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Research in land use and land cover change: A bibliometric analysis

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ABSTRACT

Human-caused land use and land cover (LULC) changes have a significant impact on the Earth's climate and landscape. People have relied on nature and their land to survive throughout human history. This study presents a comprehensive bibliometric analysis of research in the field of LULC over a period spanning 45 years (1977-2021). This article aims to lay the groundwork for a focused research framework in LULC, guiding researchers and stakeholders towards addressing critical issues and advancing understanding in this vital area of study. Utilizing the Web of Science database, Bibliometric techniques and visual mapping were utilized to analyze 1,892 to assess research trends, contributions from countries and institutions, influential authors, and co-citation networks. Our findings demonstrate a significant growth in publications related to LULC, particularly since 2015, indicating a heightened focus on this field. Key contributors, including countries such as China, the United States, and Germany, were identified, along with their international collaborations. The most influential articles and authors were highlighted, shedding light on critical research themes. Additionally, co-occurrence and co-citation analyses provided insights into evolving research domains and the interconnectedness of scholarly work. This study not only enhances our understanding of LULC research dynamics but also lays the foundation for a focused research framework, guiding future endeavors in this vital area of study.

Keywords: Data visualization, Performance analysis, Science mapping, VOSviewer, Web of Science database

INTRODUCTION

Humans have relied on nature and their land to survive throughout human history. The land is a geographical area as well as a natural resource that provides numerous necessities for living. The diversity of land differs based on its cover layers and purposes that led to the formation of the concepts of "Land Use (LU)" and "Land Cover (LC)" (Dimyati et al., 1996). It's easy to misunderstand and even become confused when it comes to LU and LC due to their strong, inherent relationship (Montalván-Burbano et al., 2021). LC is generally defined as the observed biophysical cover on the Earth's surface. It encompasses flora, man-made structures, bare rock, bare soil, and inland water surfaces (Arveti et al., 2016), while LU refers to how humans have used land, usually with an accent on the functional role of land for economic activities (Rawat & Kumar, 2015). The LULC pattern of an area is the result of natural and socio-economic variables and man's use of them through time and space. Information on LULC and best usage options is critical for selecting, planning, and implementing land use plans to meet basic human needs. Human-caused LULC changes impact the Earth's climate and landscape (Arveti et al., 2016).

Human activities that cause LULC changes are primarily influenced by socioeconomic and environmental factors. Agricultural activities, resource mining activities, and urbanization all cause significant changes in LULC (Zhang et al., 2020). LULC changes cause several environmental problems including climate change (Ioannidou et al., 2021). LULC changes have an impact on climate processes. The LULC decision-making process influences human vulnerability to climate change (Halimi et al., 2018).

LU influences LULC changes affect land usage. LC changes resulting from land use may not always reflect the degradation of the land (Nguyen & Ngo, 2018). As a result of a wide range of social factors, LU patterns are changing, affecting biodiversity, water and radiation budget, emissions of gases, and other processes that contribute to the change of the climate and biosphere. Detecting changes in LULC over time is better to understand the landscape dynamics (Nguyen & Ngo, 2018). Anthropogenic and natural activities cause LULC change, which in turn affects natural ecosystems (Kamusoko & Aniya, 2007). Effective land management involves a deep understanding of landscape patterns, changes, and human-nature interactions. The natural environment is influenced by natural processes as well as human effects. The field of LULC change is rapidly evolving, encompassing multifaceted environmental, social, and economic dimensions (Rong & Fu, 2023). However, there is a lack of comprehensive bibliometric analyses that provide a systematic overview of the existing research landscape in LULC change. Additionally, there is a need to identify gaps in current research and propose a structured research framework to guide future studies. This research problem aims to address the aforementioned gaps by conducting a rigorous bibliometric analysis of existing literature in LULC change and formulating a cohesive research framework that can guide future research endeavors in this critical field.

A substantial number of publications presenting the most recent research accomplishments on LULC changes have been published in scientific journals, allowing the public to understand LULC changes better. To the researcher's knowledge, no study has analyzed all journal articles indexed in Web of Science in these domains on bibliometric analysis over a period as broad as the one included in this study. Therefore, the objective of this study is to conduct a comprehensive bibliometric analysis of research in the field of LULC change to assess current research trends, prominent contributors, and emerging themes. The overarching aim is to lay the groundwork for a focused research framework in LULC, guiding researchers and stakeholders towards addressing critical issues and advancing understanding in this vital area of study.

METHODOLOGY

Bibliometric analysis

Bibliometric analysis is a type of statistical research that uses data repositories to trace the structure and trend of growing knowledge (Liao et al., 2018; Oliveira et al., 2021). It is a form of quantitative analysis that describes, evaluates, and monitors published academic literature (Garfield et al., 1964; Lima & Bonetti, 2020; Liu et al., 2019). The use of bibliometric analysis has expanded beyond its initial application in library and information science to quantify scientific advancement in various domains (Chen et al., 2017). Initially, the purpose of the bibliometric technique was to evaluate academic achievement by counting the number of citations an author or organization received (Pritchard, 1969). However, it is frequently employed to explain the structure and growth patterns of the various domains of knowledge today (Lima and Bonetti, 2020). In recent years, bibliometric studies have become more prominent and a variety of research has used it to present novel perspectives on research trends. Bibliometric studies help readers understand current research progress and future research goals (Liu et al., 2019). In this study, two bibliometric techniques were used: performance analysis and science mapping. The performance analysis is involved with assessing the impacts of individual publications, countries, and affiliated institutions. Science mapping is a visual representation of a field to visualize its structure, subjects, and existing linkages with other disciplines (Donthu et al., 2021; Lima & Bonetti, 2020; Mulet-Fortezaet al., 2019; Singh et al., 2020).

Data source and processing

The WoS database was used to obtain data for this investigation as it is regarded as an important and widely accepted data source for bibliometric analysis (Chen et al., 2014, 2017; Liu et al., 2019). The keywords *land use chang**, *land cover chang** (chang*" can be *change*,*changes* or *land use changing*) were selected as search parameters in the "search field". From the "All field" drop-down menu, "Title" was selected. The data search on the WoS database was refined by selecting "article, review article and data paper" as a document type from "document types" as publications in journals are commonly used as an object of bibliometric analysis (Assis & Filho, 2019) and

"English" as a language from "language." This study's data ranges from 1977 to 2021. The search yielded a total of 3180 articles from the WoS database on December 31, 2021. As the researcher intended to use only articles published in the journals, other records were excluded. Thus, 1892 articles were incorporated in the bibliometric analysis instead of 3180 articles (Figure 1). With detailed descriptions and cited references, data entries from the WoS database have been exported to a tab-delimited (text) file as well as a comma-separated value (CSV) file for further analysis. The study results were validated using an online tool provided on the WoS database's Web page. VOSviewer (1.6.14) was used to visualize co-citation analysis, keyword, and co-occurrences. The WoS database was the sole source of data for this investigation. Therefore, there was little chance of data being duplicated or mistakes being made (Rana, 2020).

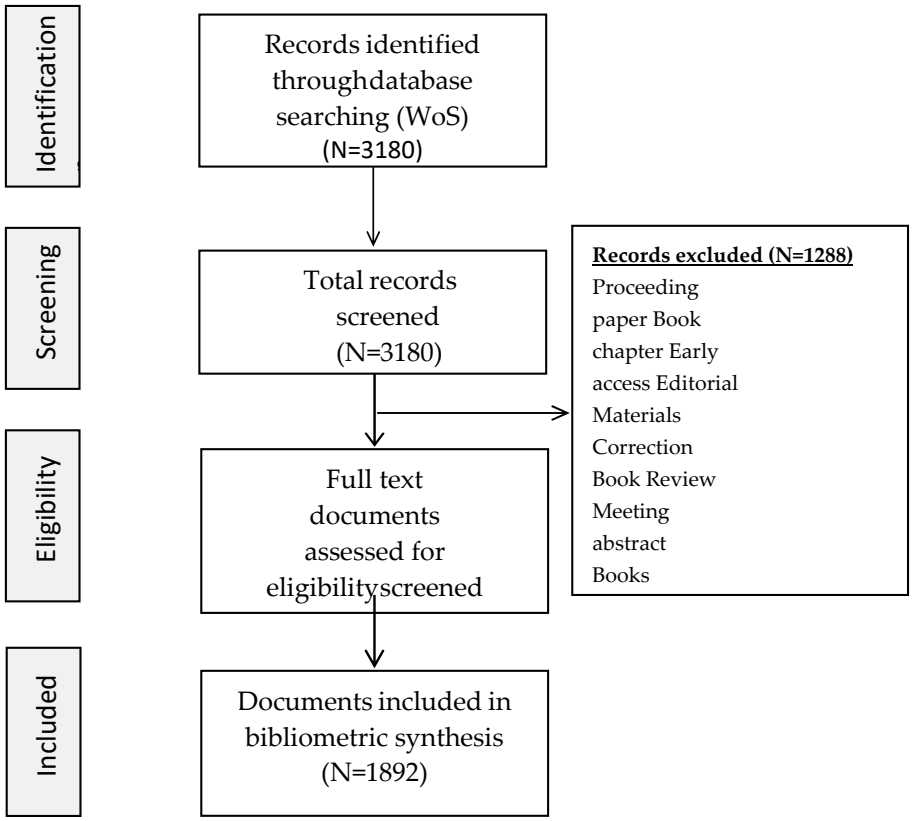

Figure 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram (Moher et al., 2009) for the systematic review of land use and land cover change

