated by wind fields far away. Also, they have carried long distances over deep water away from the wind field and their propagation direction is not the same as the local wind direction (Goodwin, Stables and Olley, 2006; Hemer, Church and Hunter, 2007; Hughes, 2016). Furthermore, swell waves can be developed from the coastal profile to a steep shoreface (Mangor, Drønen, Kærgaard and Kristensen, 2017).

The combination of ocean currents and tidal waves increases coastal land erosion. Two rainfall seasons are mainly affected by ocean current circulation in Sri Lanka. Those two different rainy seasons are Southwest monsoon from May to September and the Northeast monsoon from December to February.

Accordingly, it is dominant for the south and west coasts during South-west monsoon. This is also one of the facts contributing to the increase in coastal erosion on the southwest part because the wave conditions on the west coast during the southwest monsoon are more severe than the wave conditions of the east coast during the northeast monsoon (Senevirathna et al., 2018).

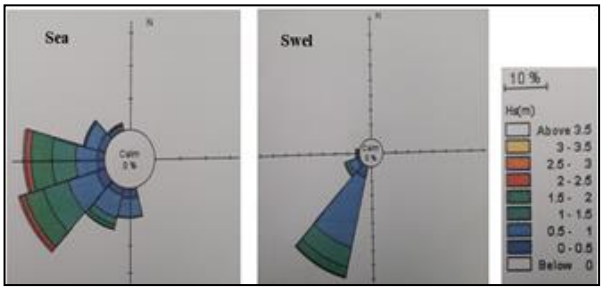

Figure 9: Annual wave roses in Beruwala

Rose petals indicate the direction of the wave and these different colors indicate the wave height. Waves are generated by the nearshore and offshore winds, which blow over the sea surface. Then, their energy is transferred to the water surface. Therefore, it can be observed that the sea waves strike more in different directions than swell waves (Figure 9). Furthermore, the wave height of the sea waves is higher than that of swell waves.

The southwest monsoon is characterized by sea waves with higher wave heights compared to these during the northeast monsoon (Figure 10).

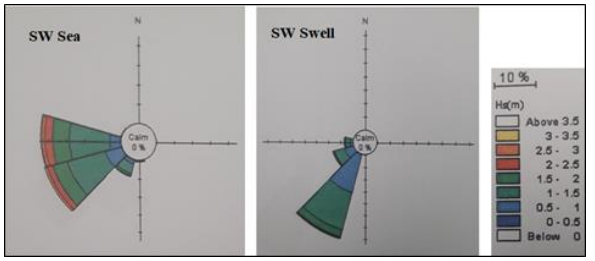

Figure 10: Southwest seasonal wave roses in Beruwala

However, waves strike in a different direction during the northeast monsoon. Also, it can be seen that waves strike generally in the same direction when comparing swell waves of southwest and northeast monsoon. Therefore, sea waves are more affected waves than swell waves. It affords increasing transport for incidence angles from 0°- 45° while decreasing transport from 45°- 90°. It seems that there are more waves with incidence angles from 0°- 45° during the northeast season. Therefore, sediment transport increases during the northeast season (Figure 11).

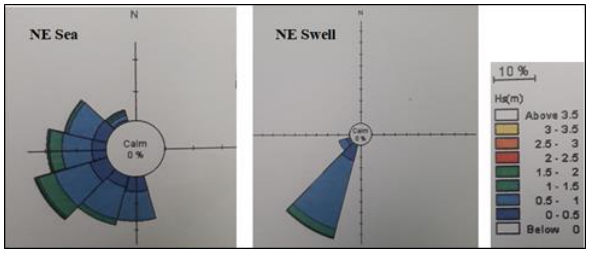

Figure 11: Northeast seasonal wave roses in Beruwala

5. Shoreline Changes

Shoreline position changes can affect coastal currents during monsoon periods. Cutting the sand bar in 2017 is the main reason for shoreline position changes in Calido beach.

The movement of material along the coast is associated with natural forces such as longshore and cross-shore currents, waves, tidal movements, and wind waves. Wave and current processes, sediment supply, coastal geology and morphology, and human mediation are primary factors that can change shoreline position (Chand & Acharya, 2010). The waves generated by the wind are one of the most important energy transfer agents along the Calido coastline. These waves release their energy by striking the coast and setting up the erosion of cross-shore and alongshore. There is no significant change of shorelines in the early years. It is a regular pattern. However, shorelines are significantly changing yearly after the year 2017 (Figure 12).

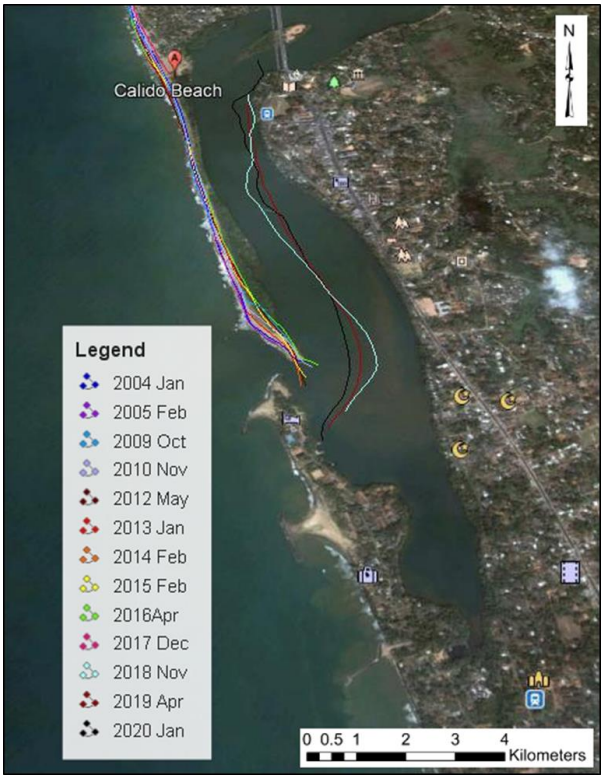

Figure 12: Annual shoreline changes in Calido beach

Accordingly, it can be observed that the sand deposition is higher on December 28 than it was on December 17. In January, it was even more so. According to these figures, it can be concluded that predominantly sand is deposited during the northeast season (Figure 13).

It can be seen that the sand deposition in February was even higher. The formation of the sand bar changed after the southwest monsoon period. The southwest monsoon may have contributed to this change, as heavy rainfall and higher wave height of waves occur during this monsoon.

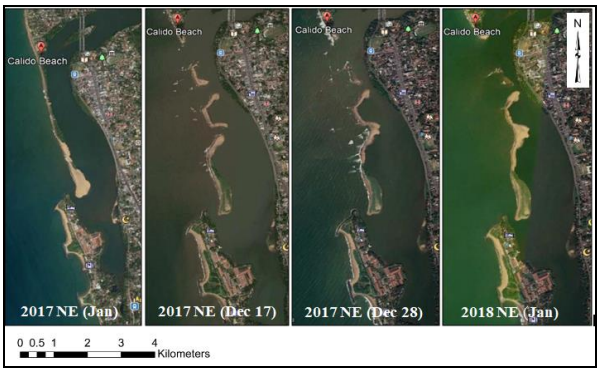

Figure 13: Seasonal shoreline changes during 2017 & 2018

Comparision of these images indicates that some areas are newly deposited, and some areas are eroded. Constructive waves can cause erosion in some areas because their strong backwash will result in beach erosion. Also, cross-shore sediment transport and alongshore sediment transport may cause the new deposition. Because of the increasing the river flow, the sand supply from the river is increased (Figure 14).

Figure 14: Seasonal shoreline changes during 2018 & 2019

These images clearly show that the direction in which the new sand is deposited is the same as that on the sediment transport map around Sri Lanka. By considering all these figures, it can be concluded that the developing rate of sand bar is less during the southwest monsoon and that predominantly sand deposited during the northeast monsoon. Hence, the southwest monsoon and northeast monsoon are the critical seasons. However, these are only seasonal changes. It gets recovered and deposited after the season (Figure 14).

Another important fact that can be seen in the study area is the sediment cell developing in the sand bar (Figure 15).

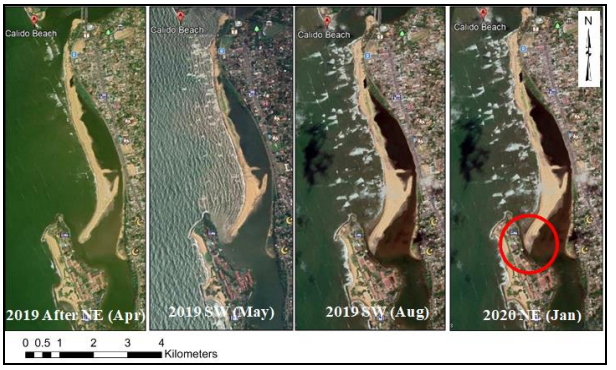

Figure 15: Seasonal shoreline changes during 2019 &2020

Sediment cells are the movement of material that is largely self-contained. Also, if the dune in the lagoon area (the area surrounded by red color in the fourth image) is covered, another huge problem will arise. It can cause water quality problems because people who live in this area normally put garbage in the water and there will be no circulation if it is closed.

Therefore, no fresh water is available in this region. This causes health problems for the people living in this area. Also, marine habitat already exists in this lagoon area. Before cutting the sand bar, the water is purified and the water flows into the sea from this region. Therefore, the side effect after cutting is more than before cutting.

When considering the seasonal shoreline changes during in 2017 and 2018 of the river mouth area, it can be identified a sand formation after cutting the sand bar. It creates a major effect on salinity intrusionin the site where the sand bar was cut (Figure 16). It can be identified that the sand bar was developed gradually during the NE season. However, after the southwest monsoon in 2018, this sand bar has eroded (Figure 16 & 17). Furthermore, sand is deposited gradually and increased near the river mouth area. However, it is also another severe problem because the dune can adjoin with the island. This situation can be clearly shown in the southwest season in 2019 (Figure 18).

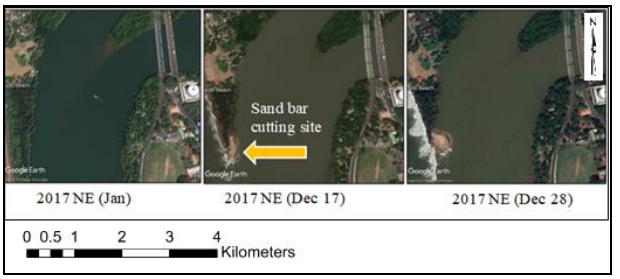

Figure 16: Seasonal shoreline changes in 2017

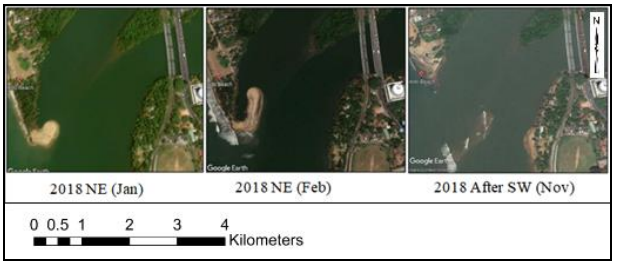

Figure 17: Seasonal shoreline changes in 2018

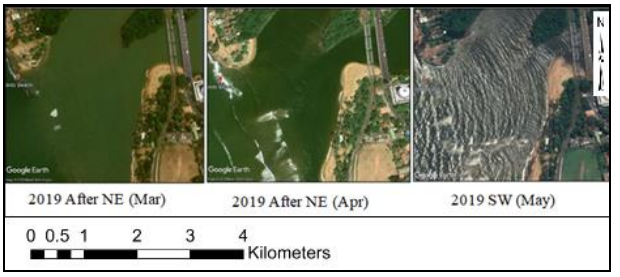

Figure 18: Seasonal shoreline changes in 2019

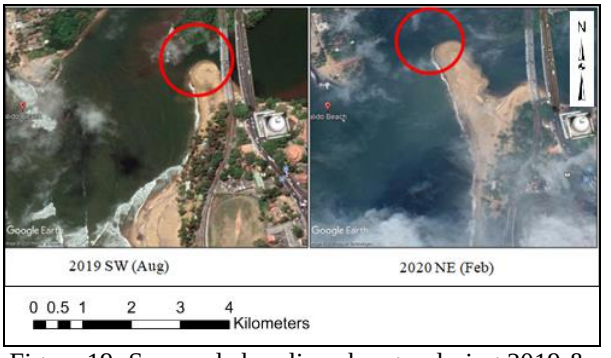

Figure 19: Seasonal shoreline changes during 2019 & 2020

Although a gradual expansion of the sand bar toward the sea can be identified in the northeast season in 2020 (Figure 19), it is a serious problem as it makes a more difficult to drain the water from the mouth of the river. Then again this area will be eroded.

4. CONCLUSIONS

In Sri Lanka, the coastal zone is a key to the sustainable development of the country. However, coastal erosion has been identified as a major natural hazard for a long time. Kalutara is one of the most critically eroded coastal areas in the country. The goal of the study was to analyze the spatial distribution of beach erosion of Calido beach in Kalutara. This study was based on qualitative analysis. Google Earth Pro was used for the completion of research objectives. Rainfall, river flow, wave climate, sediment transport, and shoreline changes are the main data that were collected.

