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Evaluation of the Cellular and Wi-Fi radiofrequency pollution levels in the Western Province of Sri Lanka

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ABSTRACT

Cellular communication networks and Wi-Fi sources are becoming abundant in the present day. There are some discussions about the adverse effects of the radiation emitted by these sources on people living in environments with higher radiation levels. In this study, background RF radiation levels due to common cellular network bands and Wi-Fi hotspots were monitored using a high-frequency spectrum analyser (SPECTRAN HF6065) within the Western Province of Sri Lanka to understand the current RF pollution levels in the environment. Results of the study reveal that the Colombo City area has the highest RF pollution levels of all the selected network bands. However, measured maximum radiation levels were approximately 0.9 % compared with the international guidelines published by International Commission on Non-Ionizing Radiation Protection (ICNIRP). Spatial distribution patterns were generated based on the measured Radio Frequency (RF) exposure levels which could be useful for the Central Environmental Authority (CEA) and Telecommunication Regulatory Commission of Sri Lanka (TRCSL) and for other concerned institutions.

Keywords: Health Impacts, RF Pollution, Spatial Distribution, Western Province.

INTRODUCTION

Wireless technologies become a necessary part of human lives especially due to the pandemic, and most people used to live with these devices than ever before. These wireless devices use Radiofrequency (RF) waves to carry their signals, which are categorised in the non-ionising radiation zone of the electromagnetic spectrum. Recently, there has been a debate in society about the health effects of these non-ionising radiations due to the exponential increase in cancers and other non-spreading diseases. The most abundant RF emitting sources in the environment are cell phones, cellular transmitting towers, Wi-Fi hotspots, and TV and Radio Transmission towers.

Radio Frequency Region and Frequency Bands

Radio Frequency (RF) is a region of the electromagnetic spectrum that falls between 3 kHz and 300 GHz. It is used to transmit radio waves, which are used in communication systems such as radio and television broadcasting, wireless networks, and cell phones. RF waves are produced by oscillators, which generate a continuous oscillating signal and these can be powered by different sources, such as electrical circuits, batteries, or transistors. The frequency of the oscillator determines the frequency of the RF wave that is produced.RF frequency bands are portions of the RF spectrum used for various wireless communication applications. They are divided into different frequency ranges to accommodate different types of transmissions. The frequency bands are usually divided into three main categories: low frequency (LF), medium frequency (MF), and high frequency (HF). LF bands are typically used for long distance

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communications, such as AM and FM radio broadcasts, while MF and HF bands are used for short distance communications, such as cell phones and Wi-Fi networks. Cellular and Wi-Fi frequency bands are also portions of the RF spectrum, but they are specifically used for cellular and Wi-Fi communication applications. Cellular frequency bands are used by cell phone networks and mobile broadband services, while Wi-Fi frequency bands are used by wireless local area networks (WLANs)(ICNIRP, 2020). The frequency bands are regulated by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in Sri Lanka, and other organisations in some other countries.

Table 1 shows the selected frequency bands and their corresponding frequency ranges in this study.

Table 1. Different cellular network bands and Wi-Fi frequency band with the corresponding frequency ranges

Network Band	Frequency Range (MHz)
GSM900	890-915 (up link) /935-960 (down link)
GSM1800	1710-1785(up link) /1805-1880 (down link)
UMTS	1885-2025(up link) /2110-2200 (down link)
LTE2.6	2500-2570(up link) /2620-2690 (down link)
(Wi-Fi) WLan 2.4	2401-2484

RF Safety and Exposure Guidelines

RF (Radio Frequency) safety refers to measures taken to prevent potential harm to individuals and the environment from exposure to RF electromagnetic fields. These fields are generated by radio frequency equipment such as cell phones, wireless networks, and broadcast towers. To ensure RF safety, guidelines and standards are established by organisations such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Federal Communications Commission (FCC). These guidelines specify the maximum permissible exposure levels for various frequencies and duration of exposure. It's important to follow these guidelines and best practices when operating or working near RF equipment, including using proper shielding and antenna placement, maintaining a safe distance from RF sources, and avoiding prolonged exposure to high levels of RF fields. Some countries in the world use different guidelines for RF exposure. However, in Sri Lanka Telecommunications Regulatory Commission follows the guidelines published by International Commission on Non-Ionizing Radiation Protection (ICNIRP). Table 2 shows the exposure guidelines published by ICNIRP in 2020(ICNIRP, 2020).

Table 2. Guidelines for non-ionising RF exposure published by ICNIRP

Exposure	Freq. Range	Incident Electric Field (V/m)	Incident Magnetic field (A/m)	Incident Plane Wave Power Density (S) (W/m^2)
Occupational	0.1-30 MHz	$660/f_m^{0.7}$	$4.9/f_m$	NA
	>30-400 MHz	61	0.16	10
	>400-2000 MHz	$3f_m^{0.5}$	$0.008f_m^{0.5}$	$f_m/40$
	>2-300 GHz	NA	NA	50
General Public	0.1-30 MHz	$300/f_m^{0.7}$	$2.2/f_m$	NA
	>30-400 MHz	27.7	0.073	2
	>400-2000 MHz	$1.375f_m^{0.5}$	$0.0037f_m^{0.5}$	$f_m/200$
	>2-300 GHz	NA	NA	10

To ensure the above guidelines, continuous monitoring is recommended by the respective authorities to make sure the safety of the people.

Exposure Level Measurements

There are many ways for humans to be exposed to RF radiation. Nearly all people are exposed to some degree of RF radiation daily. It is better to understand the elements influencing human exposure. These include RF radiation strength, volume and duration of RF exposure, Distance from the RF emitter, Tissue types that are exposed to RF radiation, frequency of the exposed RF radiation, and body resonance are the primary elements influencing human exposure.

The electric field intensity (E), magnetic field strength (B), and equivalent plane wave power density (EPPD) are the basic measurements of radio frequency electromagnetic waves at a particular point of space, and these could be measured by using high-frequency spectrum analysers or any other suitable EMR measuring instrument.

When considering exposure compliance, a Specific Absorption Rate can be used, and it measures the rate of energy absorbed by a unit mass of a particular type of tissue of a human or animal. More generally, the SAR value could evaluate thermal losses in human or animal tissues. This value depends on various properties, such as water content, the geometry of the particular type of tissue, and the incident wave frequency(Lak & Oraizi, 2013).

Health Effects of RF Waves

In 2011 World Health Organization (WHO) published a report on the research agenda for radiofrequency fields. High-priority research areas in health effects such as behavioural and neurological disorders and cancer on children and adolescents, monitoring of brain tumour incident trends through population-based cancer registries combined with population exposure data, effects on brain function due to RF exposure, RF-EMF provocation studies on children of different ages, effects of RF exposure on ageing, development, behaviour, neurodegenerative disorders and reproductive organs of animals and social science research such as determinants and dynamics of RF EMF-related health concern and perceived health risks and effects of RF exposure on wellbeing(van Deventer et al., 2011).

The International Agency for Research on Cancer (IARC) assessed the carcinogenicity of radiofrequency electromagnetic fields (RF-EMF) in 2011. RF EMF was deemed carcinogenic (Group 2B) to humans based on scant evidence of its carcinogenicity in humans and animals (IARC, 2011). In nine case-control studies undertaken in Sweden, France, and other nations, RF radiation was found to relate to glioma, an essential human malignancy, according to a study published in 2018 based on epidemiology studies published since 2011. Rising glioma incidence patterns have been noted in the UK and other nations. Meningioma and auditory neuroma are two non-malignant endpoints that are connected. Case-control studies can be more effective in assessing possible hazards for brain cancer than cohort studies or other approaches because they enable more in-depth consideration of exposure. Current epidemiological research enhances and supports the conclusion that RFR should be classified as human carcinogenic when taking into account recent animal experimental evidence (IARC Group 1) (Miller et al., 2018). The National Toxicology Program (NTP) reported a higher incidence of malignant glial tumours of the brain and heart Schwannoma in rats exposed to GSM and CDMA-modulated cell phone RF radiation in the first results of its long-term bioassays on near-field RF radiation released in 2016. The tumours found in the NTP study resemble those found in certain epidemiological studies of cell phone users (NTP (National Toxicology Program), 2016).

A large study carried out by Ramazzini Institute (RI) through the life-span of Sprague-Dawley rats in a carcinogenic investigation to assess the effects of RF radiation in a far-field scenario, simulating the ambient exposure to RF radiation produced by 1.8 GHz GSM antenna of mobile phone radio base stations shows a statistically significant increase in the incidence of heart Schwannomas in treated male rats when they exposed to a maximum r.m.s electric field intensity of 50 V/m and the particular study request to re-evaluate the IARC conclusions regarding the carcinogenic potential of RF radiation in humans (Falcioni et al., 2018) A systematic review and meta-analysis designed to investigate the association between exposure to radiofrequency radiation and the risk of breast cancer based on selected studies that were published in PubMed, Embase, Cochrane Library, Ovid MEDLINE, CINAHL Plus, Web of Science, Airiti Library, Networked Digital Library of Theses and Dissertations and ProQuest until May 2020 show a significant association between RF exposure and breast cancer risk. Furthermore, the study shows an increased risk of breast cancer, especially in women aged 50 or above years and in people who use RF sources such as mobile phones and computers (Shih et al., 2020). Another study was developed to evaluate the effect of continuous low-intensity exposure to electromagnetic fields from radio base stations (RBS) on cancer mortality, especially for breast, cervix, lung, and esophagus cancers in Brazilian people based on the number of deaths by cancer, gender, age group, gross domestic product per capita, death year, and the amount of exposure over a lifetime. The adjusted study demonstrated that cancer mortality increased directly to RBS radiofrequency exposure. For cervical cancer, the highest adjusted risk was seen. The regional study revealed that the city in southern Brazil with the highest RBS radiofrequency exposure was also the city with the highest overall cancer death rate, particularly for lung and breast cancer. The study's overall finding suggests that exposure to radiofrequency electromagnetic fields from RBS raises the mortality rate for all cancer types (Rodrigues et al., 2021).

Above are a few studies conducted by many researchers around the world, and there are more studies to confirm the adverse effects of these RF waves. Monitoring background radiation levels due to these waves is essential to minimise these effects and regulate RF exposure. The main objective of this study is to obtain an idea about the current background RF exposure levels in the most populated province in Sri Lanka, mainly due to cellular and Wi-Fi networks.

INSTRUMENTATION AND METHODOLOGY

Measurements were taken at places with at least one visible cellular tower structure and fewer radiation barriers, such as large buildings and metal structures. The peak value of the RMS electric field intensity was measured at the selected locations for the downlink of the cellular frequency bands GSM900, GSM1800, UMTS, and LTE2.6 and the peak electric field intensity due to Wi-Fi (WLan2.4) hotspots. SPECTRAN HF6065 selective spectrum analyser was used to collect all the data. This high-frequency electromagnetic wave meter can measure RF EMR within 10 MHz to 6 GHz. A compatible broadband directional antenna (Hyperlog7060) was used with the device, and the selected antenna is more accurate within the frequency range of 700 MHz to 6 GHz. Figure 01 shows the instrumentational setup used for the study.

Figure 1. Instrumental Setup

Since the setup contains a directional antenna, it was rotated 360° while holding the antenna on the horizontal plane to find the peak electric field intensity at a selected location for all the frequency bands. The data were collected in the daytime between 8 am and 4 pm within the first quarter of 2022.

RESULTS AND DISCUSSION

In this survey, 681 data points were collected within the Western Province of Sri Lanka. Figure 2 shows the collected data point in the map of the western province.

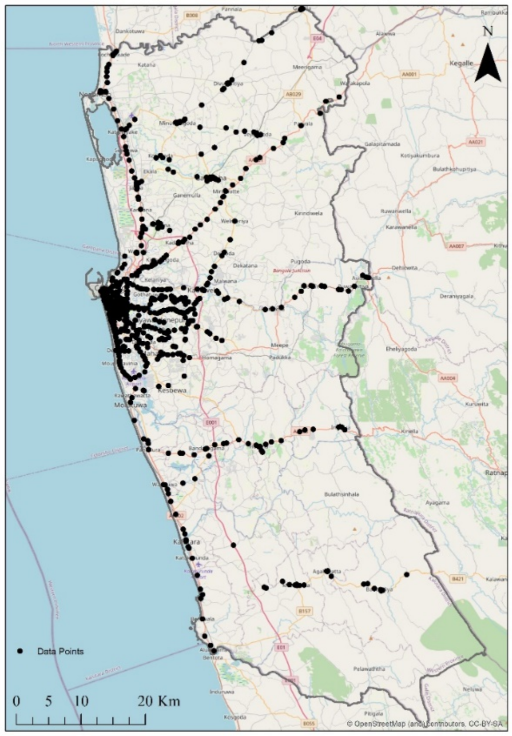

Figure 2. Survey points in the Western Province of Sri Lanka map.

Table 3 shows the calculated statistics for all the collected data in this survey.

Table 3. Calculated statistics for all the data collected in the survey within the Western Province of Sri Lanka.

Statistic	Electric field (V/m)				
	GSM900	GSM1800	UMTS	Wi-Fi (WLan2.4)	LTE2.6
Min	0.012	0.008	0.004	0.002	0.013
Max	1.031	2.325	1.487	0.155	0.978
Average	0.149	0.233	0.191	0.015	0.142
SD	0.132	0.247	0.184	0.014	0.126

Table 4 shows the location coordinates of the recorded maximum electric field intensity levels within the western province of Sri Lanka.

Table 4. Location details of the measured maximum E-field values in the survey

Frequency Band	Location Coordinates	
	Lat.	Long.
GSM900	6.884096	79.876028
GSM1800	6.927869	79.858558
UMTS	6.846181	79.866188
Wi-Fi (WLan2.4)	6.966308	79.870995
LTE2.6	7.014641	79.898051

Figure 3. shows the variation of the average of peak E-Field levels for each frequency band.

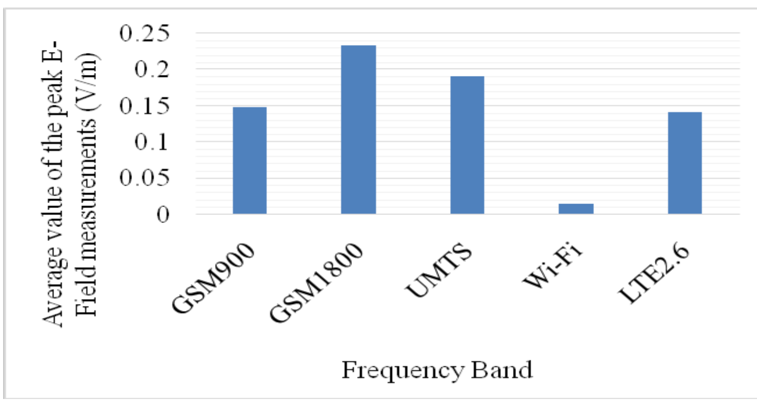

Figure 3. Variation of the calculated average values of the E field data for each frequency band.

Based on the data in the Table 3 and Figure 3,GSM1800 frequency band is more responsible for the background RF pollution levels and Wi-Fi frequency band contributes the least. However, it should be noted that most of the Wi-Fi devices are fixed inside the house, which could lead to higher exposure for the occupants due to Wi-Fi frequency bands.

Histogram for a particular data set is very important to get a visual idea about how much the data are distributed. Figure 4 shows the histogram for the collected data in the GSM900 frequency band.