RESULTS AND DISCUSSION

Performance analysis

Overview of the scientific production

The number of papers published every year is a strong indicator for assessing the growth of a subject (Rana, 2020). Figure 2 depicts the growing pattern of LULC change-related research over the last 45 years (1977-2021). The intellectual structure of LULC change research includes 1892 articles with a total of 76,760 citations. The overall number of article publications related to LULC change has increased. In 1977, one article per year was published about the LULC change; by 2021, this had increased to 288 articles per year with an average of 6.4, indicating that the fields of LULC change have received significant attention, particularly in recent decades (2010-2020). Especially after 2015, many academics began to research LULC change. This increased the number of publications. Therefore, several research directions may be pursued, such as investigating new relevant topics, examining in greater depth previously understudied areas, or even attempting to address "classic challenges". Exploring foreign collaborations could also help to broaden the scope of the investigation. Figure 2 indicates that publications in LULC changed is increasing slowly until 2014. Since 2015, the annual number of articles has increased at an accelerating rate. The current trend indicates that publications on LULC change will continue to rise substantially. Several factors could have contributed to the rapid increase in publications such as the easy accessibility of satellite imageries after 2000 and the involvement of more researchers.

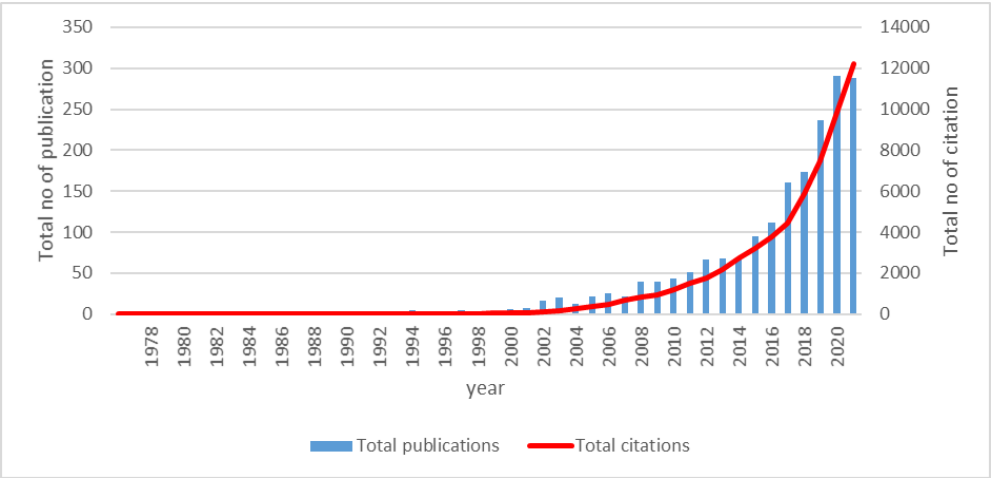

Figure 2. Distribution of articles and citations by years (1977-2021)

Figure 2 shows that the number of citations obtained per year was less than 100 until 2002. However, this number increased by more than 184 in 2003. The number of citations received has steadily increased from 291 citations in 2004 to 12242 citations in 2021. Several factors attributed to the steady increase of citations such as the increased recognition of the importance of LULC change in the context of environmental sustainability, climate change, and its impact on various ecosystems have driven more researchers and practitioners to cite relevant articles in their work (Xu & Xiao, 2022); The interdisciplinary nature of LULC research makes it relevant to a broader audience, resulting in more citations across diverse fields (Rong & Fu, 2023); Growing concerns about climate change, biodiversity loss, habitat degradation, and other environmental issues have increased the relevance and importance of LULC research. Scholars and practitioners frequently cite such studies to reinforce arguments and proposals aimed at mitigating these concerns (Xu & Xiao, 2022). Therefore, it is expected that the increasing trend of citations will continue in the following years.

Contribution of countries and institutions

One hundred sixteen countries/territories and 2082 institutions contributed to LULC change- related studies between 1977 and 2021. The map below (Figure 3) shows the countries' contributions to LULC change-related studies from 1977 to 2021. More than 50 papers have been published in 14 countries. Among the 116 countries, China has contributed the most papers (512).

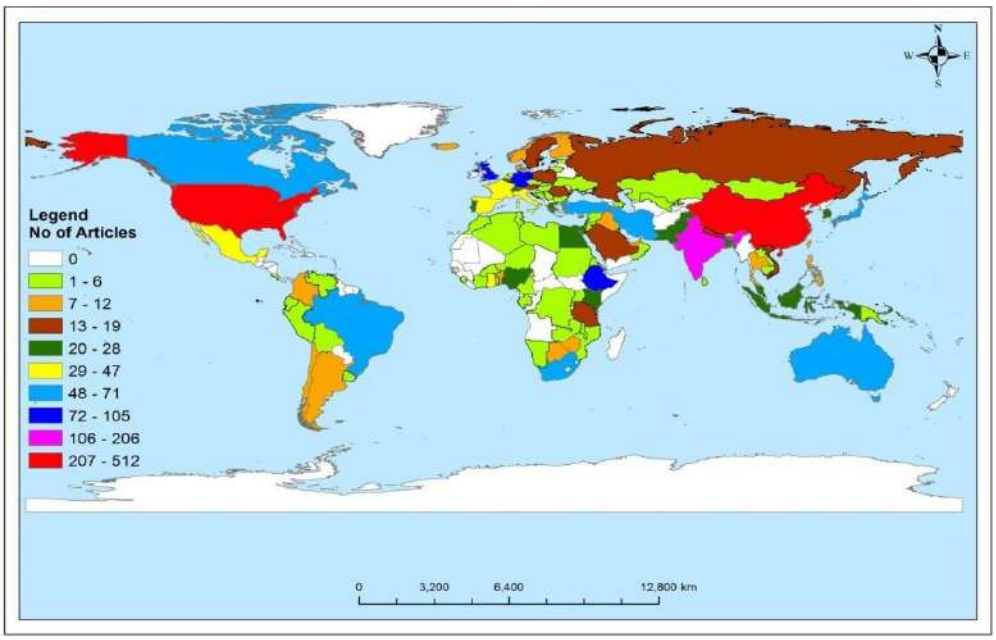

Figure 3. Worldwide distribution of LULC change-related articles from 1977 to 2021

Based on Table 1, in assessing the impact of their contributions, it is evident that while China leads in terms of the sheer volume of published articles (512), the United States takes the forefront in influence, garnering an impressive 22,572 citations for its 412 articles. This juxtaposition suggests a substantial resonance and influence of research originating from the United States. India, with 206 articles and 5,554 citations, also demonstrates a notable impact, signaling recognition of its research in the LULCC field. Germany and Ethiopia, though with fewer articles, exhibit a meaningful impact relative to their output, with Germany's 105 articles attracting 3,679 citations and Ethiopia's 82 articles amassing 1,714 citations. Figure 4 indicates that, except for 2009 and 2011, China published the most papers. China's total number of articles published has increased significantly since 2009, and it has been the most productive since 2015. This indicates that China, the United States, and India have paid close attention to LULC change issues and that these three countries have promoted LULC change research during the last four decades. Several institutions and countries are interested in LULC change-related research. Many developing countries, including China, India, and Ethiopia, have begun showing up among the top ten most leading countries in the LULC change related publications. Other countries are also expected to have their representation in the LULC change research arena. It has been observed that the majority of studies on LULC change have been published by only a few countries. Hence, more priority in LULC change research should be given to other countries, especially in developing countries as deforestation rate is higher over there (Gohain et al., 2021). Though it is recognized that LULC change is a major issue in developing counties, the study showed that few countries, institutions and authors had been involved in LULC change-related research from Asian countries.