According to the analysis, the cutting of sand bar in May, 2017 was the main cause of coastal erosion in Calido beach. The spatial distribution of eroded area was classified as high, medium, and law beach erosion. The results of the study revealed that the total extent of the eroded area was approximately 0.45 km^2. Further, the results of the study revealed that the length of the eroded area was approximately 3 km and the perimeter was about 5.52 km. Therefore, this study recommends identifying suitable protection and mitigation measures for the coastal erosion in Calido beach. The study also recommends further studies such as designing the structure of wave analysis for the return period of about 25-100 years, performing a proper Environmental Impact Assessment and Feasibility Analysis, and applying the most suitable flood control system to the Kalu River.

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ASSESSMENT OF GROUNDWATER QUALITY USING MULTIVARIATE STATISTICAL ANALYSIS IN MEDAWACHCHIYA AND HURULUWEWWA AREAS IN ANURADHAPURA DISTRICT

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ABSTRACT

Water is a scarce commodity in the North Central Province (NCP) of Sri Lanka and people use groundwater for consumptive purposes. 85% of the rural population in the NCP obtains water from shallow and deep wells. However, human health is affected by water quality in various ways. Therefore, the present study was focused on identifying the quality of groundwater in Madawachchiya and Huruluwewa by using multivariate statistical analysis. Medawachchiya area and the Huruluwewa area were both separately divided into 30 quadrants and the middle point of each was taken as a sampling location. Altogether there were 60 water sampling locations. During the survey period of two years, twenty-four water quality parameters (Temperature, DO, pH, Electrical Conductivity (EC), Total Alkalinity (TA), Total Hardness (TH), Chloride (Cl), Nitrate, Phosphate, Fluoride, sulfate, Fe, Zn, K, Na, Mg, Ca, Cr, Cd, Se, Al, Pb, Mo, and As) were analyzed. Data analysis was performed by using the multivariate statistical analysis techniques as a tool. Five parameters including pH (p-0.787), fluoride (p-0.497), Fe (p-0.116), Mg (p-0.06) and as (p-0.532) were not significantly different, while all other parameters were significantly different in both areas. Three clusters in Medawachchiya and five clusters in Huruluwewa were identified. However, Medawachchiya area (13%) indicated very less amount of groundwater samples which were good for consumptive purposes than Huruluwewa (37%). Strong positive correlations appeared in between TH vs EC (p-0.744), Orthophosphate vs K (p- 0.770) in Medawachchiya study area and TH vs EC (p-0.830), Cl vs EC (p-0.807), EC vs Na (p-0.778), EC vs Mg (p-0.788), Cl vs TH (p-0.719), TH vs Ca (p-0.715), and TH vs Mg (p-0.811) in the Huruluwewa study area. The water quality of both areas were moderated by the hydro-geochemical and agrochemical influencing factors. The study revealed that the majority of the groundwater wells were unsuitable to provide water for drinking purpose without any pre-treatment.

KEYWORDS: *Groundwater, Water quality, Cluster analysis, Correlation, Factor analysis*

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1. INTRODUCTION

Water quality effects human health, economic development, and social prosperity. The quality of the groundwater depends on the atmospheric precipitation, inland surface water, quality of recharged water, and sub-surface geochemical processes (Vasanthavigar *et al*., 2010). Most of the water resources get contaminated due to natural activities such as precipitation, weathering activities, soil erosion, and anthropogenic activities such as industrialization, agricultural activities, and waste disposal. Water is a scarce commodity in the North Central Province (NCP) of Sri Lanka and people use groundwater for consumptive purposes. 85% of the rural population in the NCP obtains water from shallow and deep wells for consumption (Lasantha *et al*, 2008, Jayewardene *et al*., 2010; Chandrajith *et al*., 2011a ;). According to the Censes 2011, 75% of the rural people in Anuradhapura district relied on the groundwater through dug wells and tube wells. The shallow groundwater is recharged by seepage from small tank cascade systems (Panabokke, 2003; Kumari *et al*, 2016; Kumari, 2020). Due to lack of suitable drinking water, people living in NCP suffer from different kind of water-borne diseases (Mahagamage & Manage, 2019; de Silva 2019)

In late nineties, medical specialists have identified an alarming high incidence of a new form of Chronic Kidney Disease (CKD) that was later named as Chronic Kidney Disease of unknown etiology (CKDu) as indicated by Wanigasuriya *et al.*, 2007. It is a non-communicable disease (Elledge *et al*., 2014) in which CKDu usually emerges slowly and not appearing until that reaches stages of 3 or 4. The CKDu is more prevalent in the north-central region of Sri Lanka, and it is believed believed to be associated with geo-environmental nephrotoxins which cause slowly progressive chronic fibrosis of kidneys (Athuraliya, 2008). Most researches suggested that the etiology of this disease may be a combination of several environmental factors such as high level of fluoride in groundwater, heavy metals such as cadmium, exposure to inorganic pesticides, and use of aluminum utensils (Herath *et al*., 2005; Bandara *et al*., 2008; Wanigasuriya, 2007; Ileperuma *et al*., 2009; Wanigasuriya, 2011; Cooray *et al*., 2019).

The CKDu in the dry zone of Sri Lanka is somewhat similar to a cases reported in Balkan countries; Bulgaria, Romania, Serbia etc. In Southern Europe. A similar type of kidney diseases with unknown etiology was reported in countries of North Central America; El Salvador, Mexico and Nicaragua, Asian countries; India, China and Taiwan and African countries such as Congo, Egypt, Morocco, Senegal, Nigeria, Libya, Burkina Faso, Tunisia and Sudan, etc. (Tatu *et al*., 1998; Stefanovic, 1999; Batuman, 2006; Stefanovic and Polenakovic, 2009).

Water quality is a combined effect of several governing parameters. Analysis of individual parameters and interpretation of data for single parameters do not give the interpretation of the collective effect of parameters on water quality.

The early studies considered individual water quality parameters and correlated them with the CKDu distribution. Therefore, the present study was focused on examining the multifactorial effects of water quality to find out the suitability of water for drinking purposes and to identify the potential environmental factors and anthropogenic activities that could affect the variation of water quality in selected study sites.

2. METHODOLOGY

Madawachchiya area with CKDu high prevalence and Huruluwewa area with less prevalence were selected as study sites. Both areas were separately divided into 30 quadrants and the middle point groundwater well was selected as the sampling locations (Figure 1). Dug wells, Tube wells, and springs were selected as groundwater sources but not in equal numbers. Selected wells were used for drinking purposes in the relevant area. All together twenty-four water quality parameters were analyzed.

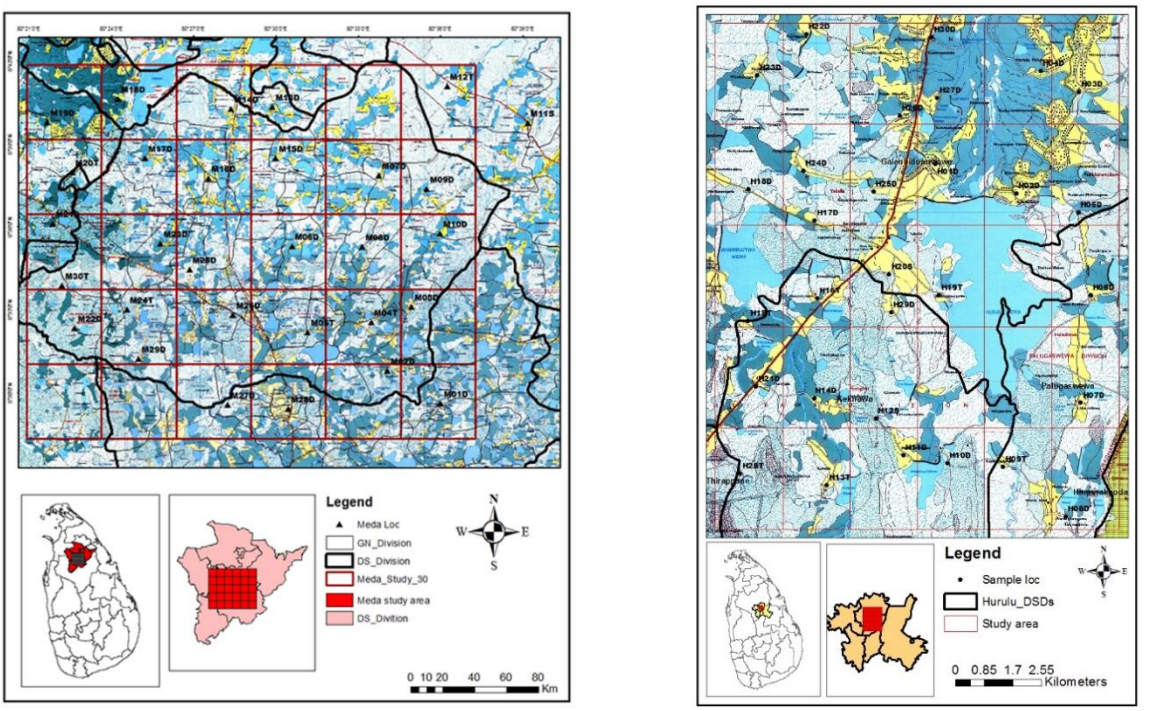

Figure 1: Madawachchiya (Left) and Huruluwewa (Right) Study areas

Temperature, DO, pH, Electrical Conductivity (EC) Total alkalinity, and total hardness were measured in the field soon after the sampling. Samples were analyzed using digital meters (pH; SenslON^{TM}+pH1, DO; SenslON^{TM} +DO6, Electrical Conductivity; SenslON^{TM} +EC5), digital titrator: (model 16900, HACH) (alkalinity, hardness and chloride) and HACH 2700DM Spectrophotometer (nitrate, phosphate, fluoride, iron and sulfate). Zn, K, Na, Mg, Cr, Cd, Se, Al, Hg, Pb, Mo, and As, Cr, Cd, Se, Al, Pb, Mo and As were analyzed using Inductively Coupled Plasma Mass Spectrometry (ThermoICapQICP-MS) at the Bandaranaike Memorial Research Institute in Nawinna and Ca was measured by using Atomic Absorption Spectrophotometer (ThermoiCE 3000) at University of Sri Jayewardenepura.

Mean values of pH of wells in both study areas were corrected for temperature by using pH temperature correction calculator. The corrected values were taken for further analysis (https://www.hamzasreef.com/Contents/Calculators/PhTempCorrection.php).

The statistical analyses was conducted through the SSPS 16.0 version. Analysis of Variance (ANOVA) and t-test was conducted to find out whether the different sources are significantly different from one another. Cluster analysis was carried out to identify similar water quality locations by using 24 water quality parameters. The correlations of each parameter were measured by using the correlation coefficient (r). According to Kumari & Rani (2014) $r > 0$ indicate positive relationship and $r < 0$ indicate a negative relationship in parameters while $r = 0$ indicates no relationship. The strength of the relationship can be determined by using this r, and when closer to +1 or -1, it gives a greater relationship. This analysis is used to distinguish the correlation between different parameters.

3. RESULTS

Due to lack of suitable drinking water available for consumption, people living in NCP suffer from a different water-borne diseases. The results of this study indicates the status of water quality based on 24 water quality parameters analyzed in 60 wells in Madawachchiya and Huruluwewa.

Out of the 24 measured parameters in the two study areas, five parameters including pH (*p*-0.787), fluoride (*p*-0.497), Fe (*p*-0.116), Mg (*p*-0.06) and As (*p*-0.532) were not statistically significantly different. However, all other parameters were significantly different in two study areas (Table 1). In both study areas, mean values of EC, total alkalinity and total hardness were greater than the threshold standard limits specified by the World Health Organization & Sri Lanka Standards drinking water standards.

The mean values calculated for water quality parameters were plotted against their sources to find out whether there is any significant difference in different water sources in the two study areas. Most water quality parameters were significantly different in dug wells, tube wells, and springs. In medawachchiya study area, except Cr (*p*-0.199), As (p-0.381), Cd (*p*-0.237), Zn (*p*-0.637), and Se (*p*-0.354), all the other water quality parameters were significantly different in the three water sources. In Huruluwewa, except for As (*p*-0.900), Cd (*p*-0.315), Zn (*p*-0.968), and Se (*p*-0.140), all the other parameters were significantly different in the three water sources (Table 2). Grey color indicates the parameters which are not significantly different.