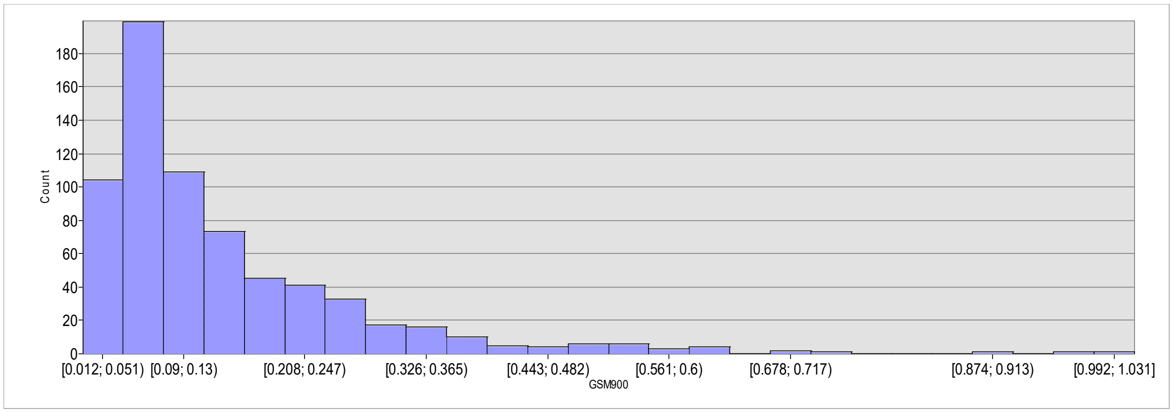

Figure 4. Histogram for the collected E field data in the GSM900 frequency band

According to Figure 4 most of the collected data for the GSM900 band are gathered between 0.051 V/m and 0.090 V/m range.

Figure 5 shows the histogram for the collected data in the GSM1800 frequency band.

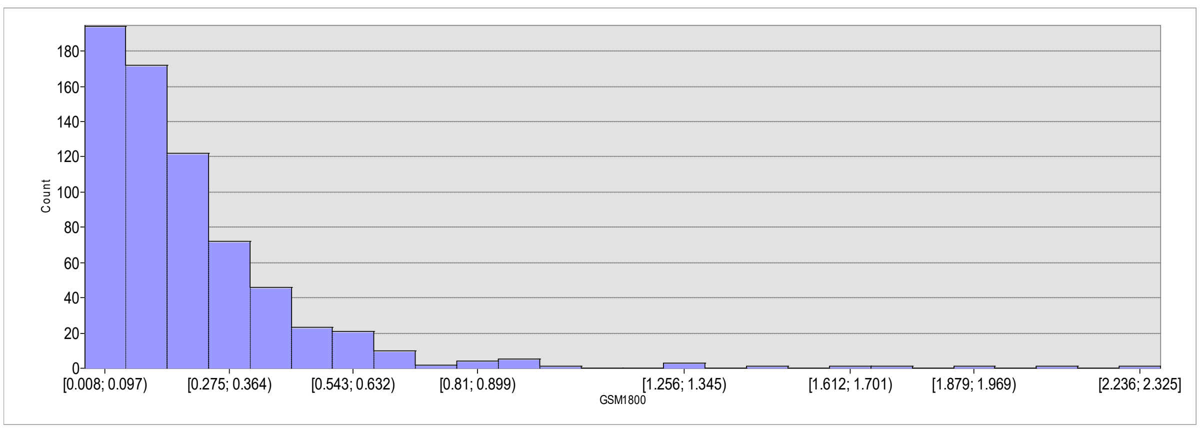

Figure 5. Histogram for the collected E field data in the GSM1800 frequency band

Based on Figure 5, most of the collected data for the GSM1800 band are gathered between the range 0.008 V/m and 0.097 V/m.

Figure 6 shows the histogram for the collected data in the UMTS frequency band.

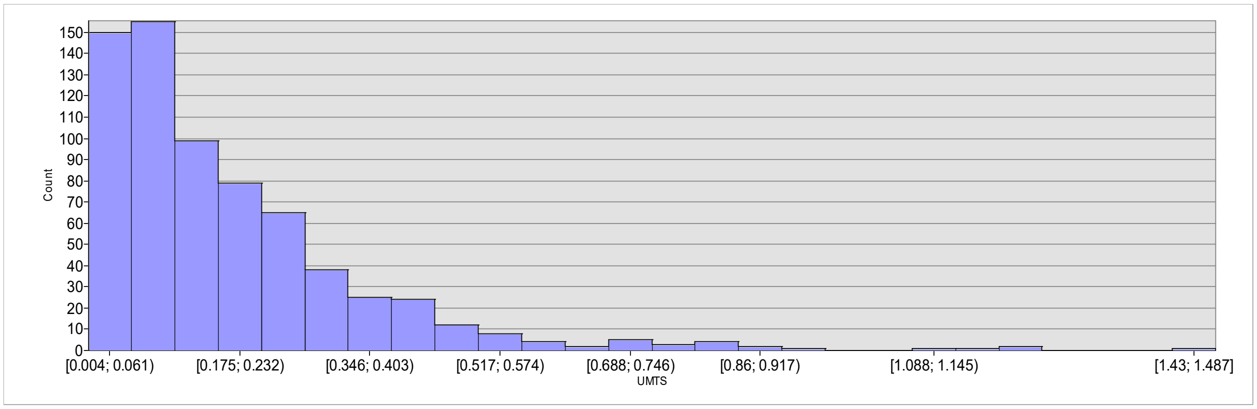

Figure 6. Histogram for the collected E field data in the UMTS frequency band

Based on Figure 6,most of the collected data for the UMTS band are below 0.175 V/m.

Figure 7 shows the histogram for the collected data in the Wi-Fi (WLan2.4) frequency band.

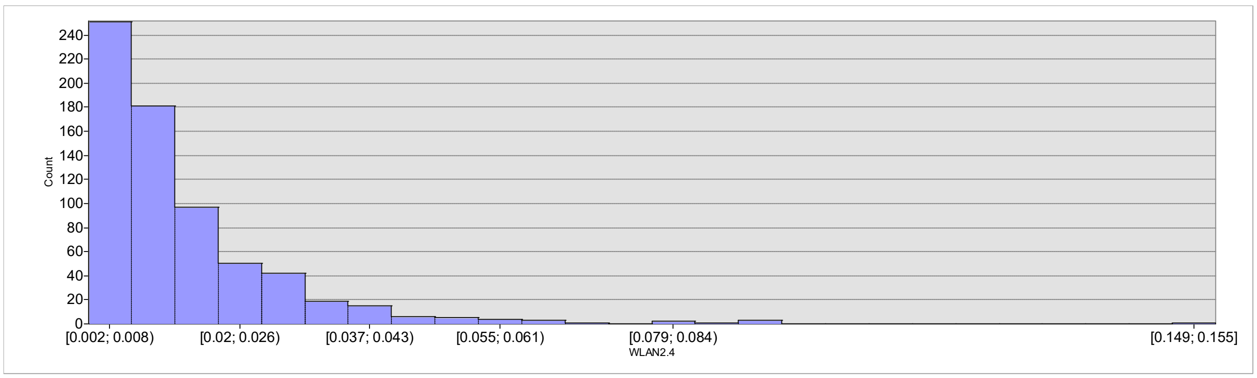

Figure 7. Histogram for the collected E field data in the Wi-Fi (WLan2.4) frequency band

Figure 7 reveals that the selected Wi-Fi frequency band's contribution to the everyday background RF radiation exposure is meagre, and most of the collected data are below the 0.02 V/m level.

Figure 8 shows the histogram for the collected data in the LTE2.6frequency band.

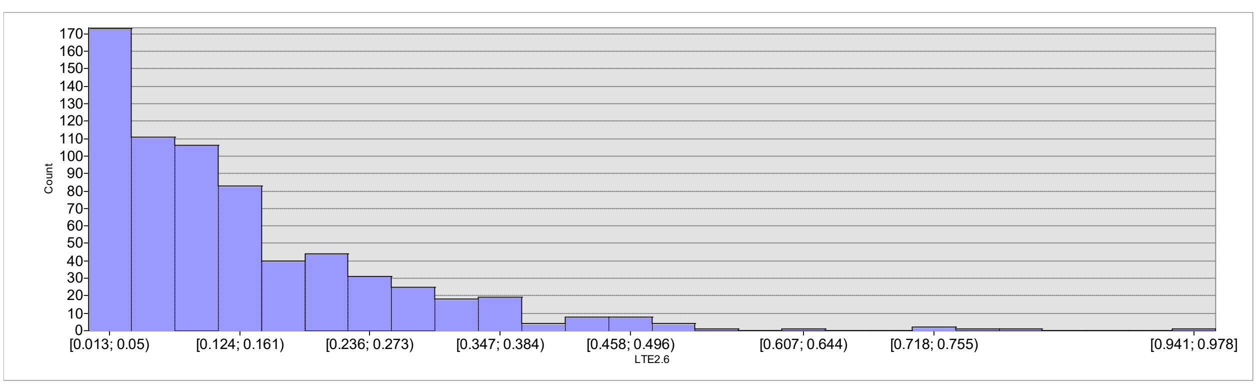

Figure 8. Histogram for the collected E field data in the LTE2.6 frequency band

Figure 8 indicates that most LTE2.6 frequency band E field levels are gathered within the range of 0.013 V/m to 0.124 V/m. This indicates that nearly the entire region of the western province is covered by the LTE2.6 band.

Based on all the histograms, it is clear that all the RF field measurements show a positively skewed distribution, which indicates lower RF exposure levels throughout the Western Province. This is generally good news for the residents, as it suggests that most locations have relatively lower RF radiation levels. However, it is crucial to pay close attention to areas with higher measurements, especially where cellular towers are situated near sensitive locations like hospitals, schools, and kindergartens. While the overall RF exposure levels seem to be within acceptable limits based on the histograms, these specific areas may warrant further investigation and monitoring.

To observe the spatial distribution of RF pollution levels within the Western Province of Sri Lanka, a spatial distribution pattern was generated using the IDW interpolation technique in ArcMap software. Figure 9 shows the corresponding spatial distribution of the E-Field for the selected frequency bands.

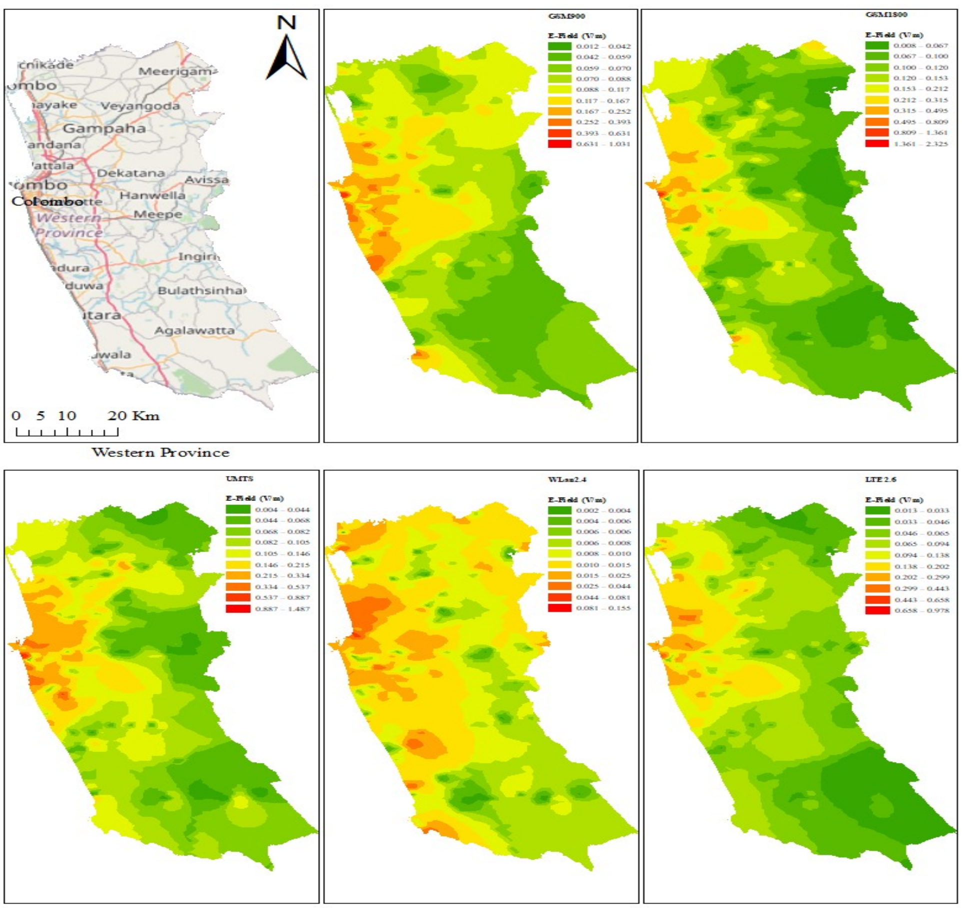

Figure 9. Predicted spatial distribution maps for E field variation based on the measured data for each frequency band.

Equivalent Plane-Wave Power Density (EPPD) levels can be calculated, to evaluate the overall exposure due to all the selected frequency bands at a particular point. Table 5 shows the calculated statistics for the equivalent plane wave values calculated based on the peak electric field intensity levels collected in this study.

Table 5. Calculated statistics for the equivalent plane wave power density (EPPD) levels calculated based on the collected data

Statistic	Equivalent plane wave power density (mW/m^{-2})
Min	0.004
Max	17.903
Average	0.695
SD	1.516

The location coordinates corresponding to the maximum EPPD is 6.927869, 79.858558. Based on the ICNIRP guidelines, the maximum permissible exposure levels depend on the frequency. However, when compared with 2 W/m^{-2}, above maximum EPPD value is approximately 0.9 %. Therefore, this reveals that as of the first quarter of 2022, the RF pollution levels do not exceed international guidelines.

Based on the calculated EPPD values, a spatial distribution pattern can be generated for the cumulative EPPD levels. Figure 10 shows the spatial distribution map of cumulative EPPD levels calculated and predicted using the IDW interpolation technique in ArcMap software based on the measured peak E-Field Values in the Western Province of Sri Lanka.

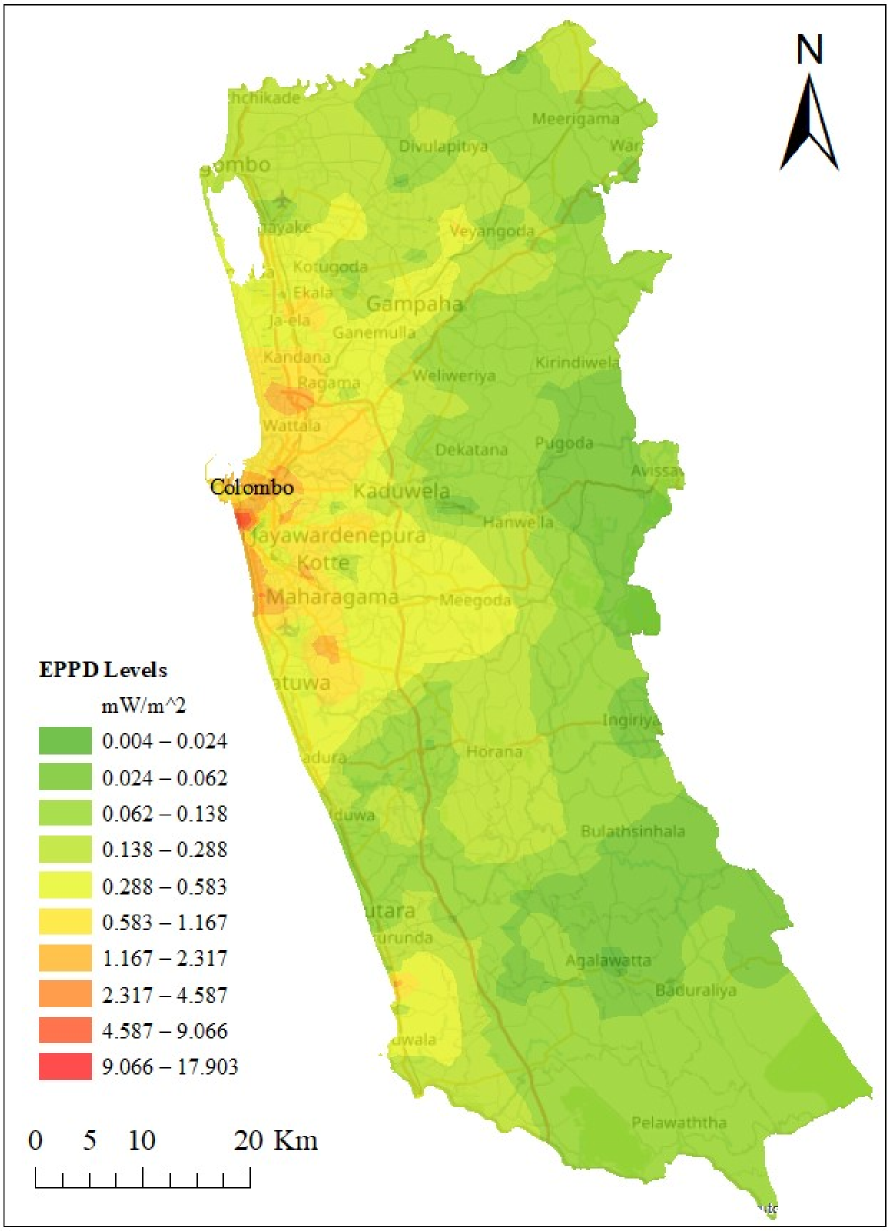

Figure 10. Spatial distribution of cumulative EPPD levels by all the selected frequency bands within the Western Province of Sri Lanka

Based on Figure 10, we can observe higher RF pollution levels in specific areas, particularly in proximity to Colombo City and along the coastal region from Moratuwa to Ja-Ela. These elevated RF pollution levels are attributed to the higher concentration of cellular towers and Wi-Fi hotspots in urban centres and densely populated coastal areas.