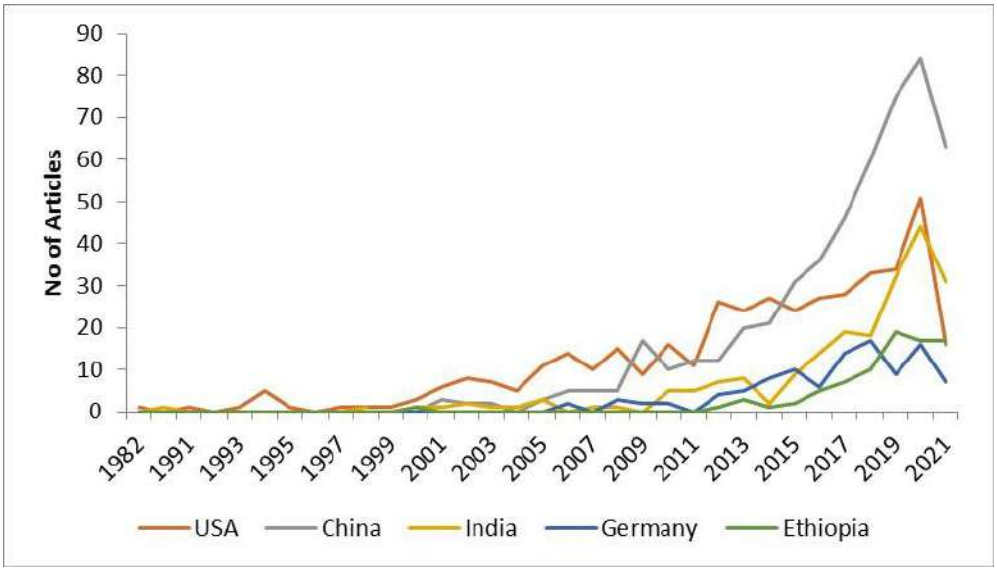

Figure 4. The number of publications from the top 5 leading countries

Table 1. Information on the ten most productive countries

Country	No of Articles	Citations
China	512	13225
United States	412	22572
India	206	5554
Germany	105	3679
Ethiopia	82	1714

VOSviewer was used to perform co-authorship analysis to evaluate the structure of research collaboration networks among each country on a particular topic. Figure 5 depicts 64 countries'/territories' scholarly collaborations among 116 countries. Each country's participation is represented by its circle size; larger circles indicate a higher frequency of collaboration (Liu et al., 2019). The width of the line, on the other hand, indicates how often two countries work together. A thicker line indicates that the two countries collaborate more frequently (Liu et al., 2019). The network consists of 64 items (nodes), 10 clusters, and 508 links with a total strength of 1320.

China, the United States and Germany have more close international corporations. China is the most active international collaboration in studies relating to LULC change (512 articles with 49 international collaborations). The United States is also actively cooperating with other countries (412 articles with 44 international collaborations). Germany is also one of the most productive international collaborations (105 articles with 40 international collaborations). It is possible to see a close collaboration between the countries that produce the greatest number of scholarly publications. Therefore, since these countries have similar research interests, researchers can easily identify potential research collaborators from these nations (Chen et al., 2017). Such worldwide collaboration increased their research capabilities and enhanced the development of LULC change-related studies. The development of LULC change research was influenced by a number of publications during this period. Scholars expanded on previous research areas in response to emerging LULC challenges. They established international collaborations for LULC change-related research.

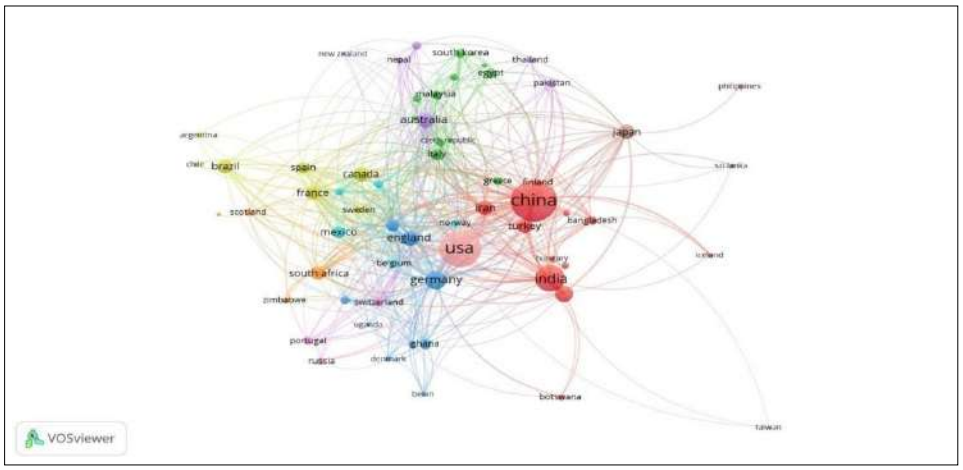

Figure 5. The international collaboration network of countries

Based on Table 2, Chinese Academy of Sciences is the most productive institution in China, with the most publications and is the most active institution in international academic collaboration on studies relating to LULC change. The academic collaboration across various institutions is also analyzed by using VOSviewer. Figure 6 depicts the corresponding collaboration network of the 175 institutions (Institution with at least five articles published). The finding indicates that Chinese institutions are more interested in international collaboration on LULC change-related research.

Table 2. Information on the five most influential Institutions

Institutions	Articles	Citations
Chinese Academy of Sciences	194	6791
The University of Chinese Academy of Sciences	65	908
Beijing Normal University	41	1225
China University of Geosciences	25	336
The National Autonomous University of Mexico	25	3232

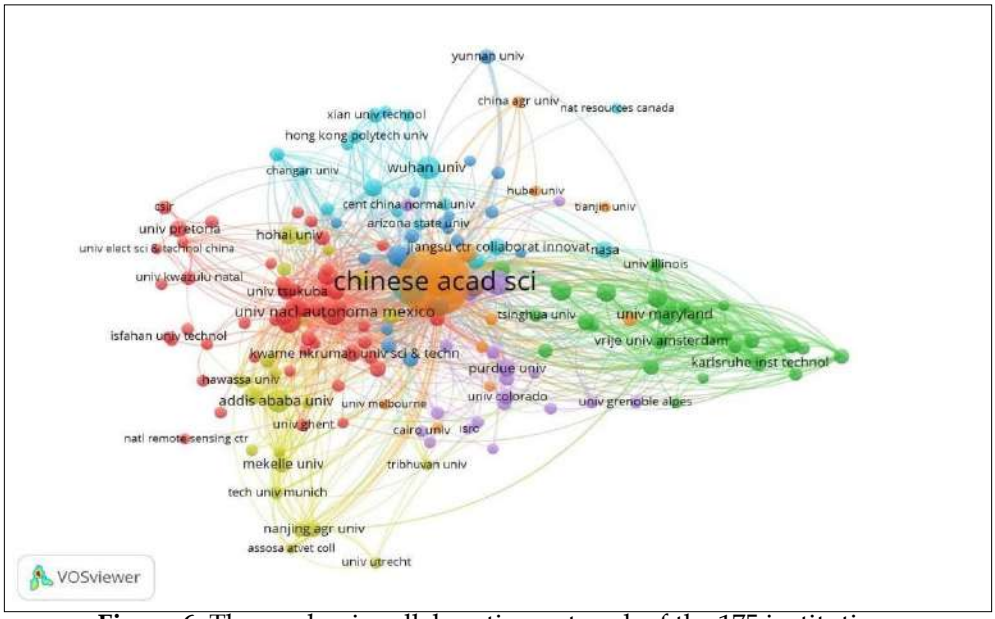

Figure 6. The academic collaboration network of the 175 institutions

Most cited articles and influential authors

The sum of the citations received by an article within a specific period will be used to determine its importance in a certain field (Fang et al., 2018; Lima & Bonetti, 2020). The most often cited articles indicate their importance as a source of information in the field; when it comes to citations, older articles have a longer time to be cited than newer ones (Chen et al., 2012). Among all the articles authored by Lambin et al. and titled "*The causes of land-use and land-cover change: moving beyond the myths*" is the most cited LULC change- related article (Lambin et al., 2001). This article was published in Global Environmental Change in 2001 and received 2152 total citations. This article tracked some of the major myths on driving forces of land-cover change and proposed alternative change pathways. The second most cited paper is titled *Remote sensing image-based analysis of the relationship between urban heat island and LULC changes*. This article was published in Remote Sensing of Environment in 2006 and received 819 total citations. This research explored the causes and consequences of urban heat islands and presented a new index called the Normalized Difference Bareness Index (NDBaI) (Chen et al., 2006). The third-most-cited publication is titled *Continuous change detection and classification of land cover using all available Landsat data.* This work was published in the journal Remote Sensing of Environment in 2014 and received 616 citations. This paper discussed a new algorithm for Continuous Change Detection and Classification (CCDC) of land cover using all available Landsat data (Zhu & Woodcock, 2014). Some of the most prominent LULC change research areas are determining the causes of LULC change, performing remote sensing image-based analysis, and monitoring and classifying continuous change. Table 3 shows the number of citations for the top five most cited articles from 1977 to 2021.