3.1 Cluster Analysis

Cluster analysis was carried out on twenty-four water quality parameters to identify the homogenous wells in both study areas. All wells were categorized into five clusters. The cluster results were compared with water quality values in both study areas to identify the different water quality categories in each cluster. Medawachchiya shows three clusters and Huruluwewa shows five clusters as illustrated Cluster Dendrogram (Figure 2). Based on the Dendrogram, there are two major clusters in the rascal length of 25. Major cluster A is divided into three sub-clusters and major cluster B is categorized into two sub-clusters. Characteristics are also considered when naming the clusters. The pollution level increase from cluster 01 to cluster 05. For the interpretation purpose C1 to C5 clusters were named as follows:

C1 - Low contaminated
C2 - Moderately contaminated
C3 - Marginally contaminated
C4 – Highly contaminated
C5 – Very highly contaminated

Table 1: Two Sample t-test to compare the significance of the parameters in the two study areas; Medawachchiya and Huruluwewa

No	Parameter	*P* value
1	Temperature	0.000
2	EC	0.000
3	DO	0.001
4	pH	0.787*
5	Total hardness	0.005
6	Total alkalinity	0.008
7	Sulfate	0.004
8	Nitrate	0.000
9	Ortho P	0.000
10	Fluoride	0.497*
11	Chloride	0.000
12	Fe	0.116*
13	Na	0.000
14	K	0.000
15	Ca	0.002
16	Mg	0.068*
17	As	0.532*
18	Cd	0.000
19	Zn	0.003
20	Se	0.000
21	Mo	0.000
22	Pb	0.002
23	Cr	0.000
24	Al	0.000

Grey color indicates the parameters which are not significantly different.

Table 2: Analysis of Variance in dug wells, tube wells and spring water qualities in both study areas

	Medawachchiya				Huruluwewa			
Parameter	Dug well	Tube well	Spring	*p*-value	Dug well	Tube well	Spring	*p*-value
Temp	28.5	29.9	28.4	0.000	28.2	29.3	27.9	0.000
EC	951	807	121	0.000	1108	1732	118	0.000
DO	5.26	5.12	5.28	0.005	5.35	4.7	5.13	0.000
pH	7.7	7.2	6.2	0.000	7.8	7.2	6.1	0.000
Total hardness	295	271	19	0.000	293	473	30	0.000
Total alkalinity	302	285	15	0.000	280	311	15	0.000
Chloride	67	50	24	0.000	97	238	10	0.000
Sulphate	24	14	1	0.000	18	23	0	0.000
Fluoride	0.73	0.64	0.03	0.000	0.72	0.69	0.03	0.000
Ortho P	0.32	0.29	0.14	0.013	0.23	0.25	0.08	0.000
Nitrate	1.9	1.0	0.4	0.001	0.9	0.8	1.5	0.000
Fe	0.03	0.04	0.02	0.001	0.03	0.05	0.03	0.001
Cr[µg/L]	0.81	0.97	0.7	0.199	0.94	2.1	0.93	0.000
As [µg/L]	0.27	0.3	0.14	0.381	0.26	0.25	0.27	0.900
Cd [µg/L]	0.34	0.39	0.26	0.237	0.27	0.28	0.32	0.315
K [mg/L]	3.3	1.2	1.0	0.039	1.1	2.9	1.5	0.000
Ca [mg/L]	33.5	26.5	1.1	0.000	37.2	44.1	1.6	0.000
Na [mg/L]	43.3	37.4	7.7	0.000	56.1	83.4	7.3	0.000
Mg [mg/L]	20.0	18.4	6.1	0.000	20.5	29.2	2.3	0.000
Zn (µg/L)	15.7	14.8	13.3	0.637	17.6	17.7	18.2	0.968
Se (µg/L)	3.7	3.4	2.4	0.354	4.5	5.3	3.9	0.140
Mo (µg/L)	1.07	0.56	0.64	0.018	1.54	1.58	0.69	0.025
pb (µg/L)	0.73	2.05	0.19	0.000	0.62	0.97	0.77	0.000
Al [µg/L]	37.9	53.5	35.6	0.001	63.8	51.6	81.7	0.004

The parameters which are not significantly different are indicated in ash colour

3.2 Correlation analysis

The correlation is used to measure the strength of statistical significance and the association between two variables. The summary of the correlation analysis is tabulated in table 3. Both study areas indicate a strong positive correlation between total hardness and EC. Strong and moderate positive correlation indicates in between, total alkalinity vs. EC, Chloride vs. EC, Sulfate vs. EC, Ca vs. EC, Na vs. EC, Mg vs. EC, total alkalinity vs. total hardness, Sulfate vs. total hardness, Mg vs. total hardness, Mg vs. total alkalinity, Na vs. Sulfate and Mg vs. Na parameters in both study areas.

All correlated parameters in both study areas (EC, total hardness, total alkalinity, Na, Ca, Mg, Cl, and Sulfate) originate from the dissolution and weathering of rock materials. Therefore, those factors were correlated. Ca vs total hardness, Na vs total hardness, sulfate vs total alkalinity, Cl vs total hardness, Na vs. total alkalinity, fluoride vs. total alkalinity, Na vs. chloride, Mg vs. chloride, Mg vs. sulfate, fluoride vs. sulfate and Mg vs. Ca were weakly correlated in Medawachchiya and strongly and moderately correlated in Huruluwewa study area.

Dissolution of minerals during the infiltration is different in Medawachchiya to Huruluwewa possibly due to differences in precipitation. According to the Meteorological data, the average precipitation for the study period was 116 mm/month in Medawachchiya and 140 mm/month in Huruluwewa. The average precipitation in Huruluwewa is higher than that of Medawachchiya. Therefore, the amount of dissolution is low in Medawachchiya than in Huruluwewa. It may be the reason for the weak correlation in the above parameters in Medawachchiya.

Medawachchiya has strongly and moderately correlated parameters such as total alkalinity vs. total hardness, orthophosphate vs K, sulfate vs. Cl, and K vs sulfate. However, in Huruluwewa, weak or no correlations exist between the above parameters.

EC is a measurement of dissolved minerals in the water. Therefore, EC is closely related with the total hardness which represent the Ca and Mg ions in water which is derived from limestone, dolomite, or chalk aquifers. Most of the mineral ions (Ca, Mg, Na. K, P, Cl, and SO4) dissolve in groundwater.

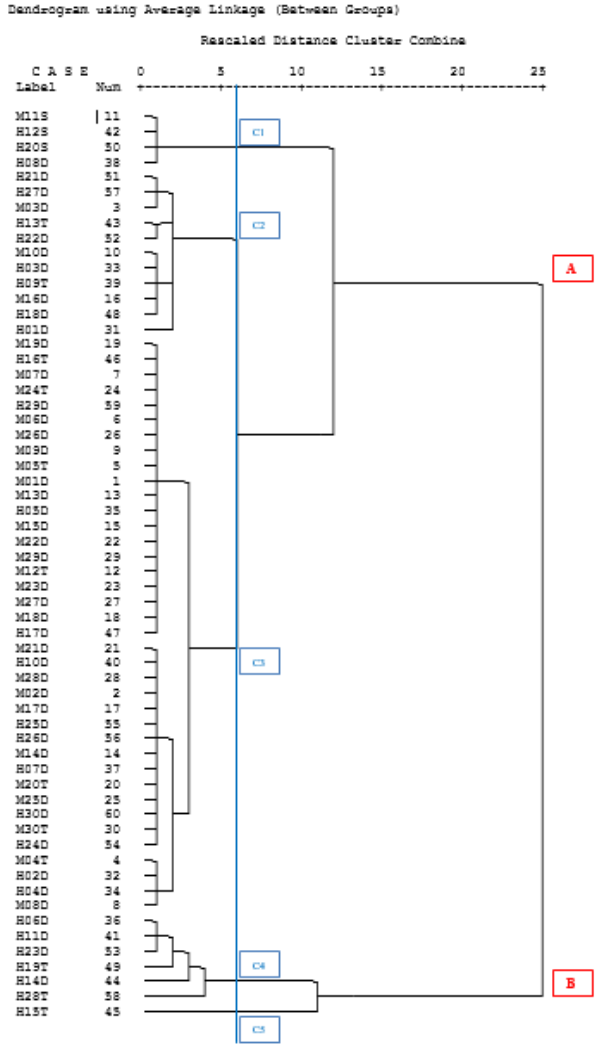

Figure 2: Dendrogram of the sampling using average linkage of Medawachchiya and Huruluwewa area sampled wells

Table 3: Summary of correlation in both study areas

Correlations	Medawachchiya	Huruluwewa
Total hardness vs. EC	**0.744***	**0.830***
Total alkalinity vs. EC	0.686	0.641
Chloride vs. EC	0.589	**0.807***
Sulfate vs. EC	0.697	0.576
Ca vs. EC	0.549	0.557
Na vs. EC	0.635	**0.778***
Mg vs. EC	0.618	**0.738***
Total alkalinity vs. pH	0.500	**0.308****
Total alkalinity vs. Total hardness	0.632	0.573
Chloride vs. Total hardness	**0.427****	**0.719***
Sulfate vs. Total hardness	0.505	0.524
Ca vs. Total hardness	**0.471****	**0.715***
Na vs. Total hardness	**0.407****	0.545
Mg vs. Total hardness	0.665	**0.811***
Sulfate vs. Total alkalinity	**0.497****	0.624
Sulfate vs. chloride	0.560	**0.385****
Na vs. Total alkalinity	**0.372****	0.672
Mg vs. Total alkalinity	0.530	0.618
Fluoride vs. Total alkalinity	**0.228****	0.653
K vs. Sulfate	0.592	**0.063****
Na vs. chloride	**0.426****	0.617
Mg vs. chloride	**0.374****	0.550
Na vs. Sulfate	0.530	0.542
Mg vs. Sulfate	**0.477****	0.533
Fluoride vs. Sulfate	**0.126****	0.621
OrthoP vs. K	**0.770***	**0.110****
Mg vs. Ca	**0.356****	0.518
Mg vs. Na	0.501	0.525
WQI vs. Total alkalinity	**0.476****	0.507
WQI vs. sulfate	0.568	0.512
WQI vs. F	**0.153****	0.593
WQI vs. Orthop	**0.740***	0.535
WQI vs K	**0.708***	**0.206****

***Strong positive correlation**

**Weak or no correlation

3.3 Principal component analysis (PCA)

PCA was used as a method of factor extraction. Factors were the preceding estimate of the amount of variation in each groundwater quality parameter. The PCA was carried out on the twenty-four parameters to identify the major variables affecting the groundwater quality during dry months and wet months separately for both study areas. The PCA was conducted using two data sets for each study area to identify the factor loading in wet months and dry months. According to the precipitation data above 50 mm precipitation per month is considered a wet month and below 50 mm precipitation per month is considered a dry month. The results of the factor loading and eigenvalues of factors in Medawachchiya are shown in Table 4. Two factors were extracted using PCA in dry months and wet months with 36 % and 34 % of total variance respectively in Medawachciya. Factor analysis was conducted using all months together and two factors were extracted with 33% of the total variance. Table 5 illustrates the factor extraction of Huruluwewa for dry and wet months and using results of all months together. According to that two factors were extracted in dry and wet months with 36% and 37% of the total variance for Huruluwewa. Only one factor was extracted with 24% of total variance when the analysis was conducted using all month's results together. Factor 1 (F1) in Medawachchiya and Huruluwewa indicated strongly and moderately positive loading on EC, total hardness, total alkalinity Ca, Na, Mg, chloride, fluoride and sulfate. This could be due to dissolution of rock particles, calcite and dolomite which were the sources for Ca, Na, Mg, chloride, fluoride, and sulfate from groundwater (Usman *et al*., 2014). According to the results, F1 can consider a hydro-geochemical influencing factor. Factor 2 (F2) is strongly and moderately positive loading on K, sulfate, orthophosphate, Na, total alkalinity, fluoride, As, Cd, Se, and Mo. Na, total alkalinity, fluoride, K, and sulfate which can dissolve in groundwater due to the weathering of igneous rock and magmatic rocks in the water.