CONCLUSIONS

During this study, the authors identified many cellular tower structures situated very close to hospitals, schools, and kindergartens, especially within the Colombo city and in the coastal region from Moratuwa to Ja-Ela. Therefore, the authors would like to recommend a high-resolution RF survey in these areas under the supervision of the Central Environmental Authority of Sri Lanka and the Telecommunication Regulatory Commission of Sri Lanka.

Based on the collected data and calculated equivalent planewave power densities, it can be concluded that as of the first quarter of 2022, the western province is safe from RF pollution levels emitted by major cellular bands and WLan2.4 network band, based on the thermal effects published by ICNIRP. However, nowadays, the scientific community is concerned about adverse effects due to non-thermal effects of RF radiation. Since no exact guidelines are published to evaluate the threshold exposure, people must take safety precautions when living in places with considerably higher RF radiation levels. Especially pregnant women and children must limit their daily exposure to these non-ionising radiations.

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Pharmacological effects of *Sesamum indicum*; Systematic review

Running Title: *Sesamum indicum*; Systematic review

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ABSTRACT

Sesamumindicum L. is a wildly used medicine in Ayurveda and traditional medicine in Sri Lanka. This study aims to analyse the most recent research findings about the pharmacological effects of S. indicum. The PubMed, Scopus, and Cochrane library databases were searched extensively and systematically for papers published between January 2011 and May 2022. We considered the PRISMA Statement to provide a good structure for systematic reviews. The keywords used to search for articles included "Sesamumindicum." Other filters were selected as the limit to medicine, open access, full-text articles, journal articles, and written English. All the data were recorded in an excel sheet, and the following number of research articles were found in the various databases; PubMed (n=03), Cochrane library (n=39), and Scopus (n=75). After removing duplicates, there were 114 articles. Those articles were further screened, firstly by reading topics and abstracts and secondly by reading the full text, and which did not match the inclusions were removed. After removing those articles, there were 27 articles, and after adding 03 additional articles, 30 articles were included in the systematic review. Finally, 08 clinical trials, 11 in-vivo, and 15 in-vitro research were analysed. According to those studies, its anti-cancer activity, antioxidant activity, antibacterial activity, antiatherosclerosis activity, anti-inflammatory activity, analgesic activity, anti-allergic activity, menstrual bleeding-inducing effect, skin whitening effect, neuroprotective activity, etc., have been proven scientifically. Limitations such as limited clinical research, not claiming all pharmacological actions, and not testing some medicinally used parts were identified.

Keywords: Pharmacological effect, Sesamumindicum, Systematic review

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INTRODUCTION

Sesamum indicum L. (*S. indicum*) is usually known as sesame in English, "*Tila*" in Sanskrit, and "*Thala*" in Sinhala. It is one of the world's oldest oilseed crops. It is used for nutritional, medical, and industrial applications worldwide. *S. indicum* is a wildly used medicine in Ayurveda and traditional medicine in Sri Lanka. Stem, Leaves, Seeds, and Oil have medicinal values.

This study aims to analyze the most recent research findings about the pharmacological effects of *S. indicum*.

METHODOLOGY

A systematic review of published full research papers reporting the pharmacological effects of *Sesamum indicum* was designed based on the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyzes) statement guidelines (Tricco *et al.*, 2018). Eligibility criteria are based on the PICO (Population, Intervention, Comparison, Outcomes) approach, study design, Language, and date.

Types of Studies

In vitro, in vivo, and clinically proven pharmacological effects were explored in this systematic study.

Inclusion Criteria

All the published full research papers from 2011 to May 2022, written in English, studied the pharmacological effects of *S. Indicum* were included.

Exclusion Criteria

Other than English, research articles were written in various other languages; Research papers published before 2011, abstract-only papers, journals with no full text available, case reports, case series, systematic review studies, and literature reviews were all eliminated.

Types of Outcomes

The primary outcome was the pharmacological effect, and the secondary outcome was the safety or adverse effects of *S. indicum*

Search Strategy

A comprehensive search of previously published research articles was conducted in PubMed, Scopus, and Cochrane library databases for studies published between January 2011 and May 2022. The keywords used to search for articles included "*Sesamum indicum*." Other filters were selected as the limit to medicine, open access, Full-text articles, journal articles, and written English.

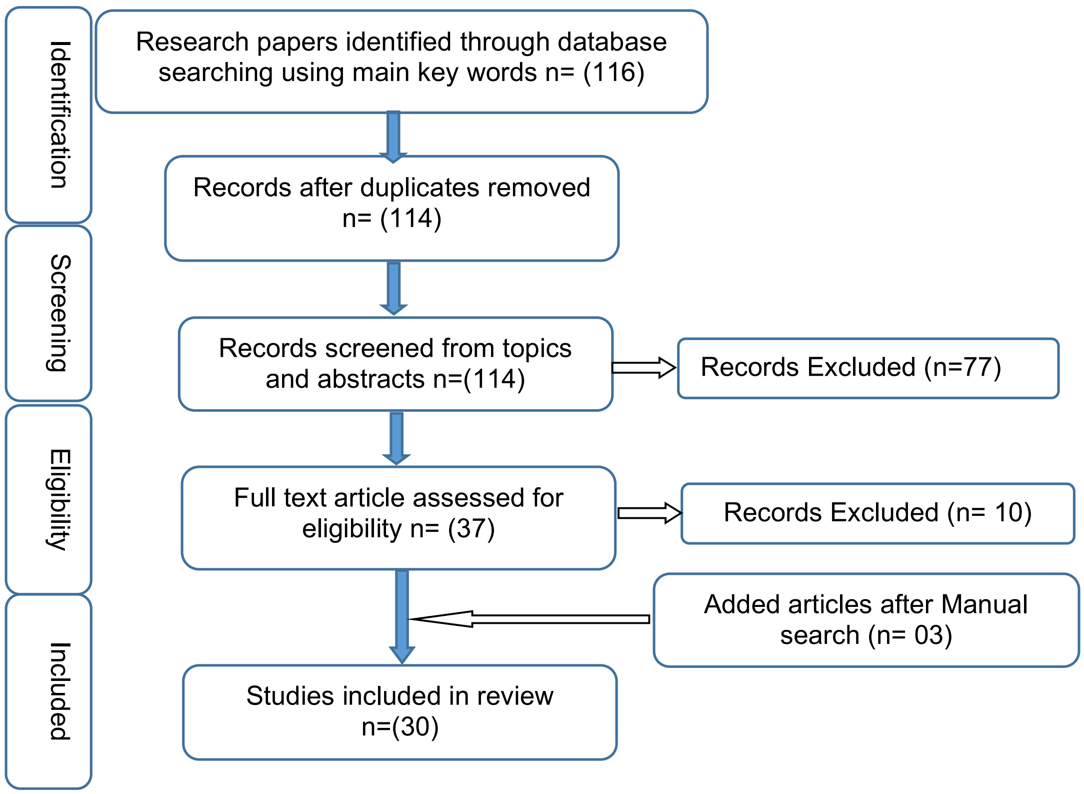

Figure 1: Search strategy

Evaluation of Article Quality

Two authors independently assessed the quality and acceptance of the articles and discrepancies were discussed until an agreement was reached.

Data Extraction

Information related to the study was collected, including the pharmacological activity, type of extract/used part, test method, laboratory organism/animal used, and Reference.

RESULTS AND DISCUSSION

Using the above-mentioned search parameters, the following number of research articles were found in the various databases; PubMed (n=03), and Cochrane library (n=39) and Scopus (n=75). After removing duplicates there were 114articles and those articles were further screened firstly by reading topics and abstracts and secondly reading full text and which did not match with the inclusions were removed. After removing those articles there were 27 articles and after adding 03 additional articles finally 30 articles were included in systematic review. Figure 1 summarizes the search approach. Finally, 08 clinical trials (Table 01), 11 in vivo studies (Table 02), and 15 in vitro research (Table 03) were analyzed (Some researchers conducted more than one study).

Table 1: Clinical Studies

	Pharmacological Activity	Used Part	Test Method	Reference
01	Analgesic effect	sesame oil	Randomized clinical trial	(Shamloo *et al.,* 2015)
02	Reduce muscle damage and oxidative stress	White Sesame seeds paste	Experimental, randomized, and placebo controlled. study	(Barbosa *et al*., 2017)
03	Inducing menstrual bleeding and maintaining regular menstruation	Powdered sesame	A single-blind randomized controlled clinical trial	(Yavari *et al.,* 2016)
04	Removal of retained. products of conception and the reduction of the severity of pain and vaginal bleeding	Sesame grinding powder	An open label randomized controlled clinical trial	(Aghababaei *etal*., 2021)
05	Analgesic effect	Sesame oil	A randomized controlled trial	(Shamloo *et al.,* 2019)
06	Effects on knee osteoarthritis	Sesame seeds powder	A randomized clinical trial	(Sadat *et al.,* 2013)
07	Effect on Lipid disorders	Paste of sesame seeds	A randomized clinical trial	(Mirmiran *et al.,* 2013)
08	Induce menstrual bleeding	Powdered sesame	Pilot study	(Yavari *et al.,* 2014)

Table 2. In-vivo Basic Experimental Studies

	Pharmacological Activity	Type of extract/ Used part	Laboratory Organism/ Animal Used	Reference
01	Anti-rheumatoid activity	Ethanolic extract of seeds	Wistar albino rats	(Ruckmani *et al.*, 2018)
02	Anti-Atherosclerotic action	Sesame oil	female LDLR - / - mice	(Narasimhulu *et al.,* 2015)
03	Anti-Inflammatory action	Sesame oil	female LDLR - / - mice	(Narasimhulu *et al.,* 2015)
04	Anti-Inflammatory and Antioxidant Activities	Sesame oil aqueous extract	Swiss Webster mice	(Selvarajan *et al.,* 2015)
05	Diminishes bone mass and bone formation	Methanol extracts of sesame seeds	Ovariectomized Female Wistar rats	(Tachibana *etal.,* 2020)
06	Diabetes-induced cardiac dysfunction	Sesamin dissolved in olive oil	STZ-induced type I diabetes rat model	(Thuy *et al.,* 2016)
07	Anti-cancer effect	Sesamol (one of the lignans in sesame seeds	6 weeks old male min mice, Apc mutant mice	(Shimizu *et al.,* 2015)
08	Reduced dementia	Sesamin and sesamolin (lignans in *S.indicum*)	Five-week-old male Slc:ddy mice	(Matsumura *et al.,* 2016)
09	Protects the femoral head from Osteonecrosis	Sesamin, isolated from *S.*	male Sprague-Dawley	(Deng *et al.,*2018)

		*indicum*seeds	rats	
10	Increased vitamin K concentrations	Sesamin extracted from white sesame seeds	male Wistar rats	(Hanzawa *etal.,* 2013)
11	Induced growth and development of mammary gland tissue	Pellets with sesame seeds	female Albino rats	(Al-Bazii *et al.,* 2019)

Table 3. In-Vitro Studies

	Pharmacological Activity	Type of extract	Test method/ Laboratory Organism	Reference
01	Anti-helicobacter pylori Activity	Ethanol extract of Leafe	*Helicobactor pylori*	(Masadeh *et al.,* 2014)
02	Anti-bacterial effect	Hexane, Ethyl acetate, and Ethanol extracts of seeds	*Staphylococcus aureus, Enterococcus faecalis, Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, and Acinetobacter baumannii*	(Hossan *et al.,*2018)
03	Anti-Cancer effect	Dichloromethane extract of leaves	Human myeloid leukemia, human hepatocellular carcinoma, human lung carcinoma, human breast adenocarcinoma, and human Colon cancer cell lines	(Iweala *et al.,* 2015)
04	Free radical scavenging activity	Ethanolic extract of *S. indicum*leaves	DPPH free radical scavenging activity	(Iweala *et al.,* 2015)
05	Anti-Inflammatory and	Sesame oil aqueous	RAW 264.7 cell s and	(Selvarajan *et al.,*

	Antioxidant Activities	extract	human umbilical vein endothelial cells (HUVECS)	2015)
06	Pancreatic lipase inhibition and reducing total body fat	*S. indicum* extract (70%)	Pancreatic lipase (Pancreatic lipase assay)	(Badmaev *et al.,* 2015)
07	Anti-cancer activity (Colon cancer)	Sesamol (one of the lignans in sesame seeds	Human colon cancer cells	(Shimizu *et al.,* 2015)
08	Impacts on T and B lymphocyte activities	sesame seeds oil and sesamol	spleen cells of 8-10 weeks old female or male Balb/c mice	(Khorrami,Daneshmandi & Mosayebi, 2018)
09	Antioxidant and hypoglycemic activities	Ethanolic and aqueous extracts of *S. indicum* seeds	DPPH radical scavenging assay and Glycogen phosphorylase enzyme assays	(Hilmi *et al.,* 2014)
10	Antioxidant and antiproliferative activities	Six sesame seed varieties (Three black and three white)	Oxygen Radical Absorbance Capacity (ORAC) and antiproliferative activity (EC50) against HepG2 Cells	(Zhou *et al*., 2016)
11	Antioxidant and Anti-Colon Cancer Activities	Ethanol extract of *S. indicum*leaf	DPPH assay, FRAP and cell viability assay. Human colon cancer cell lines	(Kim *et al.,* 2021)
12	Pro osteoblastic and anti-osteoclastic	Methanolic extract of *S. indicum*	Osteoblastic MC3T3-E1 cells (mouse calvarial	(Suzuki *et al.,*2018)

	activity		origin)	
13	Alleviate neurodegeneration	Sesamin, isolated from *S. indicum* seeds	Rat pheochromocytoma (PC12) cells	(Udomruk *et al.,* 2020)
14	Anti-melanogenesis activity	Sesamol, an active lignan isolated from *S. indicum*	The melan-a melanocyte line	(Baek and Lee, 2015)
15	Anti-allergic activities	Fermented Sesame	The human keratinocyte HaCaT cell line	(Jung et al., 2018)

Since ancient times, the S. indicum has been crucial in helping treat many disease problems in humans. According to the research studies, its anti-cancer, antioxidant, antibacterial, anti-atherosclerosis, anti-inflammatory, analgesic, anti-allergic, menstrual bleeding inducing, skin whitening, neuroprotective, etc. activities were all scientifically demonstrated. Bioactive compounds, especially lignans (Samin, Sesamin, Sesamolin, Sesamol, Saminol, Sesaminol, Sesamolactol, Sesamolinol, etc.) are responsible for pharmacological activities. Three types, black, white, and red, are used in conventional medicine and Ayurvedic medicine to treat various medical conditions, including gynecological disorders, rectal disorders, and urinary tract disorders. Further, several plant organs, especially seeds, seed oil, flowers, stem, and the entire plant, are utilized to make various medicinal preparations, including decoctions, powders, oils, alkalizes/Kshara, etc. (Anonymous, 1994). According to this study different plant organs, Seeds, leaves, seed extracts and oil were tested. Most clinical trials frequently used seed paste or powder, and roots had yet to be evaluated. Six types of sesame seeds were evaluated by Zhou et al., who concluded that the black variety outperformed the other five varieties as an antioxidant supplement. Likewise, Ayurveda claims that black seeds have more therapeutic benefits (Anonymous, 1994).