Table 3. Top five most cited articles between 1977 to 2021

Authors	Title	Publication Year	Total Citations	Average per year
Lambin et al. (2001)	The causes of land-use and land-cover change: moving beyond the myths	2001	2152	102.48
Chen et al. (2006)	Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes	2006	819	51.19
Zhu & Woodcock (2014)	Continuous change detection and classification of land cover using all available Landsat data	2014	616	77
Houghton et al. (2012)	Carbon emissions from land-use and land-cover change	2012	571	57.1
Lunetta et al. (2006)	Land-cover change detection using multi-temporal MODIS NDVI data	2006	503	31.44

Some of the prominent authors in the field of LULC change are given in Table 3. 6450 authors have produced publications on LULC change in general. Verburg, P.H., and Almut, A., published the most articles in the field (8 articles each).

Table 4. The top five authors by publications and citations

Author	Documents	Citations	Institutional Affiliation	Country
Verburg, Peter h.	8	785	VU University Amsterdam	The Netherlands
Arneth, Almut	8	242	Karlsruhe Institute of Technology	Germany
Deng, Xiangzheng	7	441	Chinese Academy of Sciences	China
Tian, Hanqin	7	390	Auburn University	United States
Shi, Wenzhong	7	136	Hong Kong Polytechnic University	China

Figure 7 shows the academic collaboration network between authors. Figure 7 shows the academic collaboration network between authors. Arneth Almut, Verburg peter, Tian Hanqin, Teketay Demel and Benediktsson Atli have shown more interest in academic collaboration. Arneth Almut (shown in red) collaboratively works with Verburg peter, Tian Hanqin, Stehfest Elke, Jain atul, De noblet-ducoudre Nathalie. They were interested in the current challenges of implementing anthropogenic land-use and land-cover change in models contributing to climate change assessments (Prestele et al., 2017). Tian Hanqin (shown in green) collaborated with Arneth Almut, Zhang Chi, Liu, Jiyuan, Kuang Wenhui, Kalin Latif and showed interest in LULC change and its impacts on climate (Li et al., 2020; Liu et al., 2009; Liu & Tian, 2010; Tian et al., 2014). Verburg peter (shown in red) works collaboratively with Stehfest Elke, Jain atul, De noblet-ducoudre Nathalie, Arneth Almut, and Herold Martin. Verburg peter focus on land-use and land-cover change models and simulations (Prestele et al., 2016; Van Asselen & Verburg, 2013; Verburg, 2006). Teketay Demel (shown in blue) works collaboratively with Kindu Mengistie, Knoke Thomas, Schneider Thomas, Soromessa Teshome, and their primary interest was identifying LULC changes in Ethiopia (Hailemariam et al., 2016; Kindu et al., 2018, 2013; Kindu & Schneider, 2015; Van Asselen & Verburg, 2013). Benediktsson Atli (shown in yellow) works collaboratively with Shi Wenzhong, Lv Zhiyongand, Liu Tongfei. They focus on applying geospatial techniques to detect LULC change (Lv et al., 2019, 2018).

Analysis of different journals

Between 1977 and 2021, 439 journals published articles on the LULC change study. The top five most popular journals are shown in Table 5. "Sustainability" (82) was the most popular journal. Although "Sustainability" produced the most papers, "Applied geography" was the most cited journal with 4136 total citations. Out of 1892 papers, it can be seen that the top five journals in these fields published approximately 18% of the papers (out of 1892) corresponding to LULC change. The relative importance of a journal in the field will be assessed using its impact factor (Iftikhar et al., 2012). Journals with greater impact factor values were considered more significant in the field than those with lower impact factor values (Chen et al., 2017; Liu et al., 2019). Among the top five most productive journals, "Applied geography" has the highest impact factor (4.240). Sustainability, Applied geography, and Remote Sensing are the leading journals in LULC change-related fields (Table 5). Other journals also encourage LULC change-related publication, but the total number of papers published is much lower than that of the top five. Furthermore, an analysis of various journals reveals that research on LULC has progressed concurrently across multiple academic disciplines.

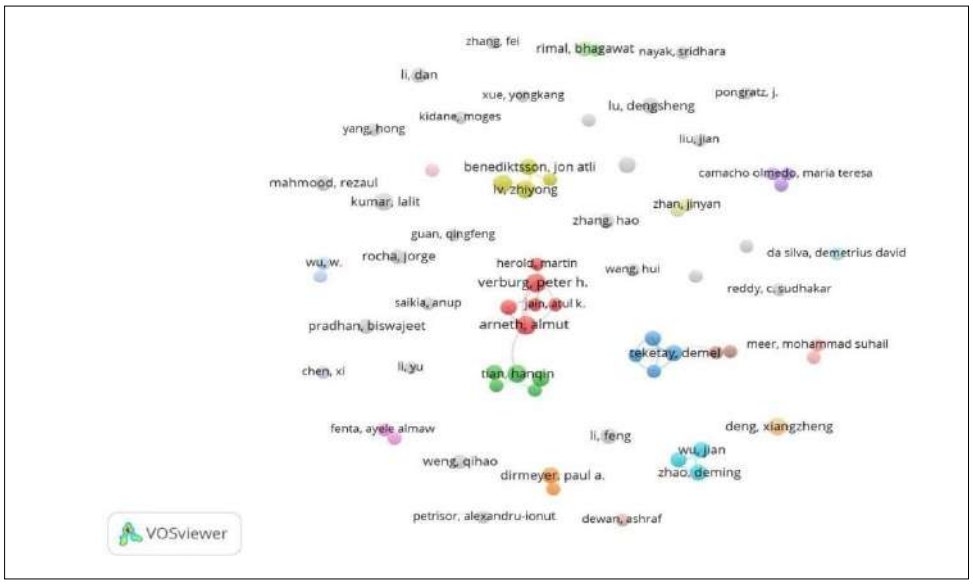

Figure 7. The academic collaboration network of the 70 authors

Table 5. The five most leading Journals with publications and citations on LULC change

Journal	Total No of Article	Total No of Citation	Impact factor (IF) (2020)	h-index
SUSTAINABILITY	82	1000	3.251	85
REMOTE SENSING	74	1209	4.848	124
ENVIRONMENTAL MONITORING AND ASSESSMENT	66	1407	2.513	109
INTERNATIONAL JOURNAL OF REMOTE SENSING	62	2306	3.151	174
APPLIED GEOGRAPHY	45	4136	4.240	99

Analysis of the intellectual structure

Co-Occurrence Author Keyword analysis

Keyword co-occurrences analysis can track new study domains, and research themes in a specific subject as keywords indicate the article's actual content (Singh et al., 2020). The co- occurrence author keywords technique tracks the frequency with which two keywords appear in the same article. Figure 8 depicts the network of the co-occurrence author keyword, which is represented by 228 keywords out of a total of 4088, that has at least five occurrences of a keyword. The network has a total strength of 4336 and comprises 12 clusters, 228 nodes, and 2454 links. In the visualization map, each circle (node) represents a keyword. The size of the circle is proportional to the number of times it has appeared in articles: the larger the size, the more frequently it has been used. The width of the line reflects the strength between the two circles. Keywords that are close in proximity and of the same color have more similarities than those that are far away and of a different color (Lima & Bonetti, 2020; Rana, 2020). The present analysis shows that studies on LULC change initially focused on LULC change detection but later focused on LULC change management. The results suggest that research related to LULC will eventually expand to popular academic topics. In addition, LULC change management will continue to be the key theme in the future.