Table 4: Rotated Component Matrix for factor extraction in Medawachchiya

Parameters	Dry months[a]		Wet months[b]		Overall	
	F1	F2	F1	F2	F1	F2
Temp	0.137	0.093	0.073	0.033	0.133	-0.038
EC	**0.856**	0.204	**0.908**	0.166	**0.903**	0.163
DO	0.149	-0.08	-0.062	0.057	0.019	-0.094
pH	0.513	0.132	0.402	-0.068	0.315	0.099
TH	**0.862**	0.036	**0.846**	0.044	**0.777**	0.065
TA	**0.708**	0.351	**0.762**	0.254	**0.657**	0.308
Cl	**0.697**	0.077	**0.544**	0.042	**0.680**	0.066
SO4	**0.663**	**0.508**	**0.638**	**0.515**	**0.680**	0.493
Fl	**0.522**	-0.392	0.436	-0.467	0.373	-0.214
OrthoP	0.228	**0.857**	0.205	**0.770**	0.163	**0.870**
NO3	0.278	-0.279	0.147	-0.181	0.096	-0.065
Fe	-0.04	-0.008	-0.006	-0.107	-0.005	-0.069
Cr	-0.054	0.208	-0.009	-0.036	0.02	0.031
As	-0.096	0.290	0.030	0.042	0.008	0.114
Cd	-0.100	-0.022	0.040	-0.287	0.018	-0.094
K	0.162	**0.912**	0.260	**0.891**	0.192	**0.888**
Ca	0.486	0.165	**0.657**	0.105	**0.549**	0.164
Na	**0.708**	0.07	**0.634**	0.14	**0.760**	0.039
Mg	**0.785**	-0.012	**0.752**	-0.015	**0.757**	-0.011
Zn	-0.183	-0.11	-0.061	-0.251	-0.167	-0.052
Se	-0.154	0.153	0.190	-0.189	0.004	0.045
Mo	0.096	**0.794**	0.112	0.383	0.083	**0.664**
Pb	0.034	-0.133	0.118	0.184	0.079	-0.09
Al	-0.052	0.068	-0.100	-0.191	-0.131	0.051
Eigenvalue	5.818	2.867	5.276	2.789	5.411	2.495
% of varience	24.24	11.945	21.985	11.62	22.544	10.397
Cumulative %	24.24	36.185	21.985	33.604	22.544	32.941

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

F. Factor

Strong loading

Moderate loading

Table 5: Rotated Component Matrix for factor extraction of Huruluwewa study area

Parameters	Dry months[a]		Wet months[b]		Overall
	F1	F2	F1	F2	F1
Temp	0.147	-0.363	0.092	0.104	0.129
EC	**0.878**	-0.072	**0.803**	0.422	**0.882**
DO	-0.135	0.085	-0.085	-0.063	-0.142
pH	0.052	0.067	0.049	0.267	0.091
TH	**0.910**	-0.106	**0.890**	0.320	**0.914**
TA	**0.526**	-0.108	0.299	**0.805**	**0.537**
Cl	**0.782**	-0.122	**0.809**	0.087	**0.788**
SO4	**0.601**	-0.001	0.382	**0.700**	**0.605**
Fl	0.312	0.002	0.082	**0.866**	0.332
OrthoP	0.107	0.004	0.040	0.042	0.059
NO3	-0.222	-0.015	-0.139	0.149	-0.269
Fe	-0.044	0.059	0.156	0.105	0.103
Cr	0.040	0.453	0.222	-0.094	0.080
As	-0.088	**0.796**	-0.149	-0.017	-0.095
Cd	-0.139	**0.693**	0.052	-0.021	-0.080
K	0.114	0.079	0.050	0.051	0.108
Ca	**0.794**	0.029	**0.848**	-0.026	**0.783**
Na	**0.580**	-0.142	0.495	**0.561**	**0.631**
Mg	**0.787**	0.077	**0.707**	0.478	**0.802**
Zn	-0.319	0.263	-0.341	-0.127	-0.403
Se	-0.028	**0.704**	0.037	0.309	0.063
Mo	0.179	**0.567**	0.118	**0.620**	0.189
Pb	0.002	0.014	-0.041	-0.212	-0.096
Al	0.009	0.161	-0.137	0.001	-0.155
Eigenvalue	5.802	2.759	6.135	2.849	5.835
% of variance	24.173	11.492	25.653	11.869	24.314
% of cumulative	24.173	35.670	25.653	37.432	24.314
Extraction Method: Principal Component Analysis.					
Rotation Method: Varimax with Kaiser Normalization.					

F. Factor

Strong loading

Moderate loading

However, total alkalinity and fluoride were loaded only in wet months in Huruluwewa. It may be due to heavy rain and the dissolution of rock particles in water. Potassium feldspar was usually the main source of K. Dissolution of fertilizers to the water may be the courses for the loadings of orthophosphate, K, As, Cd, Se, and Mo in water. Considering dry months and all months together results orthophosphate, As, Cd, Se and Mo were the most influencing parameters in F2. Therefore, F2 acts as a fertilizer influence factor.

4. DISCUSSION

Temperature, EC, DO, pH, total hardness and total alkalinity were considered as general water quality parameters. Spring water indicated the lowest average temperature, pH, EC, total hardness and total alkalinity values in both study areas. However, the tube wells indicated the lowest DO values in both study areas. Dug wells indicated the highest mean concentrations of water quality parameters except for temperature. Tube well water was extracted from deeper part of the surface compared to dug wells. The lowest temperature was recorded in springs. Dissolve Oxygen in deep water is relatively less than in surface water. Therefore, tube wells indicated the lowest average DO concentrations in both study areas. Spring water indicates lower average EC values than that of dug and tube wells. Water infiltration and dissolution of rock particles of water gives the mineral particles to groundwater in dug wells and tube wells. Huruluwewa tube wells and dug wells indicated higher average EC values than these of Medawachchiya.

Springs indicated the lowest major cations and anions of both study areas except nitrate in the Huruluwewa compared to that of tube wells and dug wells. Water infiltration through the soil and rock particles may lead to increase in the values of above water quality parameters in tube wells and in dug wells.

Therefore, dissolved mineral particles were higher in tube wells and dug wells than in springs. Fertilizer application, infiltration and dissolving phosphate-containing rock in water cause nutrient enrichment in dug wells and tube wells in both study areas. Most of the researchers have studied the water quality in dug wells, tube wells and springs. However, few studies compared the water quality concentrations with each sources (Mahagamage & Manage 2019). Mahagamage & Manage also revealed the lower concentration level of EC (79.00µS/cm -106.33µS/cm) in Medawachchiya, Padaviya and Kebithigollewa sampled springs and 77.60µS/cm-1303.00µS/cm Electrical Conductivity was recorded in wells. Jayasekara *et al*. (2013) revealed that low prevalence of CKDu is noted in communities where water consumes from springs. According to the present study most water quality parameters indicated lower concentrations in spring waters than the other two types. Therefore, the above statement tallies with the present findings.

The EC in the study areas were recorded as extremely high with a variance in the range of 52.5 µS/cm to 3400 µS/cm (Chandrajith *et al*., 2011) in Medawachchiya. Chandrajith *et al*. (2011) indicated that EC ranged from 500 µS/cm to 1500 µS/cm in Medawachchiya compared to Huruluwewa (230 µS/cm to 1129 µS/cm). Gunatilake (2016) revealed that average EC level in the dry zone is 857 µS/cm and that is comparable with the present study. Paranagama (2013) revealed that the total hardness recorded in the Medawachchiya ranged from 60 mg/L as $CaCO_3$ to 685 mg/L as $CaCO_3$ and total hardness is strongly related to the prevalence of CKDu. The results of the present study further confirmed the results of Paranagama (2013). WHO is third progress report which was submitted to the Health Ministry of Sri Lanka on 19th February 2012 mentioned that 99% of the CKDu patients have used hard to very hard water for drinking. Therefore, it may be one of the reasons for the prevalence of CKDu. Gunatilake (2016) implied that the average total hardness in the dry zone is 236 mg/L and varied up to 1104 mg/L as. Chandrajith *et al*. (2011a) noted that total hardness of water from Medawachchiya ranged from 208 to 676 mg/L as $CaCO_3$ and in Huruluwewa it ranged from 15 to 590 mg/L as $CaCO_3$. However, the highest value recorded for Huruluwewa in the present study is greater than the values recorded by Chandrajith *et al*., (2011b). Chandrajith *et al*. (2011b) revealed that phosphate (PO_4^{3-}) in Medawachchiya ranged from 0.14 to 0.61 mg/L and Huruluwewa ranged from 0.06 to 0.65 mg/L.

Jayewardana *et al* (2010) noted that phosphate range in the dry zone was 0.5 – 5.00 mg/L. Fairly low levels of fluoride were reported in the study areas due to source of waters such as spring water or mixing of groundwater with irrigation water. Chandrajith *et al* (2012) revealed high fluoride levels in Medawachchiya ranging from 0.52 to 4.9 mg/L and Huruluwewa from 0.02 to 1.68 mg/L. According to the Lasantha (2008) fluoride in Anuradhapura district was in the range of 0.78 to 2.68 mg/L. Chandrajith *et al*. (2011a) revealed that Cd concentration in water was not exceeding the standard levels in their sampling locations in the North Central Province. Similar results were obtained from the present research.

The Highland complex (HC) predominantly consists of alkaline meta-igneous rocks such as metabasites, charnockitic, granitic gneisses, and politic rocks in Sri Lanka. The superficial deposits found in the Anuradhapura area are the alluvium along major rivers and the regolith which overlies the crystalline rocks (Dissanayake and Weerasooriya, 1985; Panabokke and Perara, 2005 Cooray *et al*., 2019; Mahagamage & Manage 2019).

The Vijayan complex (VC) covers the lowlands of the southeast to the highland series. This type of rock is also found in the Anuradapura region. The VC consists predominantly of gneisses, granitic gneisses, augen gneisses, and migmatites. Soil overburdens of the in-situ weathered rocks are extended from few meters to a tens of meters. The presence of montmorillonite in dry zone soil indicates the slow weathering processes compared to the wet zone (Dissanayake and Weerasooriya, 1985; Dissanayake & Chandrajith 2007; Jayawardana *et al*., 2010; Chandrajith *et al.,* 2020.). The geology of the Anuradhapura area is composed of rock types of the Wanni complex (WC). The high fluoride sites on WC predominantly consist of alkaline meta-igneous rocks such as metabasites, charnockitic, granitic gneisses and politic rocks. The superficial deposits found in the Anuradhapura area are mainly alluvium deposits along major rivers and the regolith which overlies the crystalline rocks (Panabokke and Perara, 2005).

Igneous rock and magmatic rocks contain most of the mineral ions. Therefore, total hardness EC, Ca, Mg were correlated with each other. Runoff from the soil will contribute to the correlation between these ions in water. Total alkalinity is a measure of mainly CO_3^{2-} and HCO_3^--e ions in water. Therefore, total hardness and total alkalinity also are correlated with each other. Agricultural activities contribute to a high concentration of sulfate and orthophosphate in water. Therefore, the above correlations appear in the parameters analyzed in the present study in Medawachchiya and Huruluwewa study areas.

Kumar and Singh (2010) used PCA to analyze factors that influence the water quality in Sanganer Tehsil, Jaipur, India. Two factors were identified through PCA. Factor one includes EC, TDS, Ca total hardness. Mg total hardness, total hardness, chloride, total alkalinity Na, K, and nitrate which originated from anthropogenic causes such as industrial and agricultural pollution. Factor two includes pH and fluoride which originated by natural sources.

Paranagama *et al*. (2013) considered Cl, F, N, P, Ca, Mg, Na, and Cd ions for factor analysis. In the present study, other parameters except for F, N and Cd resulted as variables in factors where percentage variance over 10. This is comparable to Paranagama *et al*. (2013). In the collected water samples except for F, P and N resulted as variables in factors with percentage variance was over 10 comparable with Paranagama *et al*. (2013) in non-patients' water samples. Gulgundi and Shetty (2018) also indicated that the same factors affected the groundwater quality in urban Bangaluru, India. Further PCA has revealed the groundwater quality variation is mainly by the dissolution of minerals from rock water interactions in the aquifer, effect of anthropogenic activities, and ion exchanging processes in water. The present study also loaded the same factors which affect the quality of groundwater in the above studies.

5. CONCLUSION

The present study has analyzed water quality parameters in Medawachchiya and Huruluwewa areas in Anuradhapura district Sri Lanka. The quality of

water is significantly different from springs, dug wells and tube wells

The groundwater of both areas could be classified in to five clusters. Medawachchiya area with 13% and Huruluwewa with 37% ground water sources were identified as good water sources for drinking purpose. The wells, namely, M03D, M10D, M11S and M16D wells in Medawachchiya and H01D, H03D, H08D, H09T, H12S, H13T, H18D, H21D, H22D and H27D in Huruluwewa were suitable for drinking purpose. Therefore, majority of sampled wells were unsuitable for drinking purpose without any treatment.

It was observed that EC has strong and moderately positive correlation with the Total Hardness, Total Alkalinity, chloride, sulfur, Ca and Mg 32% and 24%. Cumulative variations appear in Medawachchiya and Huruluwewa areas to be from water quality parameters associated with natural processes corresponding to dissolution of rock and agricultural activities such as non-point sources. Further, the hydro-geochemical and agro-chemical factors may influence the water quality status in both study areas.

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REDEFINING THE ROLE OF AIRPOWER FOR NATION BUILDING IN PEACETIME

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ABSTRACT

Airpower is offensive by nature. In the post conflict situation after the defeat of brutal terrorism in 2009, airpower was performing its traditional role of preserving the peace for almost a decade. However, economy and development of the nation crippled by two consecutive incidents. The Easter Sunday attack in 2019 and COVID-19 pandemic. These two incidents directly influenced fields such as trading, tourism, finance, education, transportation, development and so on. The high cost involved in maintaining airpower in battle ready condition has become an extra burden for the nation with the depleted economic status. Thus, gradually truncating of budgetary allocation for the maintenance of airpower occurred. Re-fleeting plans had to be suspended. Hence, an exploratory qualitative study was conducted with an inductive approach examining the present gap between sustenance of Air Force and national interest. Further, the potentials/competencies of airpower could be utilized in nation building without hampering its primary role of assuring security, and safety of the nation was examined. In this paper the following key potentials are highlighted, which can contribute for national growth. They are United Nations (UN) deployment of air assets, enhancing surveillance and reconnaissance capabilities, restart manufacturing of military equipment, and improving research and development capabilities. Recommendations were made in order to achieve the improvements such as procuring aircraft for UN peacekeeping operation deployments, optimizing surveillance and recce, improving research and development facilities and recommencement of military equipment manufacturing. These recommendations would contribute to the r national growth and support the sustenance of airpower in the long run.