CONCLUSION

Sesamum indicum's pharmacological properties are primarily highlighted in this review and many pharmacological effects of Sesamum indicum were scientifically proven by in vitro and in vivo studies. More clinical research must be done to fully understand its therapeutic potential and need to conduct scientific safety assessments further. Especially many gynecological disorders, Urinary and rectal diseases are treated with S. indicum, particularly in traditional and Ayurvedic medicine; nevertheless, there are very few clinical studies on such illnesses or ailments. Sesamum indicum was also used to treat diseases in Ayurveda and traditional medicine as a raw drug and in various pharmacological preparations. Thus, studies using those pharmacological formulations are also needed to prove their therapeutic value. Hence, limitations were identified in those studies, such as limited clinical research, not claiming all pharmacological actions, and not testing some medicinally used parts.

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Evaluation of the perceived palatability levels of grazing forages of wild asian elephants in Sri Lanka

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ABSTRACT

The relative preference of Asian elephants for particular plant species is one of the important factors in enhancing forage availability through elephant-specific conceptual conservation strategies in habitat enrichment to keep elephants inside fragmented landscapes. The dilemma posed by the human-elephant conflict and the loss of forage lands due to the burgeoning population density of Sri Lanka indicates the necessity of sustainable forage availability. The information on the palatability levels of forage plants of elephants grazing in Sri Lankan forests and lands is rare. Thus, the present investigation focused on the perceived palatability levels of forages consumed by wild elephants in distinct provinces in the country. An online, piloted, and validated questionnaire was conducted to gather information from respondents with field experience and expertise. The responders were chosen at random, and the questionnaire was administered. A list of palatable plant species was compiled based on the literature, field surveys, and interviews conducted with wildlife experts. Twenty-two common elephant fodder plants were identified from eight provinces on the island, including three herbaceous, 14 types of grass, and five sedges. The perceived palatability scores differ across the provinces, plant types, and species. Of the 22 listed forage plants, Pennisetum purpureum, Sacciolepis interrupta, Panicum maximum, and Echinochloa glabrescens surpass the rest, with relatively higher palatability scores. Thus,increasing the availability of forage plants with higher palatability levels secures and sustains the wild elephants in Sri Lanka. Further studies are required to understand the spatiotemporal variation of these plants entirely.

Keywords: Human-Elephant Conflict (HEC), Perceived Forage Palatability, Asian elephants, Wildlife Conservation, Sri Lanka.

INTRODUCTION

The Asian elephant (Elephas maximus), a member of the genus in the family Elephantidae, is widely distributed in South Asian and Southeast Asian countries (Gorade & Datar, 2014). In Sri Lanka, it has been reported that a total of ca. 5879 elephants, according to the Department of Wildlife Conservation (DWC) report (2011), have been spatially concentrated in the Mahaweli and Eastern regions(The Department of Wildlife Conservation, 2013; Insurance, 2019; Fernando et al., 2021). However, it has been reported that the elephant population was subjected to fluctuations through 1951 when there was an increase (1500 elephants in 1951). Since then, the elephant population has continuously increased to 1600-2200 in 1969, 2000- 4000 in 1978, and 5879 in 2011 (Fernando et al., 2011). The

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estimated elephant population in Sri Lanka in 2017 was ca. 6000, thus, 300,000 kg for their daily food requirement (Santiapillai et al., 2010).

As far as the island's human population is concerned, there has been substantial growth during the past ten years, and this substantial increase in the population has created unexpected pressure on the island's natural forests(Tharangi et al., 2022a). According to the literature about forest cover and forest cover changes, it has decreased from 82% in 1882 to 29.7% in 2017 (Ruzaik, 2021). Therefore, the existing forest cover is not supportive of feeding and providing habitats for the elephant population in the country. Meanwhile, based on the unpublished information available for 2021 at the Wildlife Department, the elephant deaths during 2010 – 2021 indicated a significant increasing trend with a total of 3181 deaths, while human deaths vice versa and accounted for 685. According to a recent IUCN status report, the Asian elephant has been included in the "Endangered" category (Fernando et al., 2021). The declining forest cover, associated with human population increase, has led to perpetual HEC.

The increase in forage availability would lead to minimizing the HEC. In this regard, identifying the plants that could be introduced into inaccessible lands is worthwhile. The grasses possess higher adaptability and regenerative capacity and thrive well in varying climatic conditions. Therefore, it is appropriate to increase the abundance of grazing grass availability.

The behavior of wild elephants causes several issues, centering around human death and injuries, property losses, crop losses, and social losses (LIFE, 2019). In addition, many incidents of human-induced damage to elephants have been reported, even leading to deaths (LaDue et al., 2021; De Silva et al., 2013). This situation is now referred to as the Human-Elephant Conflict (HEC). There are several migratory measures in practice, including the introduction of electric fences and trenching to restrict elephants' movement.

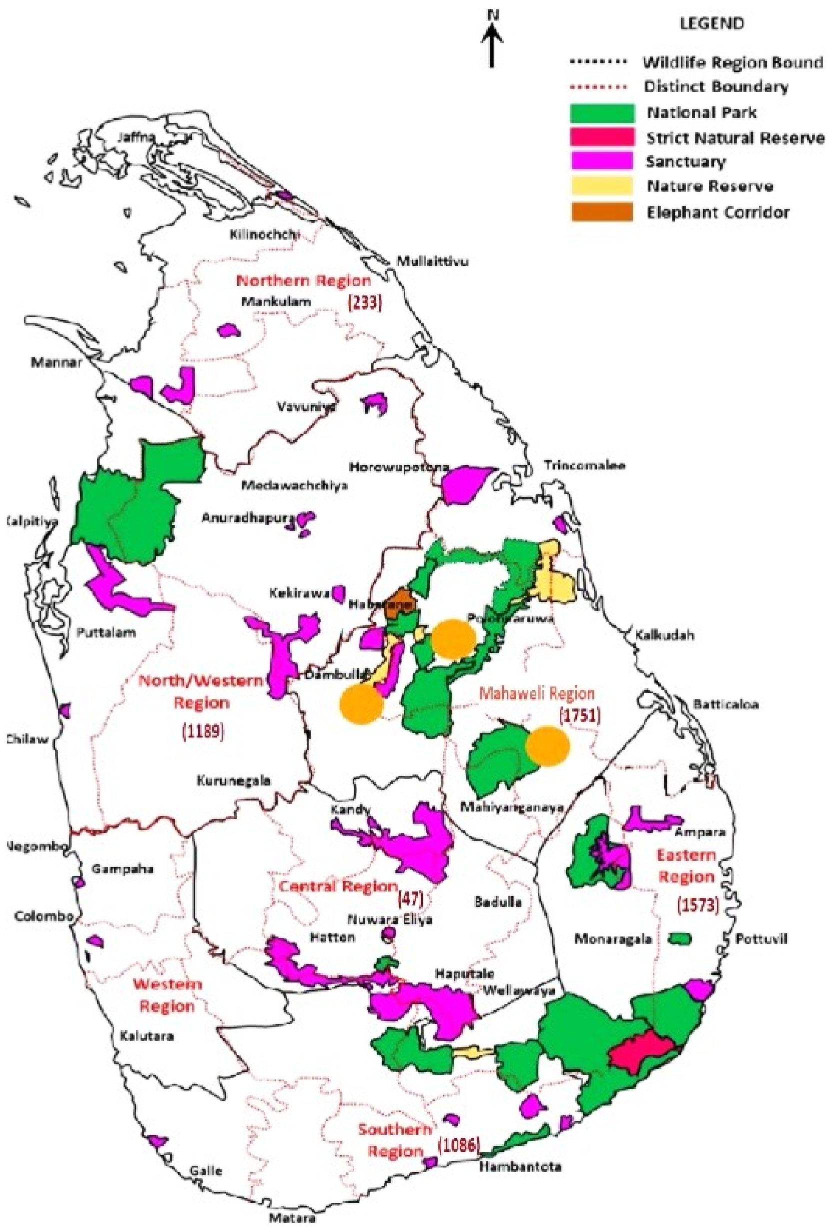

Figure 1. Distribution of elephants by Wildlife regions in Sri Lanka (Modified after Rajapakse et al., 2019).

However, HEC remains persistent as most existing prevention strategies driven by site-specific factors only offer short-term solutions, while mitigation strategies transfer conflict risk from one place to another (Shaffer et al., 2019). For a sustainable solution for the HEC, a holistic approach to the problem is essential, and the factors of basic needs such as water, food, and breeding sites are important in such endeavours (Skitka et al., 2011).Asian elephants, as mega-herbivores, are shown to consume a wide variety of vegetation, as many as 165 species of plants belonging to 56 families (Bhatt et al., 2011).

Therefore, identifying the palatability levels and preferences for each plant species is important in enhancing the habitat enrichment endeavours to mitigate human-elephant conflict (EHC) by avoiding the implementation of fences, including biological and electric, with unsustainable pressure on elephant behaviour (Bhatt et al., 2011; Krishnan & Braude, 2014).

Regarding feeding behaviour, feeding behaviours such as fodder palatability, availability, and nutrient requirement play a crucial role in finding migratory measures for the HEC (Nakano et al., 2020). Therefore, it is necessary to focus on the increase in the availability of grass fodder. It is a well-known fact that forage palatability is associated with physical characteristics such as fiber content, level of maturity, toughness, succulence, and leafiness, which can be determined by observing the forage intake of elephants. Further, forage palatability, availability of grass species, and the physiology of an animal were major factors influencing the relative preference (Stimulation, 2013; Gorade & Datar, 2014).The relative preference of Asian elephants for particular plant species is an important enhancing factor in forage availability through elephant-specific conceptual conservation strategies in habitat enrichment to keep elephants inside the fragmented landscapes. A comprehensive literature survey on the relative palatability level of wild range elephants for each grazing forage in Sri Lanka revealed that there was a scarcity of in-depth studies available on the feeding behaviour and diets of Asian elephants grazing on rangelands and secondary forests (Ashton et al., 1997; Samansiri & Weerakoon, 2007).

However, mitigating EHC through wild elephant management and enhancing habitat enrichment techniques requires a crucial understanding of feeding behaviour and ecology (Krishnan & Braude, 2014).For the survival of wild-range Asian elephants in fragmented landscapes through a habitat enrichment approach and co-existence strategy, an in-depth research is required to fill the gaps of knowledge about the relative preference of fodder plants of Asian elephants in the ranging forests in Sri Lanka (Kumar et al., 2010).

Therefore, the present study was carried out to evaluate the most palatable fodder species, which is part of ongoing research increase Asian elephant fodder availability based on the behaviour of wild elephants in elephant-ranging forest ecosystems. The study's findings would provide information for policymaking and implementing mitigatory measures for the ever-growing HEC. Further, the finding indirectly contributes to the reduction of economic losses as well as to conserve the elephant population in the country. For the survival of wild-range Asian elephants in fragmented landscapes through co-existence strategy, in-depth researches are required to fill the gaps of knowledge about the relative preference of forage plants of the Asian elephants in the ranging forests in Sri Lanka. Thus, this preliminary study aimed to evaluate the responder-rated palatability levels of selected herbaceous plants in relation to the distribution of the elephant population in Sri Lanka for the habitat enrichment approach.

METHODOLOGY

Sri Lanka, an island located southeast of the southernmost tip of the Indian subcontinent, lies between 5°55' and 9°51' northern latitudes, consisting of an approximate area of 65610 km2(Kumar et al., 2010). The present survey was conducted in the provinces where wild-elephant populations are, except in the Western Province (Figure 1).

As an initial step of the study, field visits were conducted during June–July 2021 in the Wilpattu, Ampara, Weli Oya, Mullaithivu, and Puttalam areas to select the sampling sites. Most of the responders encountered in the field visits, especially laymen such as farmers, mainly considered only the crops they cultivated. Therefore, responders were chosen based on knowledge of rangeland and interest in wild animals. During the field visits, an attempt was made to collect information on the wild plants preferred by wild elephants. Further, elephant-repellent plants were also noted during the visits but were not included in the study. A list of 22 herbaceous plants that were found in different provinces of the country was considered (Samansiri & Weerakoon, 2007; Djufri &Wardiah, 2017; Chathura & Perera, 2017), and the plant list was validated through a literature survey (Samansiri & Weerakoon, 2007).

Further, selected plants were confirmed as forages using secondary data and the taxonomic identity of the plants was determined by consulting relevant literature such as Townsend (1980; Cramer, 1981); Koyama, 1985; Clayton, 1994; Pedley & Rudd, 1996; Alahakoon et al., 2017; Samansiri & Weerakoon, 2007; and Ashton et al., 1997).The study employed the survey method in collecting information. A questionnaire was prepared and validated by subject experts, piloted, and validated. The validated questionnaire was converted into Google Form, an E-Based survey tool since the prevailing pandemic condition of the country precludes the field survey (Tharangi et al., 2023). The Google form was disseminated through emails and social media and follow-up by telephone communication during October-December, 2021. The questionnaire included 22 items with a 6-point Likert Scale viz. 0 = Unknown/ Not in this region,1 = Weekly palatable, 2 = Mild palatable, 3 =Moderately palatable, 4 = Strongly palatable and, 5 = Intensely palatable, as shown in Table 1(Joshi et al., 2015) and further responder's ratings of the Likert scale were converted into the scores by using weighted mean formula (Equation :1).

Table 1. Likert scale with responses.

Response	Scale
Intensely palatable	5
Strongly palatable	4
Moderately palatable	3
Mild palatable	2
Weekly palatable	1
Unknown/ Not in this region	0

An additional survey was also conducted from July 2021 to August 2021 to evaluate the questioner and assess errors and avoid confusion among respondents since rangers of the Wild Life Conservation Department and ecologists were interviewed from different regions of the country to make a list of-preferred herbaceous plant species by wild elephants (Alahakoon et al., 2017; Samansiri & Weerakoon, 2007; Gorade & Datar, 2014). Since the names of plant species are region-specific, the questionnaire was modified by attaching photographs of relevant plants, and vernacular names of each plant species were inserted into the questionnaire after getting feedback from most respondents. The data gathered through the survey was explored for errors and was subjected to descriptive and inferential statistical analysis. The responses to the items, except for zero values, were transformed into scores according to Equation (1) (Clark-Carter, 2010), and these scores were further converted into percentile values (Bodenham & Adams, 2016). The frequency distribution, mean, and standard deviation were calculated for the dataset. Further, analysis of variance was carried out using one-way analysis of variance (ANOVA) to compare the means. All the calculations and analyses were done through SPSS software (PC Ver. 26, IBM, 2019).

$Weighted\ Sum = \sum_{i}^{n}(xi * wi)$ - Equation (1).

Where,

*w*i = Weight assigned to the indication (Scale of Palatability Level)

*x*i = Number of responses for each indication (Field experts) (Clark-Carter, 2010)

RESULTS

The study included eight provinces of the country, and the common herbaceous plants grown in each province are listed in Table 2. The chosen list of plants includes 5 sedges, 3 herbaceous, and 14 grasses from different island provinces.

Table 2. Selected plant species and their families, with scientific names followed by common vernacular names.