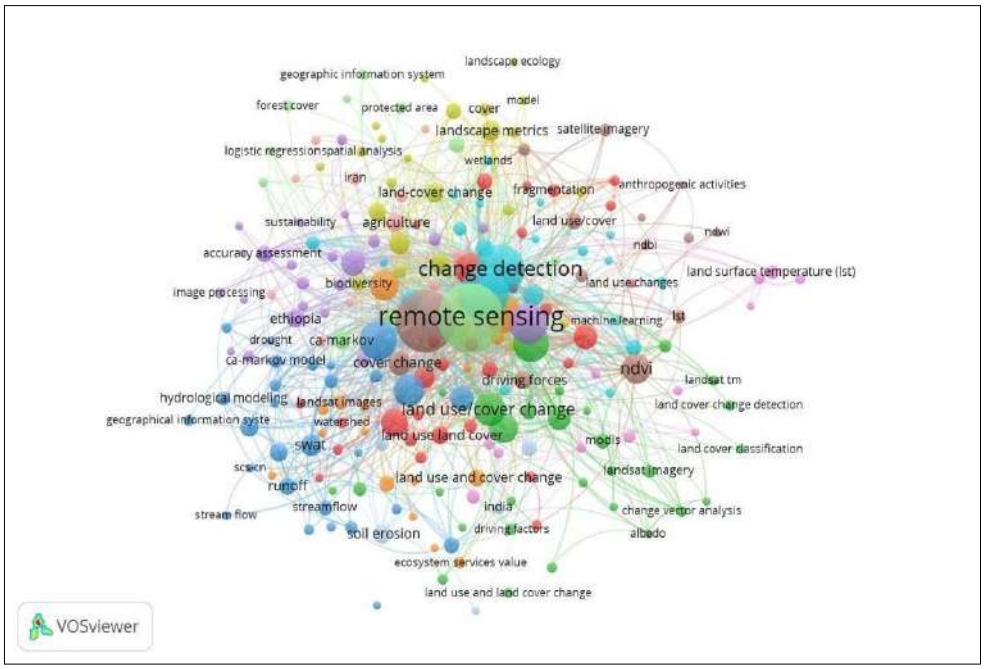

Figure 8. Co-occurrence keywords network of the 228 keywords or keywords network of the 228 keywords

The top five author's keywords used in LULC change-related research between 1977 and 2021 are shown in Table 6.

Table 6. Top five author's keywords

Keywords	Occurrences	Total link strength
Remote sensing	280	273
Land use	224	232
Land cover	156	204
Change detection	142	140
GIS	139	157

Co-citation analysis of cited-authors

Authors, journals, and references have all been studied using co-citation techniques. Co-citation is known as "*how often two earlier articles are referenced in a subsequent article*" (Fang et al., 2018). It counts how many times two articles are cited in a third. (Singh et al., 2020). The process of spatial expansion can be better understood with the help of co-citation analysis. Hence, it can be a useful tool for visualizing the structure of a subject. The co- citation analysis of "Cited Authors" is shown in Figure 9, represented by 119 researchers out of a total of 38816, who have at least 50 citations. The network of cited authors is made up of 5 clusters, 119 nodes, and 5582 links with a total strength of 54573. Red represents the first cluster with 35 authors; green represents the second cluster with 34 authors; and the third, fourth, and fifth clusters are shown in blue, yellow, and purple with 20, 17, and 13 authors, respectively. However, in terms of co-citations, the primary cluster, which is in green, is made up of the most cited authors who focus on LULC change modelling (Van Asselen & Verburg, 2013). The second cluster (green) mainly focus on applying geospatial techniques in LULC change detection. The third cluster is blue, addressed carbon emissions from LULC change (Houghton et al., 2012). The fourth cluster (Yellow) primarily focus on LULC change detection. The fifth cluster focuses on land Use Planning and Natural Resource Conservation (Arnold et al., 2020).

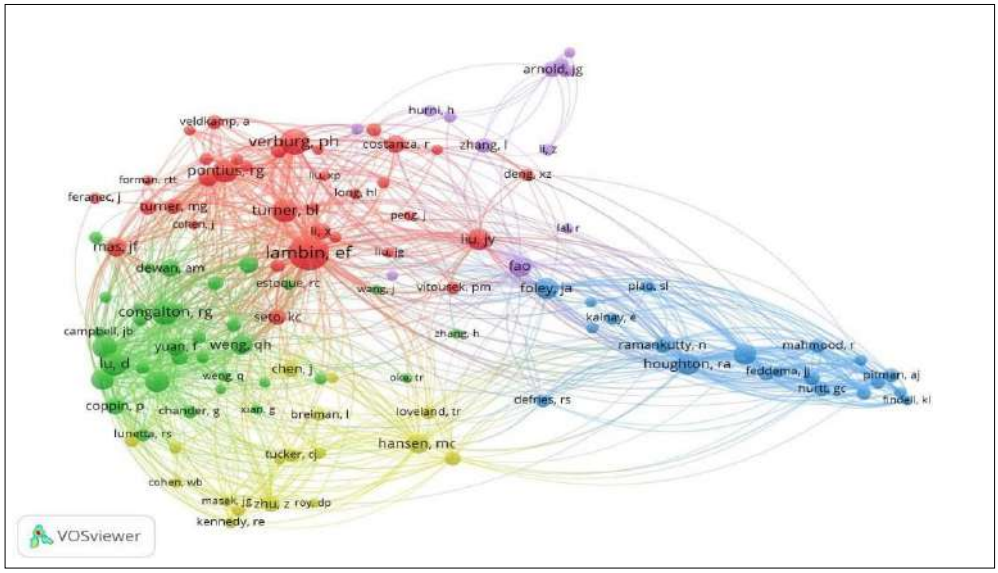

Figure 9. Co-citation network of the 119 cited

Co-citation analysis of cited sources (Journals)

The co-citation cited sources analysis determined the field in which research is cited (Montalván-Burbano et al., 2021). Figure 10 shows the co-citation cited sources, including 453 journals out of 20875 sources, which met the minimum citation of a source of 20 citations. The network of co-citation cited sources consists of 5 clusters, 453 nodes, 65998 links, and a total strength of 1452314. Journals in the first cluster (red)focus on applying Remote sensing and GIS in LULC change. The journals in the second cluster (green) are concerned with the urban landscape, urban ecology, and environment. The journals in the cluster (blue) focus on hydrology and soil. Journals in fourth cluster (yellow) concentrate on climate and global atmospheric changes. Journals in fifth cluster (purple) focus on geographical issues related to LULC change.

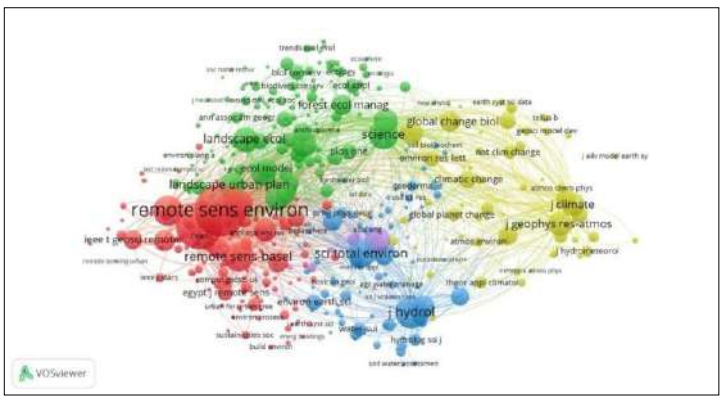

Figure 10. Co-citation network of the 453 cited sources

CONCLUSIONS

The extensive bibliometric analysis undertaken in this study offers a comprehensive landscape of research in the field of Land Use and Land Cover (LULC) change. By examining current research trends, identifying significant contributors, and recognizing emerging themes, valuable insights into the trajectory and focus of LULC change research have been gained. The analysis revealed a notable increase in LULC change research publications over the past 45 years, highlighting a growing interest in the field, particularly in recent years. Key author keywords such as remote sensing, land cover, land use, change detection, and GIS underscore the interdisciplinary nature of LULC research. Notably, China, the United States, and India emerged as leading countries in LULC- change related research, displaying substantial international collaboration. Chinese institutions, especially the Chinese Academy of Sciences, demonstrated significant productivity and engagement in global academic collaborations, indicating a collaborative approach to addressing LULC change challenges. The study also emphasized influential journals like "Sustainability," "Applied Geography," and "Remote Sensing," crucial in disseminating LULC research and shaping the field's progress. In terms of research themes, the analysis indicated a transition from an initial focus on LULC change detection to a broader emphasis on LULC change management, signifying a maturation in the understanding of the field. As research continues to evolve, it is anticipated that LULC change management will remain a prominent theme, addressing critical challenges and promoting sustainable land use practices. The research framework arising from this analysis will provide guidance for researchers and stakeholders in prioritizing critical issues within LULC change. This foundational work will serve as a valuable resource for academia, policymakers, and practitioners aiming to have a meaningful impact on the global landscape.