KEYWORDS: *Airpower, Research and Development, Nation Building, Sustenance.*

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1. INTRODUCTION

"Country without a strong Air Force is at the mercy of any aggressor."

-Mohmmad Ali Jinnah (First Prime Minister of Pakistan)-

Airpower is offensive by nature. Hence, role of airpower was utilized primarily for kinetic operations and secondarily for non-kinetic operations. However, the algorithms of modern airpower had expanded its limits beyond its orthodox roles thus contributing to myriads of disciplines for sustenance and growth. Sri Lanka employed its limited airpower effectively during the humanitarian operations conducted during 2006-2009 against Liberation Tigers of Tamil Eelam (LTTE) terrorists, who fought on the lines of ethnicity for nearly three decades. During the post conflict scenario, the national interest was focused on economic and infrastructure development, which had been curtailed for decades due to the higher expenses, incurred in mitigating terrorism. Same time the budgetary allocation for airpower faced a gradual decline due to its high maintenance and operational costs. The forecasted plans for re-fleeting had to be suspended. Further the potential of airpower and associated strengths were underutilized considering only the cost involved, thus neglecting their direct and indirect bearing on national security and development.

Hence, after more than a decade (2009-2020) from the victory against terror, under the present circumstances it is not too late to redefine the role of airpower in an effective and productive manner contributing for national growth without hindering its primary role of safeguarding the nation. This redirection could contribute for the holistic support required from each and every stakeholder in the present context for a sustainable national development.

The Problem identified is that if the role of the Sri Lanka Air Force (SLAF) continues to be without any adaptation to the contemporary situation it will create a gap between national interests and sustenance of SLAF. Further, it will keep on widening until such time the organizational objectives are skew to national inter and national objectives.

The significance of this paper is that the researchers are studying this gap and mean to bridge the gap in order to sustain SLAF as a fundamental organization whilst benefitting the national requirements through its capabilities and capacities, thus creating a win-win situation. Hence, this paper is intended to find out the competencies and capacities which can be utilized in order to support national security and development beyond its hard assigned orthodox roles and to propose viable recommendations based on facts. Objectives of the paper are as follows.

- To identify the difficulties in sustenance of the SLAF due to present constrains.
- To recognize the potentials, competencies and capacities of SLAF which can be utilized for nation building.
- Propose viable recommendations to contribute SLAF competencies, potentials and capacities for nation building efforts.

2. METHODOLOGY

An inductive approach was followed to find means to the observed phenomenon. During the exploratory qualitative study, researchers have followed interpretivism as the philosophy whilst encompassing grounded theory strategy. A cross sectional time horizon was employed as the time horizon and the collection of primary data was conducted mainly through interviewing respondents from user formations of SLAF from a different array of professionals employed for the roles discussed in this paper. Secondary data were collected through white papers published by SLAF, regional and global counterparts out of which some are classified in nature. Data collection and analysis has been the technique.

The conceptual framework has elucidated, what the researchers expect to explore through this paper. The following conceptual framework was developed in line with the three exploratory research objectives which intend to work as the outline of the paper.

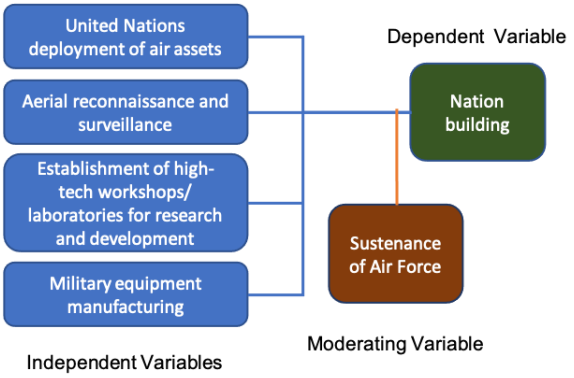

Figure 1: Conceptual Framework
Source: Author

3. BACKGROUND

3.1 Contemporary situation in Sri Lanka

After the defeat of LTTE terrorism in 2009, the economy of the nation started a new expedition since 2009 mainly based on tourism and construction. A number of foreign investors were keen to invest for the infrastructure development which happened to be a highly felt need such as a high-way road network, expansion of port and airport facilities, expansion of various kind of power plants, city developments, development in hotel and hospitality infrastructure, sports/recreational infrastructure etc. A remarkable rise in the tourists inflow was a great strength in providing life to the conflict torn island nation.

Unfortunately, on 21st April 2019, a series of bomb blasts were deliberately conducted by jihadists aiming churches and top hotels targeting Christian followers and foreign tourists, thus massacring more than 250 innocent people and badly injuring more than 500 people, both local and foreign nationals. Hence, the industry of tourism faced a prominent decline (approximately 20% drop) in tourists' inflow due to security and safety reasons. Also the COVID-19 pandemic completely devastated not only the industry of tourism which was recovering from the terrible memories of Ester Sunday massacre, but also the other fields such as trading, education, construction, transportation etc. After closing of ports and airports for foreign tourists in March 2020, only a limited essential function is in action which involves with an extra cost and an effort due to COVID-19 protocols.

Countries with strong economies could have more options of alleviating the drawbacks generated by COVID-19 pandemic. Nevertheless, the small and developing economies like Sri Lanka encountered a severe impact on its stability and survivability which had two major blows consecutively on its economic income. Drawbacks the island nation is having at present are higher national debt, poor national production, and higher degree of dependence on imported goods, gradual dilution of foreign reserves, higher trade deficit, inflation etc. Therefore, it is a demanding task to recover from present status and regain the track of development.

3.2 Requirement of national growth and security

Being a developing country there are many objectives to be met in order to uplift the general living standards of the general public. Those requirements span across the sectors such as education, health, transportation, power generation etc. Economic stability is proportional to the vulnerability if sufficient measures are not taken in order to ensure the security and safety. Primary responsibility of providing security and safety to the nation lies with the military. Furthermore, the forecasted economic development would not be met due to the limitations imposed by COVID-19 pandemic, like travel restrictions and disturbances to the global trading.

Being a responsible stakeholder, the SLAF could not remain indolent performing only their conventional roles, which consume a significant amount of defence budget. Hence, the time has come for a new way forward required to utilize the capabilities of airpower beyond orthodox options. The resources of airpower could support national growth without hindering the primary role of guaranteeing the safety and security of the nation. Formulating a proper security structure is a great relief for a nation speeding up on development. Furthermore, nation building is an assigned task for the military forces during peacetime, specifically in post war scenario, where a nation transits from war to peace. This period imposes responsibilities to the government and private stakeholders alike while allowing more liberty to develop and growth. However, the manpower,

machinery and technical knowhow of SLAF would be an immense support particularly for the technical sectors.

4. DISCUSSION

Areas, which could be supplemented by airpower for an effective output

Being a tech savvy organization, SLAF operates a fleet of aircraft, technical and logistical maintenance facilities, technical workshops and laboratories, technical training centres etc. Furthermore, SLAF is strengthened by approximately 35000+ men in blues belonging to different array of professions such as flying, engineering, technical, logistical, administrative etc. These professionals are highly trained and specialized particularly for their profession. Keeping such a capable and potential group in lagoon is not a productive employment. Instead, these highly trained personnel could be employed in their own profession in order to make an outcome, which would have more orientation towards national security thus supporting growth. Hence, this paper was penned in order to ascertain an effective employment of existing strengths of SLAF airpower and the viable areas of improvement without exerting additional pressure to the state in the long run.

It was revealed that the following areas which already exist in an ordinary scale could be developed into higher levels to have a greater output. All these options are being successfully practiced by regional and global counterparts. They are proved to have ever developing potential which are as follows.

- United Nations deployment of air assets
- Aerial reconnaissance and surveillance
- Establishment of high-tech workshops/ laboratories for research and development
- Military equipment manufacturing

4.1 United Nations (UN) deployment of air assets

UN deployment of air assets is an assured income to the national economy, which had been already utilized by SLAF. So far, SLAF had deployed two separate UN

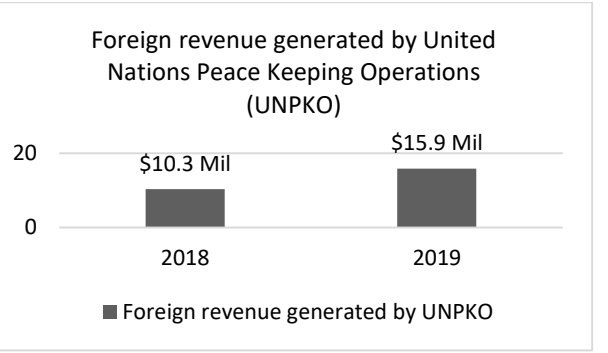

Figure 2: Foreign revenue generated by UNPKO (Source: SLAF Annual Performance Reports - 2018&2019)

contingents for UNPKO in South Sudan and Central Africa comprised with three Mi-17 utility helicopters in each. In addition, SLAF was offered with more contingents where unavailability of required assets denied the opportunities. Moreover, fixed wing transport platforms also would be deployed for further growth. SLAF possesses AN-32B medium transport aircraft fleet underutilized due to the absence of a clearly defined role and task. Deploying these aircraft for UN operations would open new opportunities for SLAF. Further, it would aid in utilizing the crew for better usage.

Figure 3: SLAF Mi-17 helicopters deployed for UNPKO (Source: www.airforce.lk)

Nonetheless, there are regional counterparts such as Bangladesh Air Force who had employed a greater number of UN contingents with a greater number of air assets, which represent significant amount of their national income. Apart from the direct payment made by UN for the employment of air assets, ground assets and the crew for the operation of the contingent, there are indirect gains to the SLAF, which are as follows:

- Valuable flying experience for the aircrew employed in the contingent

- Motivation of the crew

1) Valuable flying experience for the aircrew employed in the contingent: Since the budgetary allocation for the SLAF is truncated which, is a natural phenomenon in a post conflict situation, aircrew get limited opportunities for both in operational and training aspects. Comparatively a UN deployed aircrew member logs a greater amount of flying experiences during one year, which is the normal contract period for a UN employment. Apart from that, the associated supporting elements also get a good exposure for operational encounters, which is no more available after the conclusion of anti-terrorism operations in 2009. This helps to retain and continue the invaluable operational experience, which becomes extremely vital in future operational requirements. There is a remarkable difference between operationally tested aircrew and who have not been operationally tested, mainly due to the increased life threat and pressure in actual operational environment. Gaining air experience with additional benefits during UN deployments become a win-win situation for both the states financial capacity and the SLAF.

2) *Motivation of the crew:* In addition, the motivation of the UN employed aircrew is apparently higher with compared to the others due to higher personal income which is approximately 8 million LKR in addition to their usual pay during one fiscal year of employment. Further, foreign exposure and the operational experience they log, helps to uplift their professionalism / crew ratings in the long run. Therefore, the more the number of air assets and crew can be deployed for UN missions more will be the income for national economy and the more competent and experienced aircrew and supporting crew will be the SLAF would retain.

4.2 Aerial reconnaissance (recce) and surveillance

Aerial recce is relatively important for an Island nation like Sri Lanka. Being located in the maritime center of Indian Ocean having a significant and important sea territory to safeguard, it inevitably becomes a joint effort and responsibility of Sri Lanka Navy (SLN) and SLAF. However, only the air assets enjoy the required height, speed and reach within the specified region with minimum time delay. The area of responsibility expands up to the Exclusive Economic Zone (EEZ), which is approximately 200 nm form the coastline to north, east and south. (Lonneville, 2020). However, continental shell is believed to expand up to 75000 km^2 in addition to present EEZ.

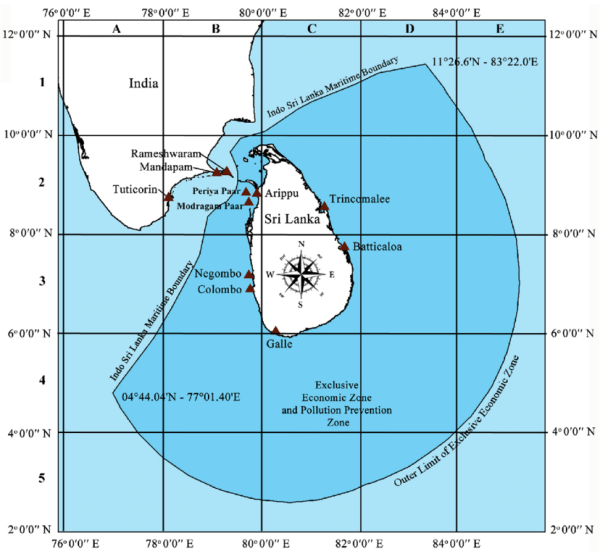

Figure 4 : EEZ of Sri Lanka (Source**:** Maritime Boundaries Geodatabase, Flanders Marine Institute)

At present SLAF conducts aerial recce over land and over sea both. However, because of depletion of the fleet due to limited maintenance budget, this function is gradually becoming unrealistic. Now SLAF is in a situation where it can provide recce support for SLN and Sri Lanka Coast Guards (SLCG) on request still with limitations. Now the expected output from the SLAF would not be delivered even at critical instances such as breach of security and territorial violations. The maritime reconnaissance is of key importance particularly due to following reasons.