Scientific Name	Family	Vernacular name §	Plant Type
Achyranthes aspera L.	Amaranthaceae	Gas Karalheba	Herb
Schoenoplectusgrossus (L.f.) Palla	Cyperaceae	Thunhiriya	Sedge
*Cyperus haspan*L.	Cyperaceae	Halpan	Sedge
Cyperus iria L.	Cyperaceae	Thunessa	Sedge
Cyperus rotundus L.	Cyperaceae	Kalanduru	Sedge
Fimbrisstylis miliacea (L.) Vahl	Cyperaceae	Mudu halpan	Sedge
Alysicarpus vaginalis(L.) DC	Fabaceae	Aswenna	Herb
Echinochloa colona(L.) Link	Poaceae	Gira thana	Grass
Echinochloa crusgalli(L.) Beauv	Poaceae	Wel marakku	Grass
Eleusine indica (L.) Gaertn.	Poaceae	Bela thana	Grass
Imperata cylindrica (L.) Beauv	Poaceae	Illuk	Grass
Isachne globose (Thunb.) Kuntze	Poaceae	Batadella	Grass

*Ischaemum timorense*Kunth	Poaceae	Rila thana	Grass
*Leersia hexandra*SW	Poaceae	Layu	Grass
*Panicum maximum*Jacq.	Poaceae	Gini thana	Grass
*Panicum repens*L.	Poaceae	Etora (Atawara)	Grass
*Echinochloaglabrescens*Kossenko	Poaceae	Bajiri	Grass
*Iachaemum rugosum*Salisb.	Poaceae	Gojarawalu	Grass
*Pennisetum purpureum*K. Schumach.	Poaceae	Ali maana	Grass
Sacciolepis interrupta(Willd.) Stapf	Poaceae	Beru	Grass
Dactyloctenium aegyptium(L.) Willd.	Poaceae	Putu thana	Grass
Bacopa monnieri(L.) Pennel	Scrophulariaceae	Lunuwila	Herb

§ - Sinhala

Present study limited the number of plant species due to available time, resources, labor and secondary data. The results obtained from the analyses were presented under the following themes: descriptive and inferential statistics.

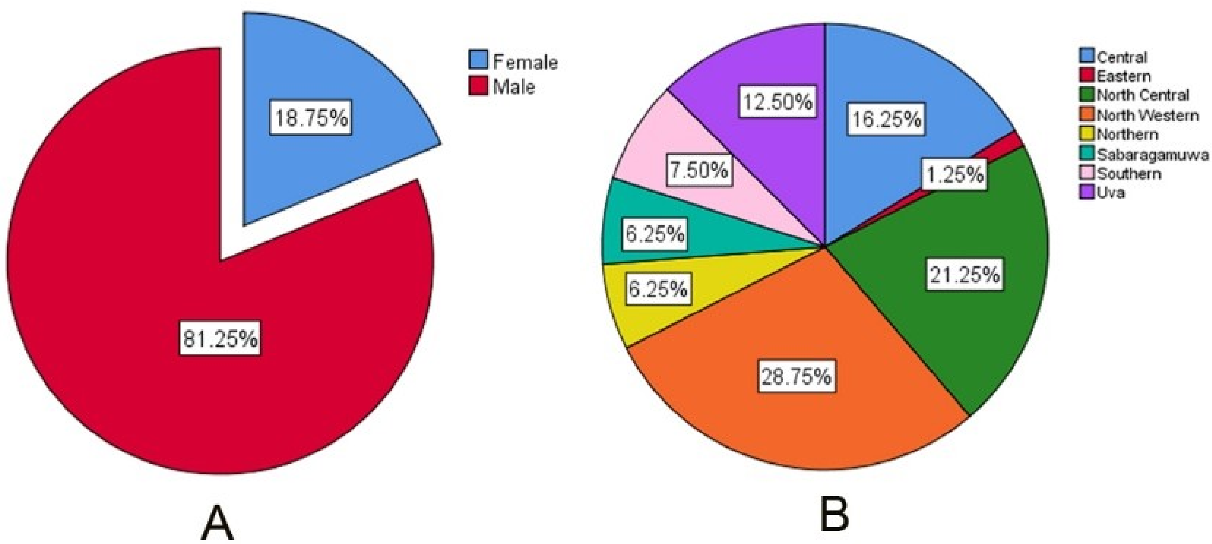

Figure 2. Distribution of responders' gender (A) and province (B) within the sample.

The distribution of gender in the total sample and the distribution of respondents by provinces are shown in Fig. 2, A, and B. Gender distribution in the total samples indicated less female participation (18.8%) in the field survey. In contrast, the majority of respondents were male (81.3%). The majority of responders were represented from the North Western Province (28.7%), North Central Province (21.3%), and Central Province (16.3%). The rest of the provinces were more or less equally represented in the sample and varied from 1.3% to 7.5%.The distribution of plants and their palatability levels in the different provinces is shown in Fig. 3 which represents the information in a dual-axis graph summarizing the variation of the palatability of plant species across different provinces.

According to the figure, there were certain plant species, such as *Sacciolepis interrupta* (Beru), which were highly preferred by wild elephants in the provinces, such as Eastern and North Central Provinces. Further, the plant's palatability level variation in the Southern and Sabaragamuwa Provinces is considerably lower than that of the rest of the provinces. Meanwhile, discernible within-province variation in the palatability level of the plant was also observed in the plants included in the study. Thus, plant palatability levels indicate a noticeable spatial variation across the provinces in the country.

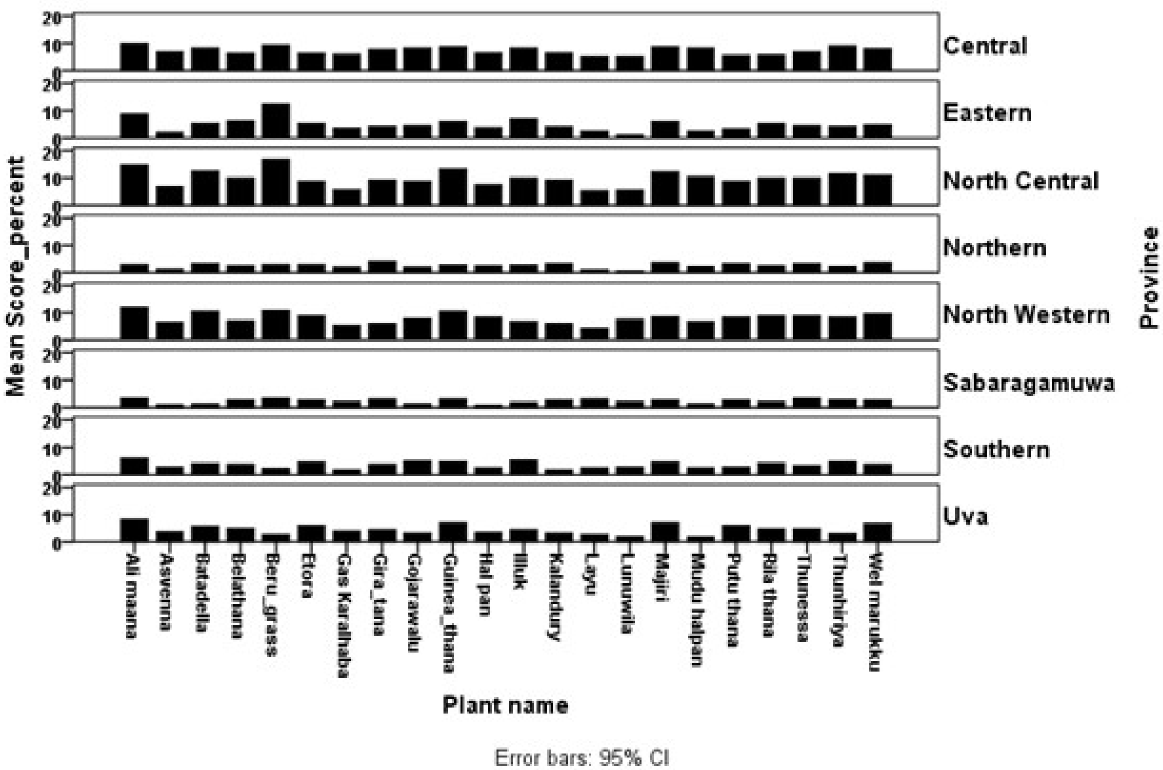

Figure 3. Distribution pattern of palatability level (Mean Score_percent) of plants by provinces.

The information in a dual-axis graph is represented in Fig.3 that summarizes the variation of the palatability of plant species across different provinces.

The distribution of the mean palatability score (expressed as %) among the plant species is shown in Table 3. The mean palatability scores of *Pennisetum purpureum* (Ali maana), *Sacciolepis interrupta* (Beru), and

Panicum maximum (Gini thana) were 8.22%, 7.5% and 7.0%, respectively. The mean palatability of a sub-set of plants, which included *Echinochloa glabrescens* (Bajiri), *Isachne globosa* (Batadella), and *Echinochloa crusgalli* (Welmarukku), fell within the mean palatability range of 6.6% - 6.25%. The mean palatability of *Imperata cylindrica* (Illuk) and *Schoenoplectus grossus* (Thunhiria) ranged from 5.78% to 5.72%. The rest of the fodder plants indicated low palatability percentages (4.56% -3.31%).

Table 3. Shows the averaged percentage palatability score among the elephant fodder plants collected in the study.

Plant name	Mean (%)	Std. Error
Pennisetum purpurerium (Ali maana)	8.22	1.44
Sacciolepis interrupta (Beru)	7.53	1.94
Panicum maximum (Ginithana)	7.00	1.30
Echinochloa glabrescens (Bajiri)	6.66	1.12
Isachne globose (Batadella)	6.34	1.35
Echinochloacrusgalli (Wel marukku)	6.25	1.08
Imperata cylindrica (Illuk)	5.78	0.98
Schoenoplectus grossus (Thunhiriya)	5.72	1.21
Panicum repens (Etora)	5.63	0.83
Cyperus iria (Thunessa)	5.56	0.94
Eleusine indica (Belathana)	5.41	0.90
Ischaemum timorense (Rila) thana	5.41	0.98
Echinochloa colona (Gira thana)	5.34	0.76
Iachaemum rugosum(Gojarawalu)	5.09	1.02
Dactyloctenium aegyptium (Putu thana)	5.03	0.88
Cyperus rotundus (Kalanduru)	4.56	0.88
Fimbrisstylis miliacea (Mudu halpan)	4.47	1.24
Cyperus haspan (Halpan)	4.41	0.95
Alysicarpus vaginalis (Asvenna)	3.84	0.88
Achyranthes aspera (Gas Karalhaba)	3.78	0.62
Leersia hexandra (Layu)	3.31	0.53
Bacopa monnieri (Lunuwila)	3.31	0.88

The variation of the average percentage palatability score across the type of elephant fodder plant is depicted in Fig. 4. According to the figure; the grasses surpass the rest of the plant types by having the highest palatability score (63.64%). The lowest palatability score was observed for the herbs (13.64%), and the palatability score of the sedges falls between the grasses and sedges.

The summary of the ANOVA is presented in Table 4. It indicates that there were significant differences in palatability scores (expressed as %), with the F-value associated with higher statistical significance ($F = 51.445$, $p < 0.05$).

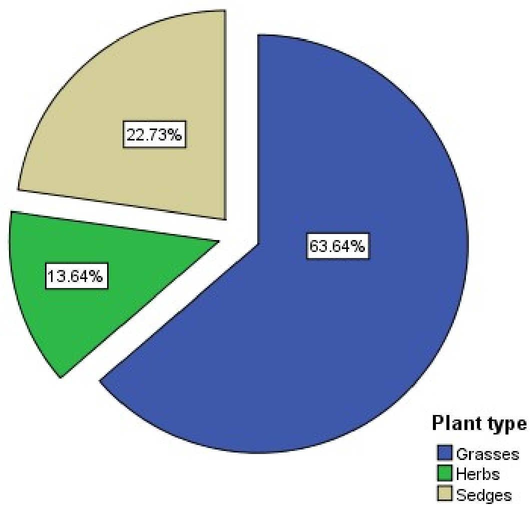

Figure 4. Variation of the palatability scores across by the plant types.

However, the plant variation was statistically insignificant ($F= 1.452$, $p > 0.05$).

Table 4. Summary of the Analysis of Variance (ANOVA) performed on the palatability levels across the provinces and plant species.

	Sum of Squares	**df**	**Mean Square**	**F ratio**	**Sig.**
Province					
Between Province	1158.568	7	165.510	51.445	0.000
Within Province	540.497	168	3.217		
Total	1699.065	175			
Plants					
Between plants	280.87	21	13.375	1.452	0.103
Within plants	1418.195	154	9.209		
Total	1699.065	175			

The sample included a higher number of male responders (81%) and a considerably lower number of female responders, and this may be due to the poor female participation in the workforce in the fieldwork in wildlife-related professions (Prakash et al., 2021). The difference between the responses and the gender of the responders did not vary considerably across the samples. This may be due to the higher representation of males as field experts in the sample population. The number of responders possibly indicated the respective extent of the wildlife-protected areas included in the study. For instance, Southern, Northcentral, Central, and Uva provinces represented higher numbers of responders and were 20%, 21%, 16%, and 13%, respectively. The Western Province has not been considered since the province does not include wild elephant range areas. The selected plant list included twenty-two elephant fodder plants, representing 3 herbaceous, 14 types of grass, and 5 sedges, mainly occurring in secondary forests, grasslands, and wetlands in the seven provinces. As far as plant types are concerned, there was a considerable difference in their distribution. The higher occurrence of grasses (64%) compared to sedges (23%) and herbs (14%)was reported in the study. This could be attributed to the fact that the grasses can distribute a wider range of ecological conditions and are much more resistant to drought than the sedges. Further, grasses often grow in association with marshland and inland water bodies and are adapted to periodic emergence and disappearance with the water availability fluctuation(Le Roux & Bariac, 1998; Wilcox et al., 2021). The spatial distribution of these plants indicates an ecological provenance and the occurrence of certain plants, such as Sacciolep is interrupta (Beru), which is more or less confined to the wetland of the drier areas, and the invasive grasses such as naturalized Panicum maximum (Ginithana), as widely distributed in the island irrespective of the climatic conditions. Further, the emergence of the plant species included in the study is associated with the prevailing climatic condition of the island, and much of the sedges and grasses growing in the wetland and the inland reservoirs are disappeared during the droughts and reappear in the rainy periods (Nawaz et al., 2014). Therefore, the availability of certain plant species under consideration indicated a seasonality. Thus, there was a spatiotemporal variation in the abundance of elephant fodder plants across the provinces than in others (Table 4).

Based on the perceived palatability levels, the following plants can be placed in descending order of palatability: Pennisetum purpureum (Ali maana) (8.22%), Sacciolepis interrupta (Beru) (7.53%), Panicum maximum (Gini thana) (7.00%), and Echinochloa glabrescens (Bajiri) (6.66%) (Table 3). However, the palatability of plant species could vary, which is governed by the prevailing climatic conditions of the area under consideration. Previous studies also support this finding (Le Roux & Bariac, 1998); (Kagan et al., 2019).Thus, elephants inhabited different provinces of the different climatic regions of the country may depend on the available plant species under different climatic conditions (Nawaz et al., 2014).

Further, the availability of such plant species directly or indirectly affects the roaming of elephants, aggravating the HEC and other socio-economic grievances of wild elephants. In this preliminary study, based on the available time, resources, and labor, it was decided to limit the number of plant species. But, many hundreds of plant species serve as elephant forages in accordance with literature and survey studies. The findings of this study can be used as a bases-line for future studies with an increased number of forage plants. In addition, diversification of particular elephant fodder plant species would sustain the availability of fodder plants irrespective of the seasonal variation of the climate. For instance, a mixture of forage plants, including drought-resistant and submerge-resistant, would effectively maintain year-round fodder availability (Tharangi et al., 2022b). Thus,fodder plants' availability and palatability levels secure and sustain the grazing forage for wild elephants in Sri Lanka.

CONCLUSION

Even though Sri Lankan elephants feed on a variety of fodder plants, higher perceived palatability scores were observed for Pennisetum purpureum (Ali maana), Sacciolep is interrupta (Beru), Panicum maximum (Gini thana), and Echinochloa glabrescens (Bajiri). Since the perceived patentability score of the fodder plant species represents the opinion of the respondents, the laboratory analyses, as well as field analyses of the selected grasses for their functional types, chemical composition, physical properties, and the variation of these properties with the soil and climatic parameters, are of importance in the determination of elephant forage preferences.