LIMITATIONS

This research has some limitations as well. The data were obtained only from the WoS core database. Although it is the most recognized database, it includes only a part of the total data available. Therefore, future research should be undertaken using other databases to validate the findings of this study. Some quality, non-English articles could not be included in this bibliometric analysis because of the language restrictions of this study. Consequently, the contribution of non-English speaking countries will be overlooked. Also, this study is restricted to the use of only scientific articles and omitted other types of materials, including conferences, books, and book chapters. Different search words may have an impact on the retrieval results. A complete domain mapping of the LULC change study can be generated using a variety of mapping techniques. Despite these drawbacks, the findings offer a thorough bibliometric overview of the most significant LULC change research trends over the previous 45 years.

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Growth and yield of chili (*Capsicum annuum*) as affected by foliar application of fermented rice washed water with aquarium wastewater

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ABSTRACT

The present experiment aimed to study the impact of fermented rice washed water (FRW) combined with aquarium wastewater on growth and yield of chili cultivation. A Randomized Completely Block Design (RCBD) was used to set up the experiment which has five treatments and four replications. The treatment combinations were; recommended fertilizer at basal and top dressing (Control T1), 10 tons/ha compost with 2.5% (T2), 5% (T3), 7.5% (T4) and 10% (T5) aquarium water with 2.5% FRW. Foliar application of fertilizer solution was done at the 1st, 3rd, 5th, 7th, and 9th weeks after transplanting. The result showed that T4 performed well in growth and yield components of chili. There was no significant variation ($P>0.05$) in total yield of chili between T1 and T4. The research has a conclusion that 10t/ha compost with foliar spray of 7.5% aquarium water combined with 2.5% rice washing water (T4) would be the appropriate substitute fertilizer for the cultivation of chili.

Keywords: Aquarium water, Chili, Compost, Fermented rice washed water, Yield

INTRODUCTION

Chili (*Capsicum annuum*) is one of the most significant cash crops grown in Sri Lanka for its fresh and dried pods, which have high economic value in the country because they are essential for daily diets as well as raw materials in the food and pharmaceutical industries (Dahanayake et al., 2013). Chili is a rich source of many minerals and contains vitamins, and amino acids, which are crucial for human health (Olatunji & Afolayan, 2018).

In agriculture, synthetic fertilizers are utilized to manage plant nutrient deficits by offering abundant nutrition. Nevertheless, excessive application of fertilizer can result in an array of issues, including nutrient loss, groundwater and surface water contamination, acidity or basification of the soil, a decline in beneficial microbial populations, and increased sensitivity to destructive insects (Bisht & Chauhan, 2021). Liquid organic fertilizers are nutrient-rich manures produced from crop residues either from plant or animal sources, as well as from green manures, animal manures, and household food waste and deliver crops with soluble and readily available nutrients (Ranasinghe et al., 2019). In addition to the essential plant nutrients, liquidorganic fertilizers have beneficial microorganisms which help to recycle organic matter and take a part role in the degradation of substrates in the fermentation process (Kasim & Ahmed, 2011).

Rice is a staple food in Sri Lanka. After washing rice, wastewater is available in most households (Nabayi et al., 2021), and in the community, rice washing water has not been used much in agriculture. The rice washing water is discharged more with other household waste without utilization. Rice water contains 0.015% nitrogen (N), 16.306% phosphorus (P), 0.02% potassium (K), 2.944% calcium (Ca), 14.252% magnesium (Mg), 0.027% sulphur (S), 0.0427% iron (Fe), and 0.043% vitamin B1 (Bilal et al., 2019). Therefore, plants would benefit from these nutrients available in the rice washing water especially Vitamin B1 contributes to metabolism in terms of converting carbohydrates into energy to drive activity in plants. The plants would benefit from promptly carrying out metabolic activities to adjust to the environment or media when under stress from transplanting or open root circumstances. Moreover, vitamin B1 plays a pivotal role in helping plants resist easily withering by boosting nutrient uptake in the soil solution through its presence in washed rice water (Febriyanti et al., 2021).

However, the lack of community interest in utilizing rice washing water in agriculture is due to limited knowledge about the content of important substances in the rice washing water that is beneficial for plant growth (Mohan et al., 2014). Aquarium water is another source which is rich in beneficial microorganisms as well as N, P, K and trace nutrients supply for the plants (Charles et al., 2017). Changing portions of the fish tank's water often is a basic management strategy (Nozzi & Graber, 2018). Various researchers have remarked on the foliar treatment with different liquid fertilizers; however, it appears that there is a dearth of knowledge on

chilli cultivation in Sri Lanka using foliar spraying of fermented rice water mixed with aquarium water. Hence, the current research was conducted to determine the impact of foliar sprays of fermented rice water and aquarium water on the growth and yield of chilies.

METHODOLOGY

A field experiment was designed at a home garden in Willgamuwa, Matale district, Sri Lanka.The study location receives an average maximum temperature of 32°C and rainfall ranging from 1950 mm to 2000 mm. The humidity level of the site was 75%–87%. For this experiment, the chili variety MI-2 was used. Rice water was collected after washing the rice at the household. Then the washed rice water was kept for two days in a shaded area for the fermentation process. Aquarium water was collected from an ornamental fish tank. Later the FRW and fish tank water were diluted, and solutions were prepared according to the treatments.

A total of five treatments, each with four replicates were used in a Randomized Completely Block Design (RCBD) experiment. The treatment combinations were recommended fertilizer at basal and top dressing (T1-Control), 10 tons/ha compost with 2.5% (T2), 5% (T3), 7.5% (T4) and 10% (T5) aquarium water with 2.5% FRW. The foliar application was done at the 1st, 3rd, 5th, 7th, and 9th weeks after transplanting (WAT). The germination percentage of the seed was examined and found to be 90%. All agronomic procedures, except for providing fertilizer, were carried out in line with the recommendation of the Department of Agriculture, Sri Lanka. Destructive sampling was used to measure growth and yield metrics from the 2nd to the 10th WAT. Both parametric and non-parametric statistics were used to analyze the acquired data.

RESULTS AND DISCUSSION

Plant height

The effect of the application of aquarium water and fermented rice water (FRW) on the average plant height of chili from the 2nd to 10th week after transplanting (WAT) is shown in Table 1. Aquarium water and FRW application at 10th WAT showed a significant effect on plant height ($P<0.05$). However, significant changes ($P>0.05$) were not observed at the 2nd, 4th, 6th and 8th WAT. At the 10th WAT, the tallest growth of plants was noted in T1 (control), followed by T4. But there were no significant ($P<0.05$) differences between T1 and T4 them. The foliar application of 7.5% aquarium water combined with 2.5% FRW resulted in a rise in chili plant height which could be attributed to the better availability of plant nutrients that enhance the vegetative growth and development of the number of cells by cell division and elongation in a plant. Our findings are comparable to those of Sairi et al. (2018), who discovered that fermented rice enhanced plant height when wash water was applied to chili seedlings. In addition, green mustard plants treated with fermented rice wash water exhibited greater plant height, chlorophyll contents and fresh plant weight (Wijiyanti et al., 2019).