- Illegal fishing
- Illegal migrants
- Smuggling and illegal trafficking of goods
- Piracy

1) *Illegal fishing:* Sri Lankan sea harvest was continuously purloined by Indian fishermen, who especially approach form North and North West of the Island. They are found to be using advanced technology, larger trawlers and illegal poaching methods. Bottom

trawling method used by Indian fishermen damages the seabed for many years to come depleting potential and threatening the sustenance of environmental balance. This issue has been more prominent in post COVID-19 pandemic. These fishermen are great in numbers and capacity of fishing. Therefore, they are capable of making a significant loss to national sea harvest. Losing the income inflicts short-term losses while their illegal fishing techniques affect the future fishing income and destabilize the natural habitats of sea creatures.

Figure 5: Increased illegal Indian migrants/sea poachers across IMBL
Source: Classified

2) *Illegal migrants:* Illegal migrants from neighbouring countries have been an issue for a long time. However, illegal migrants especially from India showed a rise during the COVID-19 pandemic. Especially at night, significant increment of vessel movements across Indo Sri Lanka Maritime Boundary (IMBL) is observed during the worldwide lock down, and SLAF was continuously called for aerial support for SLN. However, limited number of platforms, in SLAF possession at present, restricts the effective usage of the airpower for such requirements.

3) *Smuggling and illegal trafficking of goods:* Location of the Island nation is effectively utilized for smuggling, human trafficking and drug trafficking. Sri Lanka is identified as a transit hub for illegal activities, which utilize the veil of high sea traffic encountered throughout the year, which exceeds the monitoring capacity of SLAF. Most prominent activity is trafficking of drugs. These monitoring tasks require sophisticated equipment and platforms. Traditional recce wherewithal is not capable of catering to such demand.

4) *Piracy:* One of the most vulnerable areas for piracy is Gulf of Aden and eastwards towards Sri Lanka. This is a prime threat to the one of the world's busiest Sea Lines of Communication (SLOC), which lies 3-4 nm from the Islands. Southern coast. These issues are co-monitored by SLN and coast guards with the aerial support of SLAF on request at present. However, to implement a more productive mechanism it requires continuous surveillance of these aspects by aerial means. Once detected and reported, onward actions are taken by SLN and SLCG.

Apart from the maritime recce operations, SLAF conducts recce over natural reserves over land, where, increased illegal activities were observed such as deforestation, illegal sand mining, cannabis plantation etc. Monitoring and reporting of these illegal activities have a serious impact on the economy of the country, safety of the natural resources, peaceful environment and image of the nation. However, SLAF requires making more platforms available for such requirements. Effective effort for proper surveillance and recce is vital in addressing the unique issues highlighted above. The political hierarchy often perceives these efforts as expenses. However, in actual case these efforts act as an investment rather than an expense, though the affair is costly. Only this exclusive role of airpower could provide the real time information for speedy actions, which can diminish the possible long-term damages they would cause. The cost of possible damage these illegitimate activities could cause in the long run would be incomparable to the expenses to mitigate the same.

4.3 Establishment of high-tech workshops / laboratories for research and development

At present Sri Lanka is not actively interested in research and development. Long practiced open economy concept since 1977 resulted in the following long-term consequences. The national production was gradually declined, and importation was gradually increased. Many products, which were self-sufficient such as rice, salt, spices, dairy products, etc., started depending on imports. Along with the deterioration of national production, the requirement of research and

development was hardly felt, thus dwindling the facilities for such efforts.

As at now we do not possess sufficient magnitude of workshop / laboratory facilities and they are not at the required level of sophistication, capacity and potential except few such as Colombo dockyard, Sri Lanka Atomic Energy institute, SLAF etc. Reminding the saying *"Every dark cloud has a silver lining"*, during the COVID-19 pandemic an increased interest was waved across the country for related protective measures which were restricted to import due to travel and transportation bans. During the period, military and civil research and development facilities delivered speedy and effective solutions. Now a trend has been setup to encourage the national production, which obviously requires the insight of proper research and development work.

Figure 6: SLAF R&D project for an Unmanned Aerial Vehicle (UAV). Source: www.dailynews.lk

In developed countries the military research and development plays a vital role in partnership with their civilian counterparts. Maintenance of such hi-tech laboratory /workshop complexes are challenging for profit-oriented entities due to the time, resources and effort, which is usually unpredictable irrespective of the objectives. Thus, making market penetration for a total new entity in this sector is a costly and a risky affair.

At present SLAF operates moderate workshop / laboratory facilities for non-destructive testing (NDT), heat treatments, carbon fiber production, limited engine and airframe overhauling facilities etc. These facilities could be expanded and upgraded up to higher levels in order to function in partnership with other entities, which seek services in such nature. They are sister services, universities and civilian organizations. Maintenance and management of the complex could be included to the existing setup with ease due to the available human capital and effective leadership along with management capabilities inherited by military organizations. This would be developed for limited areas initially and could expand gradually to the other important disciplines such as construction, engineering, medical etc. Present laboratory and workshop facilities would provide a great foundation to kick off facilities that are more sophisticated in future.

4.4 Military equipment manufacturing

Military equipment are usually high in cost mainly due the monopolistic nature of the venture. Sustenance of an elongated military encounter depends on timely supply of the required war making potentials. However, the government admin and financial regulations does not facilitate a speedy delivery of items required. On the other hand, the alternative quick procurement procedures are embedded with higher cost factor.

Decades ago, SLAF was in the process of manufacturing limited improvised explosive devises and another minor military hardware, which was a good start-up. Unfortunately, the open economy concept and higher demand for the military hardware during the peaks of anti-terrorism operations against LTTE, suspended further development of the line of manufacturing thus forcing the facilities and capabilities to perish. The bitter lessons due to sole dependence on military equipment importation was learned in a hard way in the face of military equipment embargos imposed especially by state sympathizers of the western world who supported the clear cause of terrorism of LTTE throughout the conflict.

Post conflict situation has eased the rapid requirement of military equipment. Sufficient number of stocks are still available which bulk purchased during the time of conflict were. It is the best time to restart the manufacturing of military equipment in combination with the research and development efforts discussed above. The efforts can be started with minor projects such as manufacturing of military clothing and accessories, small arms and munitions, improvised

explosive devices, communication equipment etc. and gradually expand to the higher-level productions with time for self-sustenance. Effective and quality products could be put into the international market for greater income. Countries like Israel, Singapore, Brazil, Indonesia and Malaysia are classic examples for such approaches.

Further, modern airpower heavily depends upon the avionics. The military software development is also a possible and feasible option considering the tech savviness of the modern generation of the nation. An increased brain drain could be observed in the field of Information Technology due to the absence of lucrative gains and limited job opportunities. Establishment of a military software development program could retain a portion of the skilled and young workforce which is a sector with significant brain drain and further it can save a significant amount of money which is expended for the avionics related software and equipment. This facility could be easily enhanced in order to cater to the requirements of sister services that share the techno requirement of communication, data links and associated navigational measures. This effort would develop state avionics related technology as we provide an opportunity for new generation Information Technology professionals to work on.

5. RECOMMENDATIONS

In line with the points discussed above, the following recommendations could be made, which are feasible with the present capabilities and resources, that could be developed into greater levels with experience. Capital cost of these recommendations would be comparatively high due to the nature of the field and furthermore not all outcomes could be financially measured. Nonetheless, all these recommendations would have definite long-term benefits to the nation in general and to the SLAF in particular.

5.1 Procuring of aircraft for UN deployment.

Procure a greater number of utility helicopters and fixed wing aircraft in order to deploy in UN missions supplementing the existing fleet is a prime recommendation. Return of income within few years of time is assured considering the past employments of air assets in UN missions though the capital cost of the effort would be high. As elaborated, it will not only make financial benefits to the national economy, but also will provide experience and motivated men in blues for the future security demands of the nation.

5.2 Procuring of aircraft for surveillance and recce

Procure suitable and sufficient number of platforms for the purpose of effective surveillance and recce supplementing the current aging fleet is a highly felt requirement as of now. They should have the capability to cover the total area of EEZ. This can ensure effective mitigation of illegal activities such as illegal fishing, human / drug trafficking and illegal migration in combination with SLN and SLGC. Further, monitoring and reporting of plantation of cannabis, deforestation and illegal sand mining in coordination with law enforcement agencies which have an indirect bearing upon the national economy and a solid bearing upon the national image, is of prime importance for the fostering of tourism and global trading.

5.3 Improve research and development facilities

"The first essential of air power necessary for our national security is preeminence in Research."- General Henry "Hap" Arnold-

Expansion and improvement of existing research and development facilities with long-term objectives is required. This venture could be progressed as a partnership with universities and civilian institutions that share the same interest in areas, which are not classified. This effort can foster local manufacturing efforts and save unnecessary expenditure of importation.

5.4 Manufacturing of military equipment

Restarting the manufacturing of military hardware and software from the basic level in coordination with research and development projects so as to achieve long term and more advanced manufacturing objectives is a timely requirement. This step could retain significant

amount of money spent for foreign military procurement. Further, with development, Sri Lanka could enter into the international military market, which would provide a noteworthy contribution to the national economy. In addition, this could create more high-tech job opportunities possibly reducing brain draining in respective fields.

6. CONCLUSION

In peacetime, the primary role of the airpower happened to be the preserving peace. Modern day security and politico-economic dynamics are such that we will never know the demand for kinetic force. To maintain an airpower, which is the deciding factor in modern warfare in operational ready status, needs deliberately, planned long-term training and development programs. It inevitably consumes significant amount of resources. For a developing nation like Sri Lanka with a small economy, it would be a difficult task to maintain such a costly affair. However, it is difficult to obtain new forms of airpower which encounters heavy geopolitical influences, money, effort and time. Therefore, it would be advisable to retain the knowledge, skills and equipment related to air power, which we already have until such time we are capable of developing into greater heights in future.

Nevertheless, airpower demands continuous support from the state in its elongated process of expansion. It is required to maintain the hard-earned airpower, and in the meantime, it is required to ease out the burden on tax paying citizenry for maintaining such a costly affair. In this paper, it was revealed that there are resources, competencies and potentials with SLAF, underutilized as at now. In order to achieve sustenance and effective utilization of SLAF to a reasonable degree this paper provides viable recommendations. The thematic recommendations made in this paper are an extension and a further development of existing facilities / capabilities. The beginning of the process could be of small scale, which obviously could be developed into greater levels with time and effort. Medium of air would be utilized by more sectors in future as it provides many effective options. Therefore, the development of aerial capabilities would be a significant factor for future development in any nation.

7. ACKNOWLEDGMENT

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COMPARATIVE STUDY OF THE FACTORS ASSOCIATED WITH WAGES AND WAGE DIFFERENTIALS OF GRADUATE EMPLOYEES BETWEEN PUBLIC AND PRIVATE SECTORS IN SRI LANKA

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ABSTRACT

The main objective of this study is to analyze the differences in earnings between the Public and Private sector graduate employees in Sri Lanka using a sample of 1,421 graduate employees derived from the secondary data in the Sri Lanka Labour Force Survey, 2018. The study used the Endogenous Switching regression model to comparatively study the hourly log earnings between public and private sector graduate employees and their wage differentials under employment switching behavior. The model concludes that being male, being an urban resident, having a non-arts degree, having managerial or professional employment, having significant positive relationships with the earnings of both private and government employment while having post-graduate employment increases earnings only in the public sector. Age squared has an impact on public sector earnings showing increasing returns. Selecting government employment was positively affected by age and being married while being male, being urban and having a non-arts degree have a significant negative association with that, according to the selection function. According to the conditional predictions of the model, switching from the public sector to the private sector will increase earnings of graduates while switching from the private sector to the public sector reduces their log hourly earnings. However, graduates are still willing to move from the private to the public sector, as a result of other non-wage benefits that ensure employment and income security. Reforms in the private sector regarding non-wage benefits including attractive social and employment security options aligned to decent work goals under sustainable development goals are needed to increase attraction towards private sector jobs among Sri Lankan graduates.

KEYWORDS: *Wage, Wage Differentials, Endogenous Switching Regression Model, Public Sector Vs. Private Sector*

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1. INTRODUCTION

Human capital stock has a significant impact on all aspects of growth and development perspectives of a country, leading to the achievement of maximum utilization of the limited physical and human resources. The free education policy practiced in Sri Lanka over 75 years caused the creation of a highly capable, educated workforce in the country and the ultimate outcome of this is the graduates produced by the State universities. Although private sector institutions have rapidly involved themselves in the higher education system within the past decade, by continuously enhancing the opportunities for higher education for the majority of school leavers in Sri Lanka, State universities play a major role in the human capital generation process even at present. Although graduates enter the market with their own different horizons and objectives to shape their life journeys, they face some issues regarding the availability of suitable employment opportunities in line with their education. Employment opportunities available for graduates are generally low because of mismatches between the demand for the labour market and education in Sri Lanka (Senarath et al., 2017).