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Impact of Electronic Media on Physical Development in Preschoolers in Sri Lanka: Parents' Perception in Kalutara District

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ABSTRACT

The impacts of electronic media on child development are mixed and beget benefits and vice versa. Home is the children's immediate environment; hence, parents' beliefs directly or indirectly impact the children's exposure to electronic media. The literature on parents' perception of electronic media by preschoolers and associated consequences is scantily in Sri Lanka. Thus, a study assessed the parents' views on preschoolers' electronic media use and its potential impacts. A piloted and validated questionnaire was administered online to a parent sample of 377 in the Kalutara district, and the data were subjected to frequency distribution and χ^2 analyses. The majority of respondents were (76.7%) from the rural sector, qualified with G C E (A/L) (45.6%), and 25.7% were unemployed. Sedentary behaviour, vision problems, and consumption of unhealthy foods resulting from electronic media use were rated negatively, reflecting the parents' awareness of the impacts except for feeding children while watching TV. Parents' neutrality in rating implies the unawareness of the impacts of electronic media on child development. Despite the weak associations among the parent's ratings with demographics, parents were well aware of the impacts of electronic media on the physical development of children. There is a need to implement strategies to build awareness among parents on the impacts of electronic media on child development. Further studies are required to establish the real impact of electronic media on child development and correlate parental perceptions.

Keywords: Child development, Electronic media, Impacts, parents' perception, Physical development,

INTRODUCTION

Electronic media has been defined as "Any means of communication requiring users to employ electromagnetic devices, whether analogue or digital (typically in contrast to print-based media)" (Chandler and Mundy, 2022, pp. 407-408). The development of communication technology and the associated infrastructural facilities led to the reach of electronic media surpassing all the limits of geographical barriers and becoming a part of everyday life for each child in rural or urban settings (Buckingham, 2013). At present, electronic media become an indispensable commodity in human life. Comparatively, all inventions cannot be considered benevolent since they have drawbacks (Smil, 2006). Therefore, electronic media negatively and positively affects users regardless of gender, age, and educational background (Medoff & Kaye, 2016). However, adults can choose between electronic media's good and bad effects because of their age-related experiences. It is a well-known fact that the use of electronic media by adults in the family can expose children to the background screen (Benedetto & Ingrassia, 2020). However, the gravity of the effects of electronic media use on preschoolers has been the focus of recent research (Ray & Jat, 2010).

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Most studies on electronic media's impact on the child have focused on each domain of the child's development (Wartella *et al.,* 2005). The child's development's physical domain encompasses gross and fine motor skills; any impact on these components results in developmental anomalies. Electronic media's impact can affect the child's development (Webster *et al*., 2019). The impact of electronic media on child development may be mixed, and many researchers have pointed out that electronic media brings benefits and *vice versa* (Stiglic *et al*., 2019). The home is the children's immediate environment, and adults' electronic media usage and beliefs directly or indirectly stimulate the children's electronic media usage (Domoff *et al.*, 2019; Beamish *et al.*, 2019; Arabiat *et al.*, 2022). Though the literature on electronic media use among preschoolers is limited in Sri Lanka, Manukulasooriya (2019) studied the parents' and teachers' views on the usage of electronic media and its possible impact on the lives of children and concluded that the majority of parents believe electronic media exposure benefited the children. Recent studies on electronic screen devices have shown that 96 % of preschoolers use electronic screens, and above 60 % are overexposed to the screens (recommended daily upper limit of one hour) (Liu *et al.*, 2021). Higher paternal education, maternal employment, and being the only child were significantly associated with electronic screen device use. However, there were gaps in the knowledge of electronic media usage and its impact on the child's physical development in Sri Lanka. Further, the parent's perception of the impact of electronic media on children would play a critical role in implementing awareness-building programs, recommending suitable intervening measures, etc.

Therefore, this study was conducted to determine the parents' perception of Sri Lankan children's use of electronic media and its effect on the physical development of preschool children.

METHODOLOGY

The study's target population was parents of preschool children in the Kalutara district of Western Province. There are 1,045 preschools in the Kalutara district, where 27,041 children aged 3-5 years are attended. Of those, only 763 were registered with the Provincial Council for preschool education (National Census of Early Childhood Development Centers in Sri Lanka, 2016). Thomas (1996) argues that it is essential to define the target population and ensure that the selected sample is representative of it. Krejci-Morgan (1970) calculated the parental sample size, resulting in 377 randomly selected parents.

The present study used a survey method to collect data and included a piloted and validated questionnaire consisting of 10 indicators with a 5-point Likert scale. Additionally, the questionnaire included demographic information of the parents. A sample of 55 randomly selected respondents completed the pilot survey. The correlation between the indicators then validated their responses, and the indicators of the physical domain showed a statistical significance of $p < 0.05$ and established a high correlation among the indicators. Internal consistency was measured by Cronbach's alpha test, which was performed for the pilot data and showed that the overall Alpha value of the study was 0.831, greater than the accepted value of 0.7 (Tavakol and Dennick, 2011). The translated questionnaire was converted into Google Forms and administered to the parents chosen for the study. Descriptions of the indicators and their codes used in the study are presented in Table 1.

Table 1. The codes and description of indicators in the physical domain of the child's development.

Codes	Description
PPD1	Most children engage in outdoor play activities learned from TV programs/computers or smartphones.
PPD2	Most children do not engage in play activities with peers and siblings since they want to watch TV or use a computer/smartphone.
PPD3	I think electronic media (TV, computer games, or smartphones) has substituted children's play activities.
PPD4	It is easy to feed children when they watch TV.
PPD5	Most children skip meals to watch TV programs or play games using computers/smartphones.
PPD6	Sitting in one place using electronic media (TV, computer, or smartphone) for long hours causes childhood obesity.
PPD7	Advertising non-nutritious foods on TV/computer increases children's unhealthy food consumption.
PPD8	Advergames in the form of TV and the internet advergames promote the consumption of unhealthy food.
PPD9	Electronic media (TV, computer, or smartphone) interfere with children's healthy sleep habits.
PPD10	Excessive use of electronic media (TV, computer, or smartphone) causes vision problems.

A database was developed using the responses from received Google forms, which were examined for entry errors and missing data. Furthermore, the responses "Strongly disagree" and "Disagree" were combined and given the label "Disagree," and the responses "Agree" and "Strongly agree" were combined and given the label "Agree." Further, "neutral" and "no response" were merged and presented under the "Neutral category. The frequency distribution of demographic and parents' responses was performed, and the χ^2 test was used to assess the association between the demographic attributed and the responses.

RESULTS AND DISCUSSION

The demographic profile of the parent sample is shown in Table 2, according to which the majority of respondents were (76.7 %) from the rural and a small fraction of urban respondents (23.3 %) represented the urban sector. According to the educational qualifications, G C E (A/L) dominated the other categories (45.6 %). The majority of responders (25.7 %) were not employed, and the rest of the responders represent employed in different professions. Of the responders included in the sample, 80.6% were female. The results show that most preschools are located in rural areas. The sample of respondents thus reflects the country's general trend in the rural population (Ritchie & Roser, 2018).

Similarly, the distribution of responders' educational qualifications reflects the general trend of the nation (UNESCO- Institute for Statistics, 2023). Since most rural females in Sri Lanka did not participate in the labour force, there was a substantial percentage of unemployed parents in the sample (Samarakoon & Mayadunne, 2018). According to a general trend, most males stay out of child-related matters, especially those involving younger children, and women are inevitably responsible for these responsibilities (Boserup *et al.*, 2013). It might be because most men had occupations and could not find the time to attend preschool children's related activities.

Table 2. The demographic profile of the parents included in the sample from Kalutara District.

Indicator	Response	Frequency	%
Location			
	Urban	88	23.3
	Rural	289	76.7
	Total	**377**	**100**
Educational Qualification			
	Primary	12	3.2
	Secondary	24	6.4
	G C E (O/L)	71	18.8
	G C E (A/L)	172	45.6
	Graduate	58	15.4
	Postgraduate	40	10.6
	Total	**377**	**100**
Occupation			
	Manager	24	6.4
	Professional	58	15.4
	Technicians and Associated Professionals	22	5.8
	Clerical Support Workers	53	14.1
	Service and Sales Workers	29	7.7
	Skilled Agricultural, Forestry, and Fishery Workers	12	3.2
	Craft-related Trades Workers	26	6.9
	Plant and Machine Operators and Assemblers	29	7.7
	Elementary occupations	17	4.5
	Armed Forces	10	2.7
	Unemployed	97	25.7
	Total	**377**	**100**
Gender of the Responder			
	Father (Male)	73	19.4
	Mother (Female)	304	80.6
	Total	**377**	**100**

The summary of the responses of "Agree/Disagree" and "Neutral" across the indicators of the physical domain (Table 3) indicated that a considerable number of responders were neutral, possibly due to the avoidance of cognitive affording, ambivalence or social desirability ranged from 16.18 % for indicator

PPD10 and 38.2 % for the indicator PPD1 (Edwards & Smith, 2014). While the responses of "Agree/Disagree" ranged from 61.80 % for PPD1 and the highest for the indicators PPD10 (83.82 %). This pattern of responses reflects that most parents are well aware of the potential effect of electronic media on their child's development. This discrepancy could be attributed to the parent's attitude toward electronic media and their understanding of the impact on the child's development (Vittrup *et al.*, 2016).

Table 3. Distribution of responses of "Agree/Disagree" and "Neutral" across the indicators of the physical domain within the sample population of the Kalutara District.

Indicator	Agree/Disagree		Neutral		Total	Percent
	Frequency	Percent	Frequency	Percent		
PPD1	233	61.80	144	38.20	377	100
PPD2	268	71.09	109	28.91	377	100
PPD3	260	68.97	117	31.03	377	100
PPD4	255	67.64	117	31.03	377	100
PPD5	260	68.97	117	31.03	377	100
PPD6	279	74.01	98	25.99	377	100
PPD7	258	68.44	119	31.56	377	100
PPD8	261	69.23	116	30.77	377	100
PPD9	299	79.31	78	20.69	377	100
PPD10	316	83.82	61	16.18	377	100

Summary information on parental perceptions of the indicators of the physical domain is presented in Table 4 and Figure 1. According to parents’ responses, television programs /computers or smartphones (PPD1), a majority believed that a positive effect on children's motivation to play outdoors contributes to the child's development. Conversely, most parents believe that many children do not play games with their peers and siblings because they want to watch TV or use a computer/smartphone (PPD2). Thus, parents believe that television or computer/smartphone use negatively impacts their children's growth. Similarly, most parents felt that electronic media (television, computer games, or smartphones) had replaced children's play activities (PPD3), excluding children from outdoor activities. However, most parents recognize that feeding their child while watching TV (PPD4) is easy and believe this positively affects their child's physical development. The parents' responses indicate that children skipping meals to watch TV programs or playing games using computers and smartphones (PPD5) negatively affect a child's physical growth. The children's sedentary behaviour results from sitting in one place using electronic media (TV, computer, or smartphone) for long hours causes childhood obesity (PPD6) is positively rated reflect the parents' awareness of the lack of physical activities and its negative contribution to the healthy growth of a child (Rodriguez-Ayllon *et al.*, 2019). Most parents agree that advertising non-nutritious foods on TV/computer increases children's consumption of unhealthy food (PPD7) and that these advertisements negatively affect physical development.

Further, parents believe that advergames in the form of TV and the internet advergames promote the consumption of unhealthy food (PPD8) and negatively impact the physical development of their children. As far as sleeping baits are concerned, the majority of parents are of the opinion that Electronic media (TV, computer, or smartphone) interfere with children's healthy sleep habits (PPD9), and excessive use of electronic media causes vision problems (PPD10). In summary, among the ten indicators of the physical domain of the child the development, indicator PPD4, parents' belief in the ease of feeding children while watching TV is a poor precedent (Vittrup *et al.*, 2016). Further, though there are skepticisms on electronic media use by children, parents believe that exposure to electronic media is essential to develop skills that enable them to keep pace with ever-expanding technologies (Lenhart *et al.*, 2001; Rideout *et al.*, 2003; St Peters *et al.*, 1991; Woodard & Gridina, 2000).

Table 4. Details of the Parents' rating of the indicators of the physical domain of the child's development.

Indicator	Response	Frequency	Percent	Contribution
PPD1	Disagree	54	23.18	Negative
	Agree	179	76.82	Positive
PPD2	Disagree	152	56.72	Negative
	Agree	116	43.28	Positive
PPD3	Disagree	169	65.00	Negative
	Agree	91	35.00	Positive
PPD4	Disagree	121	47.45	Positive
	Agree	134	52.55	Negative
PPD5	Disagree	136	52.31	Positive
	Agree	124	47.69	Negative
PPD6	Disagree	93	33.33	Positive
	Agree	186	66.67	Negative
PPD7	Disagree	87	33.72	Positive
	Agree	171	66.28	Negative
PPD8	Disagree	83	31.80	Positive
	Agree	178	68.20	Negative
PPD9	Disagree	81	27.09	Positive
	Agree	218	72.91	Negative
PPD10	Disagree	32	10.13	Positive
	Agree	284	89.87	Negative

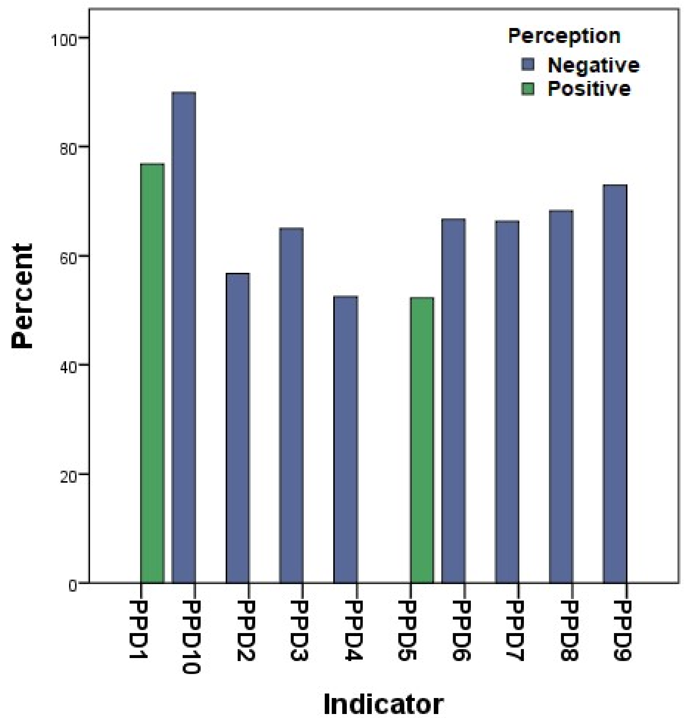

Figure 1. Distribution of parents' rating of the indicators of the physical domain of the child's development.

The association between the parents' ratings of the indicators of the physical domain of the child's development is shown in Table 5. As far as the sector of the parents is concerned, the rating for PPD1, PPD8, PPD9, and PPD10 differed significantly ($p < 0.05$); this may attribute to the fact that parents in rural setups have not been informed about the adverse physical consequences of the electronic media and the in the urban set up it may be due to the limited space for children to engage in physical activities. The association between the responders' and the rating of the indicator PPD9 indicated a significant association ($p < 0.05$), which may indicate the responders' gender composition in which female was highly dominant over the male. The association between the responses and parents' educational qualification and for the indicators PPD1, PPD9, and PPD10 were statistically significant at $p < 0.05$. This discrepancy may be attributed to the level of education and the associated knowledge of the parents' children's needs for physical activities for healthy growth. Similar observations were made for the relationship between electronic media and their effects on children's sleep and vision problems concerning the parent's occupation ($p < 0.05$).

Table 5. Association between the parents' ratings of indicator of the physical domain of the child development by sector, gender, educational qualifications, and profession.