Table 1. Aquarium water and FRW application on average plant height (cm) of chili

Treatment	2nd WAT	4th WAT	6th WAT	8th WAT	10th WAT
T1	20.05±0.40	20.10±1.20	29.75±2.45	34.15±1.48	35.55±1.15a
T2	16.70±2.00	23.10±0.90	23.65±1.65	26.05±1.85	28.85±0.35b
T3	18.40±1.10	22.45±2.75	25.85±1.55	29.25±0.95	29.95±0.25b
T4	19.25±0.35	22.60±0.50	30.55±0.80	31.40±2.20	33.25±0.65a
T5	18.35±085	20.20±0.90	28.15±0.25	29.85±1.75	30.85±1.25b
F-test	ns	ns	ns	ns	*

Root length

Table 2 illustrates the effect of aquarium water with FRW on the mean root length of chili from the 2nd WAT to the 10th WAT. The root length showed no significant difference ($P>0.05$) from 2nd to 8th WAT. According to data, there were significant changes ($P<0.01$) in average root length among tested treatments at the 10th WAT. T4 had the longest root length (7.05 cm) at the 10th WAT. The results revealed that the formulated foliar sprays with aquarium water and FRW had adequate nutrients to sustain root growth without the requirement of inorganic fertilizer in T4. A comparable observation was also documented by Sairi et al. (2018), where root length was superior when chili plants were treated with 10 ml of fermented rice after wash water once in a week along with tap water compared to NPK fertilizers.

Table 2. Aquarium water and FRW application on average root length of chili

Treatment	2 WAT	4WAT	6WAT	8WAT	10 WAT
T1	2.85±0.35	4.80±0.10	5.60±0.70	6.15±0.25	6.25±0.05b
T2	2.55±0.35	4.15±0.25	4.75±0.45	5.95±0.25	6.40±0.10b
T3	3.30±0.15	4.05±0.25	4.35±0.25	4.60±0.70	5.55±0.35b
T4	3.45±0.60	5.45±1.25	6.05±1.15	6.55±1.04	7.05±0.55a
T5	3.00±0.14	4.35±0.75	4.75±0.25	5.10±0.80	5.50±0.40b
F-test	ns	ns	ns	ns	**

Leaf dry weight

At the 6th WAT, the average dried weights of chili leaves exhibited a significant difference ($P<0.05$) between the studied treatments. However, there were no substantial variations ($P>0.05$) in the average dry leaves at the other tested weeks.

At the 6th WAT, the highest average dry weight value of 1.47 g was observed in T4 and the lowest dry value of 0.62g was observed in T5 (Table 3). However, there is no significant difference (P>0.05) between T4 and T1. The foliar sprays with FRW have also increased the average leave numbers and weight in the mung beans (Alcala, 2019).

Dry weight of stem

The dry weight of the stem of the chili from the 2nd WAT to the 10th WAT is shown in Table 4. The aquarium water and FRW application at 4th WAT showed significant effect (P<0.05) on the dry weight of the chili stem. At 4th WAT, the highest dry weight of stem (3.43 g) in the T5 and the lowest (1.98 g) dry weight of the stem were observed in T3. But T5 is not significantly (P>0.05) differ with tested treatments except T3. Nevertheless, the other tested weeks didn't show any significant variations in the attribute. The present results are supported by Hariyadi (2020), who found that application of rice washed water 500 ml/l water or 1000 ml/l water not only increased leaf numbers but also enhanced the plant height and stem diameter of tomatoes.

Table 3. Aquarium water and FRW application on average dry weight of leaves of chili

Treatment	2 WAT	4WAT	6WAT	8WAT	10 WAT
T1	0.09±0.01	0.71±0.14	1.35±0.09a	1.84±0.12	2.87±0.02
T2	0.07±0.00	0.80±0.10	0.82±0.06b	1.18±0.61	2.69±0.05
T3	0.11±0.02	0.65±0.04	0.69±0.10b	1.19±0.29	2.70±0.18
T4	0.08±0.03	0.69±0.12	1.47±0.25a	1.48±0.83	2.78±0.18
T5	0.11±0.02	0.52±0.26	0.62±0.06b	1.38±0.46	2.45±0.13
F-test	ns	ns	*	ns	ns

Table 4. Aquarium water and FRW application on average dry weight of stem of chili

Treatment	2 WAT	4WAT	6WAT	8WAT	10WAT
T1	0.48±0.12	2.24±0.07ab	3.56±0.35	3.65±0.24	3.78±0.36
T2	0.55±0.13	2.39±0.19ab	2.55±0.13	2.56±0.32	2.70±0.25
T3	0.76±0.05	1.98±0.49b	2.43±0.42	2.87±0.67	2.88±0.76
T4	0.55±0.28	2.49±0.47ab	2.58±0.17	2.61±0.85	2.62±0.26
T5	0.70±0.01	3.43±0.38a	3.47±0.46	3.51±0.32	3.61±0.07
F-test	ns	*	ns	ns	ns

Dry weight of roots

Table 5 shows the effect of Aquarium water and FRW on the average dry weight of the chili root from the 2nd to the 10th WAT. There were substantial changes ($P<0.05$) in the average dry weight of the roots at the 4th, 6th, and 8th WAT among the different treatments. Yet, no significant change ($P>0.05$) was seen during the 2nd and 10th WAT.

Table 5. Aquarium water and FRW application on average dry weight of roots of chili

Treatment	2 WAT	4WAT	6WAT	8WAT	10WAT
T1	0.11±0.00	0.86±0.10a	0.88±0.02a	1.63±0.21a	1.57±0.34
T2	0.13±0.04	0.60±0.04ab	0.81±0.06ab	0.94±0.08ab	1.18±0.18
T3	0.18±0.02	0.61±0.11ab	0.84±0.03a	1.20±0.14ab	1.47±0.15
T4	0.12±0.01	0.58±0.03b	0.99±0.02a	1.35±0.18ab	1.55±0.10
T5	0.16±0.02	0.42±0.03b	0.60±0.03b	0.82±0.28b	1.16±0.40
F-test	ns	*	*	*	ns

Leaf area

The leaf area of chili on 2nd WAT to 10th WAT is given in Table 6. Significant difference ($P<0.05$) was noted in average leaf area (LA) at 8th and 10th WAT which might be due to the highest absorption of nutrients during the growth and development. It was also found that there was no significant difference ($P>0.05$) in the treatments particularly, 2nd, 4th, and 6th WAT. This could be attributed to the addition of FRW with aquarium waste. The higher the nutrient availability, the greater the extensiveness of the leaves, and this will positively influence photosynthetic activity. This is inextricably linked to the role of organic fertilizer use of aquarium waste, since crops that do not receive additional N elements as needed would have small leaf forms, but plants that receive additional N as required will have wide leaves. Liu et al. (2008) stated that the result of the high leaf area plants was due to the improvement of photosynthesis which led to higher yield in plants. The present study was supported by Omotade et al. (2019) who showed that the treatment with aquaculture wastewater increased the leaf area of the hot peppers at 8th WAT with the help of nutrients present in the wastewater.

Table 6. Aquarium water and rice water application on average leaf area of chili

Treatment	2WAT	4WAT	6WAT	8WAT	10WAT
T1	7.99±0.75	13.22±1.90	17.67±1.25	19.78±0.42a	21.47±0.11a
T2	6.42±0.10	9.90±0.45	15.59±1.29	15.94±1.38b	15.97±0.34b
T3	7.13±1.51	14.89±1.65	16.52±0.40	18.35±0.99ab	18.70±0.80b
T4	8.89±0.42	12.63±1.99	16.26±0.94	16.43±2.20ab	17.96±1.60b
T5	6.22±0.24	13.32±1.00	18.25±1.05	19.16±0.93a	19.79±0.83ab
F-test	ns	ns	ns	*	*

Number of flowers per plant

The combined application of aquarium water and FRW significantly ($P<0.05$) enhanced the production of flowers in the chili plant at 8th and 10th WAT. It was further confirmed with the *P* and chi-squared values of 0.046 and 20.00, respectively. The flower production was highest with the value of 9 flowers at the 8th WAT in the T3, while the lowest numbers of 5 flowers were produced in the T4 and T5. At 10th WAT, the highest numbers of flowers were produced in T1 followed by T4 while the lowest were produced in T2.

Table 7. Aquarium water and FRW application on the average number of flowers of chili

Treatment	8th WAT	10th WAT
T1	8	12
T2	8	7
T3	9	8
T4	5	9
T5	5	8
Chi-square	20.00	20.00
P value	0.046	0.046

Number of pods per plant

The impact of foliar applications of aquarium water and FRW on the number of pods per plant in chili is shown in Table 8. The number of pods per plant at the 1st, 2nd, and 3rd pickings was not significantly ($P<0.05$) impacted by the application, as proved by *P* values of 0.062 and chi-square of 10.00. The maximum number of pods per plant might be due to its vigour and the more number of leaves per plant. The use of fish aquaponics water from fish increased the amount of tomato fruits and saved fertilizer usage (Khater et al., 2015).