According to the Sri Lanka Labour Force Survey (2019), the highest unemployment rate was recorded for the educated youth for many years. Out of the graduates unemployed, 54.8 per cent are arts graduates while the rest was represented by the 'all other non-art degree programmes'. Higher expectations of minimum wage levels also affect the long wait for employment. Wages and job security play major roles in the choice of graduate employment between the public and private sectors in Sri Lanka, and the graduates' decision making for selecting and switching employments experienced a similar pattern with graduate schemes offered by the governments. Most of the private sector employed graduates are also switching their employments from the private to public sectors during occasions of implementing graduate schemes in Sri Lanka.

In 2015, the government of Sri Lanka recognized that the country's "National Human Resources and Employment Policy" was essential to solve the problem of "wages and believed in ensuring productivity and decency of employment through a carefully designed wage policy (Secretariat for senior ministers: Sri Lanka, 2015). Burdett and Mortensen (1998) stated that the higher wage rate will attract a larger, steady-state labour force. Well-known efficiency wage theories in economics also explain the importance of paying higher wages for employees than the market-clearing wage to give a proper incentive for the worker to extract their maximum capacity. High recruiting and monitoring costs were reduced by the firms as a result of providing high wages, according to Shapiro and Stiglitz (1984). However, in the global financial crisis, growth of global real wages shows a fall in 2017. It was not only less than in 2016, but it also the lowered growth rate since 2008, staying far lower the levels obtaining in 2006 or 2007 according to the Global wage report (2018). According to the Central Bank Report (2018), the real wages of both formal private and public sectors in Sri Lanka eroded in 2018 when compared to 2017 and nominal wages and increasing from this period. Based on the statistical evidence, the nominal wages of public sector employees were increased marginally by one per cent in 2018 while their real wages declined marginally by two per cent in 2018 when compared to 2017 (Central Bank Report, 2018). On the other hand, nominal wages of the employees in the informal private sector was increased marginally by 0.6 per cent in 2018 while their real wages declined marginally by 3.5 per cent during 2018, when compared to 2017 (Central Bank Report, 2018).

The private sector provides higher wages for university-educated workers according to Adamchik and Bedi (2000). Education, gender, marital status, age and occupation are the factors of wage differentials in most of the countries, and female employees are negatively affected by the wage levels when compared to men, thus wage installment is unequaly paid within the sector (Meiyan, 2005). Kumara (2015), found that education is a positive impact on earning of the private sectors. And also, when increasing one additional year of schooling, the hourly wage increases by 9% approximately. Further Bowlus and Grogan (2009) stated that gender wage differentials were mainly affected on the differences of education and hours of work. Age, race and sex are considered causes of high wage differentials and the wage differentials are high

among high college leavers and graduate employees and between high school leavers and graduate employees (Murphy and Welch, 1989).

In Sri Lanka, literature and empirical studies examining factors associated with wage differentials of graduate employees between private and public sectors are limited. The main objective of this study is to conduct a comparative study on the factors affecting the earnings and earning differentials among graduates in the public and private sectors in Sri Lanka. It further discusses the impact of wage changes as a result of the switching behavior of graduate employees from private to public employment and vice versa. The research findings will be significant to government and private sector institutions for the purpose of effective employment policy formulations.

2. LITERATURE REVIEW

The literature review of this study consists of both theoretical and empirical reviews. Theoretical literature explains three main concepts while empirical literature formulates three hypotheses for this study. Firstly, theoretical literature presents a review of the aspect of efficiency wages. According to the efficiency wage theory, the productivity of a firm is affected by the wage of employees. Moreover, the positive relationship between employee productivity and wages was further established by Campbell and Kamlani (1997). In addition, higher wages in comparison to the market wage cause to increase employee efficiency and to decrease employee turnover (Shapiro and Stiglitz, 1984). According to researchers, the efficiency wage highly affected to attract the most productive workers to any private or public institution.

Secondly, the wage is an important control variable in making critical employment decisions, with risk and uncertainty being high employment efficacies as well. US economistic, Kaufman (1989) discussed the Hedonic wage theory to explain the nature of long-term wage differentials in the aspect of risk-taking. The main focus of that is to understand the impact of risks in the jobs as a result of the possibility to get injured on wage inequalities. As a result of the existence of a positive relationship between wage and risk of injury, workers are willing to accept a high-risk job only if they are paid a higher level of wages.

Thirdly, the Theory of human capital that provides the importance of education and training on earning profile is another key aspect in the theoretical literature (Dagume and Gyekye, 2016). The essence of this theory is that the expenditure on education and training is an important investment that individuals make to sharpen their marketable skills and productivity (Dagume and Gyekye, 2016). Individual differences in the years of schooling and length of on the job training were the key forces under the explanation of Becker (1985). The large size of earning differentials encourages more human capital development and higher earning gaps were not seen among qualified workers and graduates leading to discourage investment in human capital enhancements. However, in the 1950s, economists such as Mincer, Schultz, and Backer reformulated Smith's insight and developed the human capital theory by matching it with the model labour market aspects. According to that, there is a significant effect on the increase of university enrolments on wages and earnings of university graduates (Mincer et al., 1991). If the net present value of the lifetime income is greater for graduates, then many people will try to obtain degrees to increase their relative wage levels.

Fourthly, there is the Dual labour market theory which includes two different markets as primary (good) jobs and secondary (bad) jobs with a lower possibility to switch in between and with greater labour market segregation. This theory argues that employees in the primary sector use wages to maintain and ensure the key disparities of these two segments. Further, the theory argues that secondary workers are trapped in secondary employments leading to a creation of a vicious cycle of disadvantageous employments continuously for generations. When considering the characteristics of wages under this theory, primary jobs received higher wage rates than secondary employments while primary jobs generally provided more facilities to employees, such as employment stability, superior technology and good working conditions than secondary employments (Harrison and Sum, 1979). Since most of the graduates generally

involve in primary occupations in both public and government institutions, there is a rare probability to involve them in disadvantageous secondary occupations. The duality of this study discussed the differences of the main features of public and private sector employment for graduates, such as wages and job security within the sector of primary occupation (Harrison and Sum, 1979).

The empirical literature on the determination of wages is generally categorized into three categories as demographic factors, socio-economic factors and geographic factors. Among demographic factors, age is a key factor associated with wages, in both private and public sectors in the Chinese Household Income Project 1995 covering 11 provinces and CHIP 2007 covering nine provinces and the result found that 1,995 coefficients of the age factor are statistically significant on wages in both private and public sectors and that 2007 coefficients of age factor are not statistically significant on wages in both private and public sectors, according to Ma (2015).

Further, Lokshin and Sajaia (2004) observed that the age factor causes a statistically significant negative impact on wages in the private sector while that shows an insignificant relationship with wages in the public sector. A German economist, Pfeifer (2011) examined that the age square causes a statistically significant and positive impact on wages, showing the increasing returns with age. Age could also be used as a major proxy for the years of experience as well. Since most of the studies create years of labour market experiences, based on the variable of age and the years of education, using both variables of age and experiences will not be possible due to multicollinearity issues. Gender is the next key demographic aspect associated with the earning profile of workers and that is even common for graduate employees as well. The Global wage report (2018/19) covering 70 countries found that women continue to be compensated roughly 20 per cent lower wages than men globally. Further, the Gender wage gap is wider between high paid workers in high-income countries. On the other hand, the gender wage gap is also getting wider for both low and middle-income workers.

Hyder and Reilly (2005) show that there is a probable wage gap between the genders within the existing private sector than the public sector in Pakistan. More than half of the average wage differential in the typical salary paid for an hour among both private and public sectors represents the differentials of the standard attributes of gender difference (Hyder and Reilly, 2005).

According to Solotaroff et al. (2017), females are having lower wages in Sri Lanka although they are well endowed with education and experience. This was affected by the social norms, cultural beliefs and labour market behaviors of women in Sri Lanka. Mano-Negrin (2000) has found gender as the major determinates of wages in both the public and private sectors among Israeli women managers. Occupation segregation was also identified as one of the major issues for gender based wage differentials, according to Blau et al. [1998) in Agrawal (2021, p.1)]. Based on the above findings of the previous empirical studies, the following first hypothesis was formulated by the study.

H1: There is a relationship between demographic factors and hourly earnings of graduate employees in both public and private sectors in Sri Lanka.

Education & occupations are the leading factors among socio-economic factors. Having tertiary education has a positive impact on the payments of public and private sector employment (Weligamage and Siengthai, 2003). According to Afarian and Kleiner (2003), higher grade point averages earned by the student have significant positive relationships with earnings. Students with higher GPAs earn high marks from IQ and admission tests for most of the high salary employments and that will increase their earning capacity. This will enhance the motivation of students to perform quality work and to promote their intellectual abilities. The area of the degree also affects on the earning potentials of graduates. According to Clifcl and Ulucan (2021) and the wages of law, engineering, manufacturing, architecture, civil engineering graduates are higher than the education graduates in Turkey.

Nature of occupation is another major determinant of earnings in Sri Lanka. According to Nedlkoska et al. (2018) they found that graduates in the ICT profession employments earn 106% more than technical professionals; Chief executives and production managers earn 33-35% over, engineers earn 25% more; ICT graduate and health professionals earn 24% over than technical professionals (Nedlkoska et al.,2018). Since most of the graduates select teaching as their profession, this base category is important to explain the general considerations in the graduate labour markets. Based on these factors a second hypothesis was developed as follows:

H2: There is a relationship between socio-economic factors and hourly earnings of graduate employees in public and private sectors in Sri Lanka.

Locational and geographical factors are other key considerations associated with earning differentials. According to Agrawal (2021), a large part of the wage disparities in the urban and rural sectors are still unexplained. However, the urban rural segregation in the labour market was mainly affected by the education and occupational profiles of the workers. The wage gap is generally higher in the rural sector than in the urban sector and was mainly affected by the differences in educational attainment by gender (Agrawal, 2021). Based on the above findings of the previous empirical studies, the following third hypothesis was formulated by the study:

H3: Locational factors affect earnings differentials of graduates between public and private sectors.

Research Gap

Most studies explained the determinants of wage differentials at local and international levels in theoretical literature as presented above. Although there are so many studies regarding wages and wage differentials, there are far lesser studies focused on the graduate employees in general. The graduate employees who represent managerial and professional employments are the top spirit in the labour market and are highly prone to the risk of brain drain due to insufficient wages and poor living standards. The reasons for Sri Lankan graduates seeking government employment were not considered in the aspects of wages and wage differentials. This study will address this gap to propose important policy suggestions to the future labour markets in Sri Lanka.

Problem Statement

Decent work for all is one of the key goals among sustainable development goals which are to be achieved by 2030 in the world context. Wage is one of the key elements in decent work ensuring equal pay for work of equal value. However, there are disparities in wages in Sri Lanka, mainly in the public and private sectors. The majority of workers in Sri Lanka are willing to engage in public sector employment due to the pension benefits, the permanent basis of employment, fringe benefits including paid leave etc. Although the private sector too provides the same or similar types of incentives, the majority has their self-interests to join the public sector in Sri Lanka (Hausmann et al., 2020). This is a common event among the Sri Lankan graduates. Therefore, they prefer to engage in government employment by shifting from the private sector whenever they are provided with employment even via graduate schemes. This research answers the question whether there are any influences of wage differentials on the employment switching behaviour, while comparing the factors associated with wages for graduate employees in both public and private sectors in Sri Lanka. Currently, this has become a serious challenge to the labour market in Sri Lanka and there is a risk of the private sector becoming reluctant to recruit graduates to their institutions because of this switching behaviour. Thereby, this investigation is conducted to comparatively study several factors affecting the wage inequality of graduate employees in the public and private sectors in Sri Lanka.

3. METHODOLOGY

Many researches used the quantitative research approach to identify the factors associated with wage the differential between public and private sectors [Hornstein et al. (2006), Oaxaca (1973), Oboth (2021) and Weichselbaumer and Winter-Ebmer (2001)]. This research also used the quantitative approach for comparatively identifying the factors that affect the

Hourly log wages of graduate employees between the private and public sectors. The hypotheses of the study were already developed under the literature review section.

Secondary data from the Sri Lanka Labour Force Survey 2018 conducted by the Department of Census and Statistics in Sri Lanka was used for the study. The sample frame which is used for the LFS-2018 is prepared as the sampling frame of population and housing units by adopting the two stages stratified sampling procedure. The sample for the study was drawn from the survey which includes 2,073 graduates. This includes 1,578 graduate employees and the rest are unemployed or economically inactive at this moment. The final sample consists of 1,421 Graduate employees after removing the extreme values regarding the earnings. Further sample are divided as public sector denoted by 1043 and private sectors denoted by 378.

The Endogenous Switching Regression Model was used by this study to make a comparison between hourly log wages for graduate employees under two conditions of engaging with the public sector or private sector. Under the study, this model allows to regress the earning functions for both sectors simultaneously by incorporating the section decision of employment into public and private sectors as a profit estimation in the same model with consistent standard errors (Lokshin and Sajaia, 2004).