Indicator	Sector			Gender			Educational Qualification			Profession		
	Chi-Square	df	Sig.	Chi-Square	df	Sig.	Chi-Square	df	Sig.	Chi-Square	df	Sig.
PPD 1	6.997	1	0.008	1.547	1	0.214	11.371	5	0.045	9.749	10	0.463
PPD 2	0.016	1	0.900	0.356	1	0.551	4.043	5	0.543	16.019	10	0.099
PPD 3	0.024	1	0.876	0.251	1	0.616	3.819	5	0.576	10.189	10	0.424
PPD 4	1.208	1	0.272	0.208	1	0.649	3.768	5	0.583	13.257	10	0.210
PPD 5	0.261	1	0.610	0.003	1	0.954	6.661	5	0.247	7.2070	10	0.706
PPD 6	1.128	1	0.288	0.805	1	0.370	5.916	5	0.314	14.329	10	0.159
PPD 7	0.958	1	0.328	0.046	1	0.830	4.686	5	0.455	15.028	10	0.131
PPD 8	6.955	1	0.008	0.106	1	0.744	5.226	5	0.389	16.544	10	0.085
PPD 9	8.254	1	0.004	9.609	1	0.002	15.049	5	0.010	21.354	10	0.019
PPD 10	6.392	1	0.011	0.548	1	0.459	11.862	5	0.037	21.398	10	0.018

CONCLUSION

Most parents are aware of the impact of electronic media on children's physical development, which is an objective of the study. Many parents are neutral on the impact of electronic media on their children's physical development due to avoidance of cognitive effort, ambivalence, or social desirability. Most indicators were rated by parents, regardless of parental demographic background. as a reward for the child. Most indicators were more or less equally rated by parents, regardless of parental demographic background, indicating insignificant associations. However, a certain number of parents appreciated the ease brought by electronic media while feeding their children, which was used; the majority of parents appreciated the ease brought by electronic media while feeding their children as a reward for the child. Therefore, there is a need for parental awareness programmes/discussion sessions on the healthy use of electronic media for children.

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Wi-Fi fingerprint and pedestrian dead reckoning-based indoor localization with supervised learning

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ABSTRACT

The Global Positioning System is not suitable for indoor localization due to signal loss in enclosed environments. Hence, this research designed and developed a hybrid indoor localization approach by integrating the Wi-Fi fingerprinting approach with the pedestrian dead reckoning. Limitations of the Wi-Fi fingerprinting-based localization are compensated by the pedestrian dead reckoning approach which is implemented on the mobile platform. Supervised learning models such as artificial neural networks and K- nearest neighbors have been used to map offline and online datasets. The predicted locations obtained through the hybrid localization approach are compared with the true locations via Euclidean and Manhattan distance calculations. The results prove that the Wi-Fi Fingerprinting and Pedestrian Dead Reckoning together has given promising results for localization than using them alone.

Keywords: Wi-Fi, Indoor localization, Pedestrian Dead Reckoning, Artificial Neural Network, K-Nearest Neighbor

INTRODUCTION

The new trends in localization-based technologies and the cutting-edge technologies of ubiquitous computing have gained significant advancements today. Unlike in enclosed environments, the global positioning system (GPS) plays a vital role in outdoor environments. The satellite signals are broken due to the shadowing effect in indoor environments is the main problem which restricts the use of GPS inside(Yassin, 2017). Therefore, over two decades, indoor localization has been a vital topic for many researchers which address the insufficiency of global positioning systems for indoor environments.

Although a lot of studies have been done but have yet to develop a fully featured effective and accurate indoor positioning system (IPS). Indoor positioning has numerous applications, for example, giving indoor route frameworks to dazzle and outwardly hindered individuals, finding gadgets through structures, helping travellers in large unfamiliar places like mega malls, finding a crisis exit in a smoky climate, following children in packed places, etc. Indoor positioning applications might require different quality credits, and hence IPSs ought to be painstakingly chosen to meet the pre-defined need of the application. IPSs utilize various positioning components that change immensely concerning cost, accuracy, technology, adaptability, and security (Alarifi A.,et al., 2016).

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BACKGROUND

Some of the most often studied IPS technologies are; RFID, UWB , Infrared , Ultrasonic , Zigbee, Wi-Fi , Cellular Based , Bluetooth , Dead Reckoning, and Image-based Technologies (Obeidat, Shuaieb, & Obeidat, 2021).

Wi-Fi

Wi-Fi technology is selected as one of the localization methods in this research because Wi-Fi is: (1) can be accessed easily, (2) available at a low cost, (3) can be easily found in every building, (4) used in existing communication networks, (5) signals penetrate walls more than GPS. (6) existing networks cover more than one building. (7) most types of equipment are compatible and operate with Wi-Fi.

Wireless local area networks (WLANs) are now common in many places, including both homes and workplaces. These networks use variants of the IEEE (Institute of Electrical and Electronics Engineers) 802.11 standard, better known in the market as Wi-Fi. Wi-Fi stands for "wireless fidelity". These devices transmit using relatively low power in the ISM (industrial, scientific and medical) band at 2.4 GHz or 5GHz.(Malone & Malone, 2010) Wi-Fi is a high-speed internet connection and network connection without the use of any cables or wires. The wireless network is operating three essential elements that are radio signals, antenna, and router. The radio waves are keys that make Wi-Fi networking possible. (Elprocus, What is a WiFi Technology & How Does It Work?, 2023) Wi-Fi positioning is a positioning system that uses several techniques to locate a connected object or device. Wi-Fi location uses already existing infrastructure and Wi-Fi access points (APs) to calculate where a device is located. The device needs to be able to listen to the Wi-Fi AP but does not need to connect to it. Wi-Fi has a short range, but the signal can extend up to 150 meters. The accuracy generally depends on how many APs are nearby and the environment in which they are deployed. The more APs in a given area and the more precisely their position is known, the more accurate the location will be. (Jones, 2020)

RSSI (Receive Signal Strength Indicator) is an indicator and RSS (Receive Signal Strength) is the real value. Indicators mean it can be a relative value and RSSI is always a positive value and there is no unit for the RSSI. RSS can be easily obtained by common wireless devices (e.g., wireless sensors, mobile phones) without additional hardware. However, RSS are apt to be affected by indoor environments, since radio signal is easily reflected, refracted, and scattered by various indoor objects. Many RSSI purification technologies are widely used in many studies to cancel the error. Such filters are the Gaussian filter (Wang, Hwang, Peng, Park, & Park, 2021), Kalman filter(Lee, Lim, & Lee, 2016), and particle filters(Shen, Hwang, & Jeong, 2020) are typically designed to mitigate either linear or non-linear noise through smoothing.

RF values are always told in dBm and the values are negative values most of the time. Both dBm and RSSI represent signal strength where RSSI is a relative index, while dBm is an absolute number representing power levels in mW (milliwatts). RSSI is a term used to measure the relative quality of a received signal to a client device but has no absolute value.

RSSI-based indoor positioning using WLAN can be categorized into three: Trilateration, Approximate perception and Fingerprinting.

Trilateration is a mathematical method used for determining the position of an object based on measurements of the distances between the object and three or more known reference points. In

indoor localization, trilateration is used to estimate the position of a device based on the measurements of the distances between the device and a set of reference points, such as beacons or access points. The trilateration process involves calculating the intersection of the spheres centred at each reference point and having a radius equal to the measured distance between the reference point and the device. The position of the device can then be estimated by finding the intersection of the spheres, which is typically done using iterative numerical methods. Trilateration is widely used in indoor localization due to its simplicity and robustness, and it can be combined with other techniques, such as Kalman filtering, to further improve the accuracy of the localization estimate(ilçi, Gülal, Alkan, & Cizmeci, 2015)(Din, Jamil, Maniam, & Mohamed, 2018). Triangulation is a mathematical method used for determining the location of an object based on measurements from multiple reference points. In indoor localization, triangulation is used to estimate the position of a device based on the measured angles between the device and a set of reference points, such as beacons or access points. The triangulation process involves using the angles and the known positions of the reference points to calculate the position of the device. This can be done by constructing a series of triangles between the reference points and the device and using trigonometric relationships to determine the position of the device. Triangulation is commonly used in combination with other methods, such as trilateration, to provide a more accurate estimate of the device's position. It can also be used in environments where distance measurements are unreliable, such as when there is interference from other devices or physical obstacles.
When the accuracy needed is not extremely high, the propagation model approach is generally easy to use and effective. However, due to wireless signal noise and interference from indoor impediments such as multi-storey floors, doors, and walls, it is still challenging to measure the distance properly using signal attenuation(Din, Jamil, Maniam, & Mohamed, 2018)(Javed, Khan, & Asif, 2019).

Fingerprinting is the most popular method of localization because of its high accuracy compared to other methods. It does not require line-of-sight measurements of APs, has low complexity, and gains high applicability in the complex indoor environment. Fingerprinting-based localization usually consists of two main phases: offline (training) and online (test)(Subedi & Pyun, 2017).

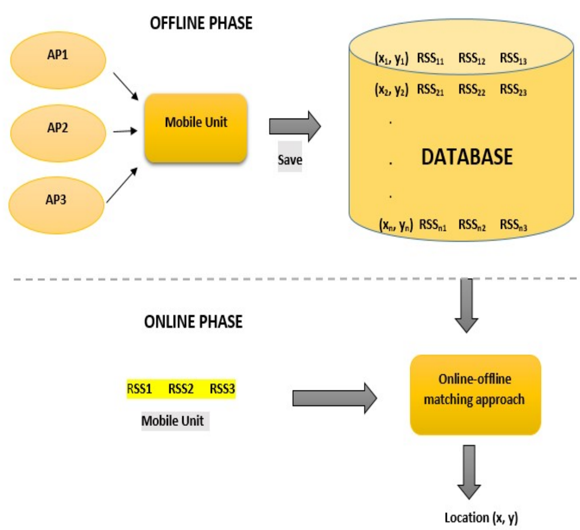

Figure 1. Two phases of fingerprinting-based localization

Offline phase-A radio map database is constructed in the offline phase by collecting the fingerprints at each location (reference points) which depends on the indoor map of the site. This fingerprint represents RSS readings from the Wi-Fi access points.

The majority of the currently accessible fingerprint database construction techniques are time- and labour-consuming. Due to the radio signal propagation impact brought on by environmental changes, the non-stationarity of Wi-Fi signal distribution poses a further hurdle that needs periodic fingerprint database updates to improve position prediction. It often takes surveying every reference point and recording fingerprints at each location to develop a Wi-Fi fingerprint database. By averaging the RSS at each reference point and providing a sense of orientation, this method enhances the dependability of a fingerprint database. However, if reference points must cover a large region and surveyors must manually label reference sites, this method is exceedingly labour- and time-intensive(Ahmad A. , Claudio, Naeini, & Sohn, 2020).

Another effort makes use of a crowdsourced fingerprint-gathering technique to reduce collection time to address this issue. Many techniques rely on sensors or input from outside sources. These outside sensors are expensive, challenging to set up and require constant upkeep(Zegeye, Amsalu, Astatke, & Moazzami, 2016).

Numerous studies have been conducted to speed up the site survey procedure(Zhuang, Syed, Li, & El-Sheimy, 2016)(Wang, Chen, Yang, & Chao, 2016). RSS prediction using interpolation or signal propagation modelling is one of the most often used techniques. Simultaneous Localization and Mapping, or Wi-Fi SLAM, is another well-liked method for building radio maps with cheap survey costs, but because of its high computing load, it is not suited for use on handheld devices with limited resources, such as smartphones. Intrusive/explicit user feedback is used in active crowdsourcing techniques to create a radio map. Although active crowdsourcing replaces the need for professional surveyors, it still requires user engagement and may be subject to deliberate deception. It has been suggested to use passive fingerprint crowdsourcing in place of active user participation. Using smartphone inertial sensors, passive crowdsourcing links fingerprints to relevant RPs. While passive crowdsourcing systems have made fingerprinting more realistic than before, they still have several drawbacks, including the necessity for GPS, a narrow range of applications, and poor accuracy(Gu, Ramezani, Khoshelham, & Zheng, 2020). Although many efforts have been made to decrease the labour and time needed to create a radio map, they have several drawbacks, including the need for active user engagement, being computationally expensive, having a limited range of applications, and having low accuracy.

Online phase-In this phase after constructing the radio map, the location of a mobile device inside a building is estimated by matching the online fingerprints of the mobile device with the corresponding fingerprints of the offline radio map database. Matching the database entries with dynamic RSS is performed using a positioning algorithm, which returns the approximate location of the mobile device. The approximated location is then displayed on an indoor map of the building which could be 2D or 3D.

Supervised Learning Methods

In the literature, several fingerprint localization algorithms have been proposed to find the best matching algorithm and try to improve the localization accuracy, many researchers propose the nearest neighbor (NN), K-nearest neighbor (KNN) (Torteeka & Chundi, 2014), weighted K-nearest neighbor (WKNN) (Shin, Lee, Lee, & Kim, 2012), Bayesian probabilistic model (BPM), and artificial neural network (ANN)(M. Zhou, 2010).

KNN

The k-Nearest Neighbor rule (k-NN) is a distance-based classifier which compares a current sample to all the labelled samples from a database. To select the K that's right for the collected data, the KNN algorithm was executed several times with different values of K and choose the K that reduces the number of errors encountered while maintaining the algorithm's ability to accurately make predictions.

ANN

ANN can be utilized for indoor positioning due to their robustness against noise and interference which are one of the major factors affecting the accuracy of IPS. The main advantage of using ANNs is that the system doesn't need prior awareness of the surroundings or noise distribution. A widely used ANN structure among modellers is the feed-forward back-propagation neural network. It is also considered one of the simplest and most general methods used for supervised training. The aim of this research is to perform indoor localization based on ANN using Wi-Fi fingerprint.

PDR for Indoor Localization

Pedestrian Dead Reckoning (PDR) is the process of calculating one's current location by using the previously known position and advancing that position over time using established or estimated speeds and trajectories (or stride lengths and directions) (Hou & Bergmann, 2017).

PDR is broadly embraced in the field of the pedestrian route with handheld gadgets such as mobile smartphones. It is specially adjusted to cell phone-based confinement as inertial sensors can be planned in a MEMS (Microelectromechanical Sensors) technology, empowering them to be implanted in lightweight gadgets(Yu, Na, Liu, & Deng, 2019). However, because of gyro float and step identification constraints, extra data is expected to help the PDR positioning cycle. For foot-mounted sensors, zero speed update (ZUPT) alignment is taken advantage of to change the positioning boundaries by identifying position stages inside the stride cycle (static stage), however, this adjustment is preposterous with handheld gadgets as a result of free hand movement and expanded trouble to distinguish the positioning stage.

Distance Matrices

Several distance metrics have been often used by researchers such as Euclidean(Wang S. , 2020), Manhattan (*Njima, et al, 2017*), Minkowski (*Jiang et al, 2020*), and Hamming (Mosleh *et al 2019*) distance. Out of these, both Manhattan and Euclidean distance methods are considered in this research**.**

Manhattan distance

Distance between two points in a grid-like path.

$d = \sum_{i=1}^{n} |x_i - y_i|$........................... Eq: 01(Gohrani, 2019)

Euclidean distance

This is the straight line distance between the two datapoints.

$d = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$........................Eq: 02 (Gohrani, 2019)

METHODOLOGY

Wi-Fi Fingerprinting based Localization

Fingerprinting is the most well-known strategy for Wi-Fi-based localization due to its high precision contrasted with different strategies. Fingerprinting-based localization is implemented in two stages: offline (preparing) and online (testing).

Stage 01: Offline phase

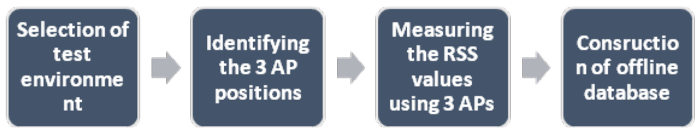

Figure 2. Process of the offline phase

Selection of test environment, identification of reference points and placements of APs

In this study, a vacant room with a dimension of 10m x 8m is selected as the test environment. The signal emitting from APs needs to be strong and steady. Therefore, the testing environment is selected such that it needs to be barrier-free and noise free for as much as it can. The layout of the experimental area with pre-defined reference points (RPs)and three APs is shown in figure 3. There are 25 reference points and each point was 1 m apart from the other.

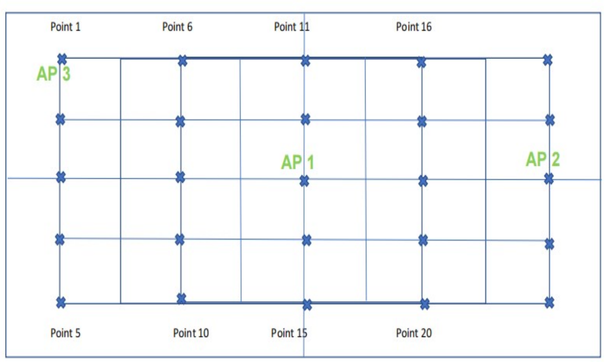

Figure 3. Experimental area including 25 reference points with 3 WAPs

In this study, indoor true locations are estimated based on the nearby outdoor GPS coordinates gained from Google Maps. First, mark the points which are outside the test area. Then, the GPS location reading corresponding to the outdoor points is obtained using Google maps. Next, the location measurements in line with the border and the middle of the test area are calculated. As the location coordinates latitude and longitude are provided by the GPS sensor. All these coordinates are converted to their respective (x, y) coordinates.

The actual coordinates of the test environment (12 points (in black) in the outer limit of the test environment) are calculated based on coordinates obtained by the Google map of outer points beyond the blue region (16 points (in blue) outside the structure of the building) as shown in figure 4.

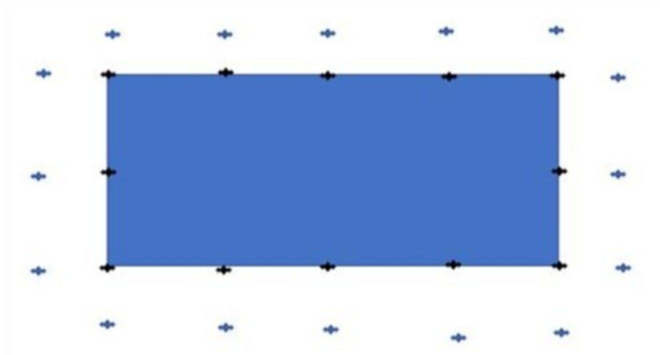

Figure 4. Calculations of true points based on Google map

Recording the RSS values and construction of the offline database

Once the coordinates of each reference point are gained the next task was to record the RSS values for the new test area with pre-defined names(labels). RSS values are calculated with the help of the Wi-Fi scanner smartphone application developed in this research as shown in the figure 8 and figure 9.The data is recorded 03 times per day, for 03 days using three APs.

There are many off-the-shelf applications are available to measure the Wi-Fi RSS in the indoor environment. However, most of the applications are unable to access more than one access point. Some smartphone applications are designed specifically for cellular networks and do not provide information about Wi-Fi networks. The accuracy of the information provided by some other smartphone applications depends on the quality and compatibility of the device's cellular hardware, which may not be reliable for all devices. The signal strength of a few applications can vary greatly in different locations and at different times, making it difficult to get a consistent measurement of network quality. Some mobile applications are typically designed to work with specific router brands and models, which means they may not be compatible with all routers. Therefore there is a need for a reliable, accurate scanner to measure more than 1 APs.

Development of a Wi-Fi Scanner Application

A high number of networks detected can indicate a congested wireless environment, which can lead to interference and slow performance. This can be particularly problematic in densely populated areas where many wireless networks are competing for the same bandwidth.

A smartphone application is developed to scan RSS of Wi-Fi signals indoors which provides details of the wireless networks in a specific area. The output of this app can provide information about the network's name (SSID), and signal strength. This app can detect the RSS of more than one AP available at a given time in the target area which is one of the key features when compared with the existing RSS readers which can provide the reading of only one AP.

The filtering option in a scanner allows network administrators to filter the results of a scan and display only the information that is relevant to their needs. This option can be particularly useful when a large number of wireless networks are present in an area, as it helps to simplify the results and make it easier to identify specific networks.

Another important aspect of the result of a Wi-Fi scanner is the signal strength of each network. The signal strength indicates the quality of the connection between the device and the network. A weak signal can indicate that the network is far away, or that physical obstructions are blocking the signal.

Android Studio is used to develop the application from the java language. The first step was to get all the available Wi-Fi SSIDs onto a listview. By using the Wi-Fi manager, available Wi-Fi was displayed on the listview. A button was created to send the required RSS value at the RP to the database. By using the button, the application can send only the required RSS value from AP to the reference point. The Android Runtime Permissions API is used to request permissions at runtime to handle the necessary user permissions to access the location and Wi-Fi state. Then the results can be displayed on the user interface, such as a list or a table, by looping through the scan.

Stage 02: Online stage

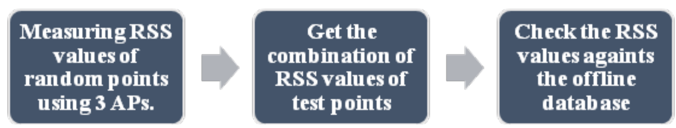

Figure 5. Online stage

According to figure 5, the online RSS values of a particular RPs are mapped against the offline database.

Selection of appropriate mapping method

ANN Model

The location of an object is determined by applying an ANN to map the real-time (online) measurements of RSS with the closest location that can be found in the radio map database (offline). In this work, a two-layer artificial neural network with gradient descent with a momentum back-propagation learning algorithm was used. The network configuration consists of three inputs from three access points and outputs with two neurons corresponding to the position of the user (x, y) and one hidden layer with ten neurons in MATLAB.

However, several shortcomings of Wi-Fi-based indoor localization are identified. The instability of RSS signals may be caused by people moving around, the material of objects inside the building, changing the order and arrangement of indoor furniture, and other disturbances such as other radio inferences, Bluetooth signals, etc. (Thewan, Ismail, Panya, & Terashima, 2016).Interference of Wi-Fi signals with other electronic devices, a limited range that may not penetrate walls or other obstructions, makes it difficult to locate devices in some areas of a building. The accuracy of the Wi-Fi signals degrades when the distance increase from the access points. Due to these reasons, the measurement accuracy of RSS signals is less. Therefore, there is a need of combining Wi-Fi-based localization with another localization technique.

Hybrid Localization

The proposed hybrid model as shown in figure 6, consists of Wi-Fi and PDR-based localization to upgrade the position exactness for indoor localization. Figure 6 shows the overall architecture of the proposed approach.

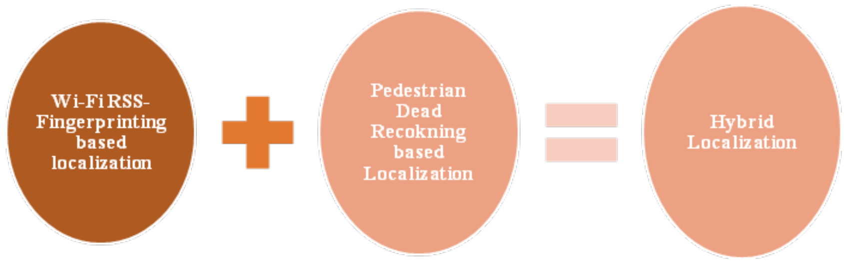

Figure 6. Proposed hybrid IP system.

PDR-based localization is implemented as a smartphone application. A walking person can monitor the step count from the source and the location coordinates of the current position. Moreover, this smartphone application can compare the position estimation of the PDR method along with the Wi-Fi method and ensures accurate localization. The user will be notified of his current location once the real-time coordinates tally with the offline coordinates of the Wi-Fi fingerprinting database. This smartphone application is personalized by including the age, height, weight and gender of the user which inturn assists to calculate the step count accurately.

Android Studio is used to develop this smartphone application along with the embedded motion sensors such as the accelerometer and attitude composite sensor in a smartphone. Based on the count and number of turns (to left or right) the PDR position is calculated. When the user is taking a turn the user needs to tilt the phone so the sensors could understand the change in the direction of the motion.

RESULTS AND DISCUSSION

Results Wi-Fi RSS Fingerprint-based Localization

Results of Wi-Fi Scanner

During the offline phase of the Wi-Fi fingerprinting, the RSS of each AP at a given reference point has to be stored in the database. The filtering options in a scanner include the ability to filter by network name (SSID), and signal strength as shown in figure 7.

The “Sort By” option in a WLAN scanner allows you to sort the results of a scan based on various criteria. This feature can be useful for quickly finding specific information or for analysing the data in a meaningful way. Some common “Sort By” options in WLAN scanners include SSID and strength of the signal as shown in figure 8.

The signal strength that we got to the list view was divided into five categories according to the quality levels of the Wi-Fi RSS. The colour codes are shown in table 1 corresponding to the dBm.

Figure 7. Filtered result

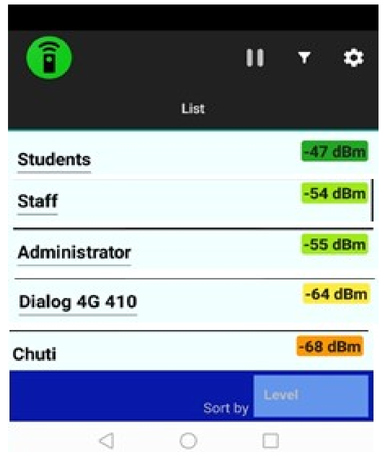

Figure 8. Sorted by level

Table 1. Signal strength vs color

dBm	Interpretation
-30dBm	Perfect Signal
-50dBm	Excellent Signal
-60dBm	Good Reliable Signal
-80dBm	Unstable Connection
-90dBm	Unlikely Connection

Figure 9. shows the location difference between the true location points and the predicted location points of a separate test set which consists of four random reference points. Arrows are points from true locations to predicted locations.

Figure 9. True vspredicted location points

It can observe that the length of the error line (arrow) is different from each other that is because of the fluctuations of the RSS signals.

Results of the ANN Model

The learning curve can determine the minimum required number of training trajectory samples and training epochs for the proposed ANN model. Figure 10 illustrates the relationship between the training and cross-validation errors vs. the number of running epochs. The number of running epochs is approximately 12.

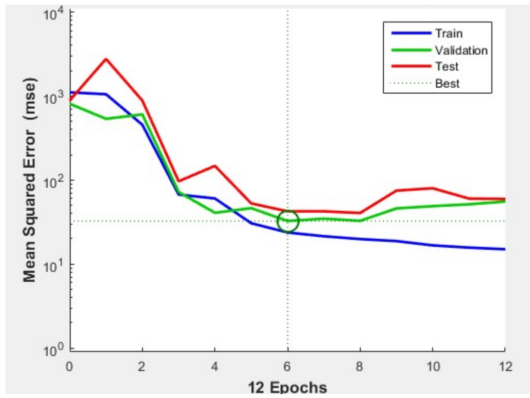

Fig. 10. Mean Squared Error vs. Epochs

The regression R-value measures the correlation between predicted locations and true locations. An R-value of 1 means a close relationship, and 0 is a random relationship. In this research 0.7996 of R is obtained which proves that there is an approximately close relationship between the true and predicted values.

Results of the KNN Model

In this experiment, the K value was kept on increasing from 1- 4 for each AP and check the way it affect the error.

Table 2. K value vs error

	K=1	K=2	K=3	K=4
Mean Absolute Error	1.0633	1.0433	1.2007	1.242
Root Mean Square Error	1.3785	1.3154	1.5434	1.653
Relative Absolute Error	26.1752	25.6829	29.5558	27.895
Root Relative Square Error	28.3402	27.0429	31.7305	31.847

After studying all these values, it is identified that the best value for K is 2 based on the reduction of errors.

Result of the Distance Matrices

By considering the gained values we calculated the following results:

- Mean Euclidean Distance: 3.067227636
- Mean Manhattan Distance: 3.356666667

Therefore, Euclidean distance matric performed well when compared with the Manhattan distance.

Results of hybrid localization

Individual factors such as age, height and weight are taken as inputs to personalize the smartphone application and to calculate the step count as shown in figure 11 (a). Whenever a user comes across a coordinate of a reference point a pop-up dialogue box will open and will notify the user of his current locationas shown in figure 11 (b).

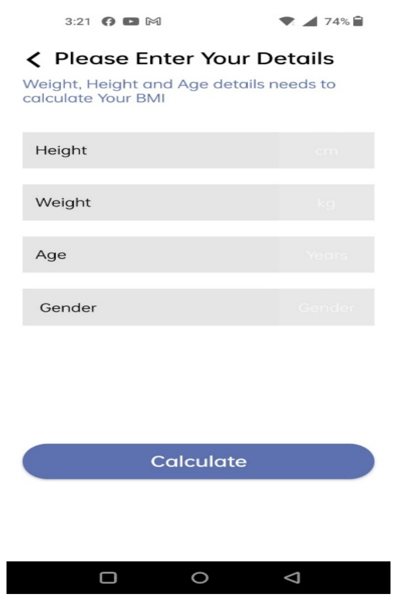

Figure 11 (a). Personalization UI

Figure. 11 (b). Step Count based on inertial sensor measurements

CONCLUTION

In this research, Wi-Fi and PDR are selected for indoor localization. Wi-Fi with RSS fingerprinting was used which was mainly implemented in two steps: online phase and offline phase. The smartphone application called WLAN scanner was developed to measure the Wi-Fi signal strength to build the offline training RSS database. KNN was implemented to match the offline and online phases of Wi-Fi RSS-based localization. Moreover, a feed-forward back-propagation neural network is developed and trained using the RSS measurements collected during the offline phase as the training data. ANN was tested against the test RSSI data collected during the online phase. PDR is the other localization used to fuse with Wi-Fi-based localization. The use of the smartphone to implement the PDR seems a better option as the smartphone itself comes with various useful inertial sensors. A novel app was developed which is capable to track the step count and the turns taken by the user to calculate the PDR. Both Euclidean and Manhattan Distance was calculated to benchmark the estimated hybrid localization points against the actual location points and Euclidean was selected as the best. Evaluation results were benchmarked against the same localization approaches in the literature. In the future, the proposed hybrid localization method can be further extended to create a map just like Google maps for the localization of unknown indoor locations such as airports, shopping malls, etc. Moreover, this app can be introduced to blind people if we could add voice feedback assistance in the future.

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1. Document to be submitted: Manuscript in MS Word format.

2. Format for typesetting
   - Paper size: A4 (210 x 297) typed single sided only.
   - Margins: Top, bottom and right margins of 25 mm and a left margin of 30 mm. 2
   - Line spacing: 1.5 (18 points) throughout the text.
   - Length: Length of the manuscript including text, tables, figures and references should not exceed 15 typed pages.
   - Page and line numbering: All pages should be sequentially numbered using Arabic Numbers. All lines should also be numbered sequentially starting from the top to the bottom of each page.
   - Font: Arial font, size 12. ! Language/spelling: UK English only.
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   - Title and running title (less than 25 Characters). They should be in bold faced letters
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   - Email address, mailing address and contact numbers of the corresponding author. Note: Identified the corresponding author by placing an asterisk after the name.

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   - Up to a maximum of the five (05) key word should be identified, arranged in alphabetical order, included immediately after the abstract.
   - Abstract should be typed in italics. Scientific names in the abstract should be underlined.
   - No reference, tables, or figures should be included in the abstract.

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   - Introduction: Justification of the research work, objectives and hypotheses should be included in the introduction.
   - Methods and Materials/ Methodology: All materials, chemicals, clinical, subjects and samples used should be identified. Analytical, survey and statistical method should be explained concisely. Common analytical methods need not be elaborated.
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   - Conclusions: Should be concise.
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   - SI units should be used.
   - A single space should be left between the numerical value and the unit.

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   - All acronyms should be written in full at the first time of appearance. Abbreviations can be used subsequently.

- The full stop should not be included in abbreviations. Where abbreviations are likely to cause ambiguity or may not be readily understood by readers, the units should be mentioned in full.

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