This is one of the most suitable econometric models to explain the switching behaviour of a certain economic variable such as earning. Demographic, socio-economic and locational factors were used as the explanatory variables to check the research hypothesis of the study.

Most of the research applied this model such as those by Samaraweera and Wijesinghe (2021), Heitmueller (2004), and Van-Ophem (1993) and they have used the Endogenous Switching regression to distinguish differentials in wages and hours. The following model used two regression equations and a with selection function.

If γ^T **Zi** +ui > 0 Individual works in Public sector, PS =1

If γ^T **Zi** +ui $\leq$ 0 Individual works in Private sector, PS =0

Regime 1: $\ln y_{1i} = \beta_1^T X_{1i} + \varepsilon_{1i}$ If PS=1

Regime 2: $\ln y_{2i} = \beta_2^T X_{2i} + \varepsilon_{2i}$ If PS=0

Where, $\mathbf{X_{1i}}$ and $\mathbf{X_{2i}}$ are vectors of independent variables [including demographic factors (age, age squared and gender), socio-economic factors [education: type of the degree & having post graduate qualification and occupation] and Geographic factors (Residential sector; being urban)]. β_1^T, β_2^T and γ^T denoted by vectors of paramenters.y_{1i} and y_{2i} are dependent variables: Ln hourly earnings of public sector (1) and private sector (0) Ln hourly earnings consist with the earning of primary employment in this study. Being public employee is the dependent variable of the selection function with the explanatory variables of age, age squared, being male, being married, being urban and having non-art degree.

The study further expects to explore the changes of hourly log wages with the mobility of graduate employees from the public sector to private and vice versa using post estimations. Four conditional predictions will be derived as the post estimations of the endogenous switching regression model to explain this more precisely.

4. RESULT AND DISCUSSION

4.1 DESCRIPTIVE ANALYSIS

The researcher used the Endogenous Switching regression model for analysis and this study used the hourly log earning of primary employment as the dependent variable. The mean age for the private sector graduate is lower than that of graduates working in the public sector. The majority of private sector graduates (66 percent) are from the non-art discipline while the public sector only reports 38 percent, showing a considerable difference of graduate employment by the discipline. Male graduates are relatively high in the private sector than in the public sector. Nearly two-thirds of graduates in both public and private sectors are

Table 1: Means and standard deviation of the explanatory Variables

Variables	Total (1421)		Public(1043)		Private (378)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Age	39.946	10.136	40.600	8.936	38.140	12.722
Age squared	1698.3 38	895.708	1728.14 6	762.471	1616.09 3	1185.6 73
Being male	0.439	0.496	0.359	0.480	0.661	0.474
Being urban	0.331	0.471	0.276	0.447	0.484	0.500
Having non art degree	0.454	0.498	0.380	0.486	0.659	0.475
Having post graduate qualification	0.160	0.367	0.170	0.376	0.135	0.342
Having managerial or professional employment	0.672	0.470	0.663	0.473	0.696	0.461
Being married	0.816	0.388	0.862	0.345	0.688	0.464

Note*- Sri Lanka Standard Classification of Occupation - 2008 (SLSCO – 08) was used to classify occupations and the first two sections were considered as managerial and professional employments.
Sources: researcher developed by using LFS data 2018

employed in managerial or professional employment showing the characteristics of primary (good) employment. The proportions of urban graduates are high in the private sector than the government sector (Table 1.).

Base category: Being female, not-having post graduate qualification, rural area, having arts degree, not-having managerial or professional occupation. According to Table 2, this regression shows how the hourly log wage in the public and private sectors varies on various factors. The study of this regression primarily takes in to consideration on several factors affecting public and private sector log hourly earnings and how it effects on wage differentials. This represents the log hourly earnings of public and private sector graduates based on the base category. It has been proven that the log hourly earnings of a graduate in the public sector are higher compared with the log hourly earnings of a graduate in the private sector for the base category.

When considering the demographic variables, age-squared significantly affects the wage level of public sector employees, indicating an age has increasing returns for the earnings. Experience and possible job ladders are relatively high for graduate employees in the public sector, while that is insignificant for the private sector. Previous researcher estimations show that in both the private and public sectors in 1995, age is statistical, but in 2007 age did not significantly affect the wage in both sectors (Ma, 2015).

Lokshin et al. (2004) also examined that age is statistically significant with a negative sign for the private sector while having a positive sign regarding the same for the public sector. Being a male graduate employee has a positive relationship with the wage level in both the private and public sectors while the rate of increment is higher for the private sector than for the public sector when compared with the base category.

According to Nedlkoska et al. (2018), the public sector installment is lower than that of the private sector, where University graduate men earned a 36% installment over A-Levels and University graduate women earned a 25% installment over A-Levels in 2015, whereas in the private sector, University graduate men earned a 66% installment than A-Levels and University graduate women earned a 128% installment (Nedlkoska et al., 2018).

4.2 ANALYSIS: ENDOGENOUS SWITCHING REGRESSION MODEL

Table 2: Coefficient of factors that affect hourly log wages: Endogenous Switching Regression model

Variables	Coef.	Std. Err.	Z	P>z
Ln hourly earnings – Private				
Age	0.0216	0.0217	0.9900	0.3210
Age squared	-0.0002	0.0002	-0.9700	0.3310
Being male	0.1645	0.0712	2.3100	0.0210
Being urban	0.1181	0.0562	2.1000	0.0360
Having non-art degree	0.2067	0.0607	3.4100	0.0010
Having post graduate qualification	-0.0028	0.0680	-0.0400	0.9670
Having managerial or professional employment	0.1732	0.0513	3.3800	0.0010
Constant	4.5471	0.3385	13.4300	0.0000
Ln hourly earnings – Public				
Age	-0.0072	0.0083	-0.8700	0.3830
Age squared	0.0002	0.0001	2.1700	0.0300
Being ale	0.0317	0.0188	1.6900	0.0910
Being urban	0.0371	0.0188	1.9700	0.0480
Having non-art degree	0.1064	0.0177	6.0300	0.0000
Having post graduate qualification	0.0759	0.0211	3.6000	0.0000
Having managerial or professional employment	0.1777	0.0169	10.5200	0.0000
Constant	5.2980	0.1768	29.9600	0.0000
Select-Public				
Age	0.2725	0.0287	9.5000	0.0000
Age squared	-0.0030	0.0003	-9.2200	0.0000
Being male	-0.7089	0.0822	-8.6300	0.0000
Being married	0.3243	0.1105	2.9300	0.0030
Being urban	-0.4572	0.0830	-5.5100	0.0000
Having non-art degree	-0.4677	0.0822	-5.6900	0.0000
Constant	-4.6839	0.5781	-8.1000	0.0000
/Lns0	-0.7569	0.0761	-9.9500	0.0000
/Lns1	-1.3990	0.0221	-63.2700	0.0000
/R0	-0.4968	0.2436	-2.0400	0.0410
/R1	-0.0597	0.1322	-0.4500	0.6520
Sigma0	0.4691	0.0357		
Sigma1	0.2469	0.0055		
Rho0	-0.4596	0.1921		
Rho1	-0.0596	0.1318		
LR test of indep. eqns. : chi2(2) = 3.17 Prob > chi2 = 0.2047				

Note: Level of significance is 0.1 (90% percent of confident level) Source: Researcher developed by using LFS, 2018

Among the socio-economic variables, the Endogenous Switching Regression model found that having non-arts degrees increase wages in both the government and private sectors, while the rate of increment is high for the private sector when compared with the base category. Further, estimations show that having post-graduate qualification increases wages in the government sector and having post-graduate degrees has a negative relationship with the private sector compared with the base category.

The researcher identified how the factor of having non-arts degree is affecting the wages under the findings of previous tests**.** Weligamage and Siengthai (2003) examined that tertiary education has a positive impact on the payments of public and private sectors. Ciftci and Ulucan (2021) also established supportive arguments. Many economists believe that education brings positive benefits, that is, attracting a highly educated person to the company will help increase the company's productivity and hence the company is willing to pay them higher wages.

Further, estimates show that the factor of having managerial or professional occupations increase wages in both the government and private sectors, while the rate of increment is high for the public sector when compared with the base category.

When considering the locational variables, wage levels of both private and public sectors are higher in the urban sector than the in rural sector, while the rate of increment is high for the private sector when compared with the base category. Under this study, the selection function of public sector employment was negatively affected by age-square, being male, having a non-arts degree, being in the urban sector while it has a positive relationship with age and being married.

Therefore, the researcher attempts to study the impact of hourly log wages on the restricted and unrestricted transition from the public sector to the private sector and vice versa, relative to the final objective of the research using the Table 3.

Table 3: Post Estimation of Endogenous Switching model
Source: Researcher developed by using LFS, 2018

Post estimation	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Xb1	1,421	5.5659	0.1754	5.2461	6.4472
Xb2	1,421	5.3550	0.1937	4.9485	5.7365
Yc1_1	1,043	5.5489	0.1649	5.2368	6.3912
Yc1_2	378	5.6129	0.1951	5.2606	6.4473
Yc2_1	1,043	5.2512	0.1669	4.5006	5.5997
Yc2_2	378	5.6421	0.1822	5.1289	5.9467
mills1	1,421	0.4590	0.3896	0.0659	3.7990
mills2	1,421	1.3851	0.5397	0.0007	2.2960

Xb1 ⟶ Unconditional expectation of Hourly log wage of graduate employee in the public sector

Xb2 ⟶ Unconditional expectations of Hourly log wage of graduate employee in the private sector

Yc1_1 ⟶ Conditional expectations of Hourly log wage, of public sector graduate employee with public sector employment

Yc1_2 ⟶ Conditional expectations of Hourly log wage, of public sector graduate employee with private sector employment

Yc2_1 ⟶ Conditional expectations of Hourly log wage, of private sector graduate employee with public sector employment

Yc2_2 ⟶ Conditional expectations of Hourly log wage, of private sector graduate employee with private sector employment

According to Table 3, it is evident that the unconditional expectations of hourly log earning in the public sector are higher than in the private sector. According to the conditional predictions of the model, switching from the public sector to the private sector

will increase earnings of graduates while switching from the private sector to the public sector reduces their log hourly earnings. For example, after the 2020 Presidential election in Sri Lanka, the government provided jobs for graduates and most of the private sector employees shift to the government sector. Shifting employment by graduates from the private to public sector will reduce earnings conditionally according to this study and this was further proved in the literature.

Previous research provided evidence that if a graduate person shifts from the private sector to the public sector; wages will decrease by 5% per cent (Vodopivec and Withanachchi, 2010). The public sector is also advantageous in the aspect of non-wage benefits practiced in the public sector, such as higher training, pension scheme and job security. This suggests that an employee can earn more money by switching from a public sector job to a private-sector job. Another conclusion is that if a graduate person shifts from the private sector to the public sector, then the level of wages decreases.

5. CONCLUSION AND RECOMMENDATION

The result of the study found that graduates are major contributors to the attainment of human capital and this has a profound effect on the public sector. Due to the low human capital of a worker in the private sector, there is always a reduction in earnings when such a worker moves to the public sector because human capital has a special place in the public sector. According to Mincer (1991), education is a factor that influences the onset and continuing earning of the economy. The investment cost for an additional education year is considered a high return on investment; meaning that higher education moves in line with higher wage levels, which in turn increases labour productivity. Finally, this research has also confirmed that while transitioning between the public and private sectors, earnings increase when an individual transfer from the public sector to the private sector. A comparative study of wage inequality in the public and private sectors in Sri Lanka can make several suggestions in line with the findings.

Furthermore, in line with the concept of the International Labour Organization, the transition from the private sector to the public sector or from the public sector to the private sector should take place to facilitate the concept of decent employment in the future. Non-wage benefits, such as job security, union rights, and compensation policies during a job loss are widespread concepts in the public sector. The Covid-19 pandemic situation is a strong example of this from Sri Lanka due to the higher income security face faced by the government employees. That is, the jobs of workers who were employed in most of the businesses in the private sector have faced some issues regarding income and employment insecurity. The major reason for recommending proposals for a secure employment programme in the private sector would be a better solution to overcome the conflict of interests towards private sector employment by graduate workers.

Then Ministry of Labour should implement policies and acts to overcome the disparities of income between male and female, mainly in the public sector as found by the study. And also Ministry of Labour should empower the job security of private-sector employees under unexpected risks and uncertainties to improve the trust of highly educated people towards the private sector. Further knowledge, skills, attitudes and mindset of graduates in public universities should be changed in ways to match with the requirements of private sector employments at the curriculum development process.
In addition to employability skills such as analytical reasoning and critical thinking, skills with teamwork, communication ethics in curricula etc. should be implemented in university education and this will help the future workforce to be flexibly adapted and standardized with various labour market demands and required competencies. Finally, graduates should be recruited via comparative examinations and based on the human resources requirements. Such long term recruitment programmes should be prepared for both the public and private sectors after studying the long-run economic and development plans for the next decades.

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