Table 8. Aquarium water and FRW application on the number of pods per plant in chili

Treatment	1st picking	2nd picking	3rd picking
T1	8	7	6
T2	9	6	7
T3	6	6	6
T4	9	8	5
T5	7	6	5
Chi-square	10.00	10.00	10.00
P value	0.062	0.062	0.062

Dry weight of pods

The effect of aquarium water and rice water FRW on the average dry weight of pods is givenin Table 9. There was a significant difference ($P<0.05$) at 1st, 2nd and 3rd picking. At 1st picking the highest value of 4.88g in T4 and low value of 3.37 g in T3. However, T4 did not differ ($P>0.05$) with tested treatments except T3. Similarly, the high dry weight of pods was noted in T4 at 2nd and 3rd picking too.

Table 9. Effect of foliar application of Aquarium water and FRW on the average dry weight of pods of chili

Treatment	1st picking	2nd picking	3rd picking
T1	4.31±0.40ab	3.31±0.10ab	2.65±0.41ab
T2	4.41±0.19ab	2.92±0.06ab	2.67±0.03ab
T3	3.37±0.27c	2.68±0.44ab	2.36±0.19b
T4	4.88±0.13a	3.99±0.13a	2.83±0.38a
T5	3.57±0.03ab	2.00±0.71b	1.60±0.03c
F-test	*	*	*

Total pod yield

Table 10 shows the effect of aquarium water with FRW on the average total yield of chilies at the first, second, and third pickings. There was a significant difference ($P<0.05$) between the first, second, and third pickings. In all pickings, the maximum total weight was noted in T4. But there are no significant differences between T4 and T1 in all pickings. The use of aquarium water along with FRW may have enhanced photosynthesis which in turn increased crop yield and increased both the quantity and weight of pods produced per plant. The present study agreed with Pattillo et al. (2020) who showed fertigation of aquaculture effluent on tomatoes produced

significantly the highest marketable fruit yield compared to the recommended fertilizer applications. Further, Fernandes et al. (2021) stated that the fish farming effluent could be used to supply nutrients without yield losses if alternating with tap water. Further, the elements *viz.* N (NH_4^+, NO_3^-), P, K, Ca, Mg, and Zn were found in the washed rice water waste and the solubilization rate increased with the duration of the fermentation which is directly associated with the beneficial microorganism (Nabayi et al., 2021). The availability of such elements could also have contributed to increasing the overall productivity of the chili.

Table 10. Aquarium water and fermented rice water application on average total yield in chilli

Treatment	1^{st} picking	2^{nd} picking	3^{rd} picking
T1	22.08±0.85ab	22.12±0.23a	18.22±1.90ab
T2	23.04±0.92ab	18.62±1.00ab	17.47±1.16ab
T3	17.96±3.41b	17.94±1.38b	14.43±0.89ab
T4	26.82±0.36a	22.86±0.21a	19.48±2.81a
T5	17.93±4.31b	16.00±1.22b	12.33±0.12b
F-test	*	*	*

CONCLUSIONS

The present study assessed several aspects of effect of the aquarium water and washed and fermented rice water on growth and yield attributes of chili (*Capsicum annuum*). In the field experiment, recommended fertilizer application (T1) and 7.5% Aquarium water with 2.5% FRW (T4) showed better growth and yield performances compared to other tested treatments. There were no substantial changes ($P>0.05$) in the total yield of chili in T4 and T1 suggesting that10t/ha compost with foliar spray of 7.5% Aquarium water with 2.5% rice washing water (T4) would be a substitute fertilizer for chili cultivation. This study must be conducted in different locations in different soils and seasons before draw a solid conclusion.

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Final Year Medical Undergraduates' Perception on the Academic Atmosphere at the Faculty of Health-Care Sciences, Eastern University Sri Lanka

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ABSTRACT

The academic atmosphere has a significant role in every institution in determining the success and effectiveness of the programmes. It has a strong impact on students' learning experiences. Moreover, it affects students' level of enthusiasm and degree of learning. It is everyone's responsibility to enhance the standard of the programmes to enhance the students' satisfaction and achievement. Therefore, it is important to study the academic atmosphere by getting feedback from the students. This study aimed to assess the final-year medical undergraduates' perception of the academic atmosphere at the Faculty of Health-Care Sciences (FHCS), Eastern University Sri Lanka (EUSL). A descriptive study was conducted with a qualitative method at FHCS in 2022. The study population included final-year medical undergraduates. A self-administered questionnaire with open-ended questions was used to collect data using a Google form. Data were collected on their perceptions from the first year to the final year and the analysis was done using a thematic analysis approach and emerging themes were categorized. Three core themes that emerged across data sets were identified. The emerging themes are Transition, Relationships with the staff, and Challenges. The study revealed mixed perceptions

with more positive insights towards coping with the Transition and Relationship with the staff. Students have more concerns about available resources in the clinical environment. Accordingly, the Medical Undergraduates successfully handled the transition status with the staff's support while highlighting the challenges in the clinical setting.

Keywords: Academic atmosphere, Challenges, Medical undergraduates, Relationship with the staff, Transition

INTRODUCTION

Academic atmosphere (Climate) plays a significant role in determining the success and effectiveness of the academic programmes in every educational institute. It has a strong impact on students' learning experience. According to Oramas & Mitchell (2018), the academic atmosphere is "everything that takes place within the classroom, department, faculty, or university", as well as the educational climate represents the students' perception of the environment, curriculum, quality, and curricular changes. Higher education is focused on developing students' skills and self-confidence to prepare the students to face the challenges in their careers and society (McCuddy et al., 2008). In medical education, it's essential to assess the student's perception to promote learning and ensure the educational programme's standards (Cerón et al., 2016) as well as to assess the teaching and learning process (Howe et al., 2015).

University planners have been at the forefront of the institution's development over the last half century as it adapted to changing environmental demands at several key moments. Environmental demands have not been static or predictable as they have shaped the structure and policy of higher education institutions over the last half century. Over the last fifty years, demands have ranged from demands for a large increase in students and research funding to demands for retrenchment and programme consolidation. The universities' personnel have employed various strategies depending on the nature of the demand (Gumport & Pusser, 1997). This study focuses on three major themes namely Transition, Relationship with the staff, and Challenges.

Transition

Transition is a vast area to study and a very important part of the students in their university life. The transition means the process of adjusting or adapting to the situation, involvement in new environment and experienced by the students (Shea, 2008). O'Shea defines the transition as a phase of significant adjustment, development, and alteration that necessitates substantial alteration from the student's perspective. It includes activities and courses outside the classroom in addition to those within (Shea, 2008). Transition implicates students' views on the whole university experience, which includes academic interaction with other students and college staff (Shea, 2008). Students are more inclined to engage with

the university if they encounter difficulties with enrolment procedures or barriers before entering the institution. Despite the fact that universities cannot control all elements of this experience, it is crucial to clarify what students can anticipate and what the institution provides in order to avoid unrealistic expectations from both ends. Students might experience fear and self-doubt as they acculturate to a new and somewhat external environment as a starting point for university study. Those who without family members or friends to give guidance until they adapt to university culture, are especially likely to experience these feelings (Shea, 2008). Students who are new to university, experience significant changes as they adapt to their new environment. Mostly culture, social, and academic are the matters that students encounter during the transition phase (Thuo et al., 2017).

Adversity or difficulty is required in order for a person to become resilient (Luthar & Cicchetti, 2000). As researchers perceive all university students around the world share the same problems. Females enrolled at secondary and high school levels in Ethiopia, for example, have faced numerous challenges (Thuo et al., 2017). According to Dawson & Pooley (2013), one of the research has shown that resilience is helpful for people facing difficulties and transitions in life, and as a result, several definitions of resilience have emerged (Dawson & Pooley, 2013). Luthar and Cicchetti (Luthar & Cicchetti, 2000) define resilience as a "multifaceted process of positive adaptation in the context of significant adversity". Despite the lack of consensus on a single definition, resilience is seen as a highly complex and multidimensional concept; this complexity is also visible in the extensive research on resilience over the past fifty years (Dawson & Pooley, 2013).

Relationship with the staff

The biggest barrier to learning, according to theorists, is the learner's lack of commitment. Motivation and perceptions of relevance are among the critical variables. These variables are impacted by the learning environment and prior experiences, as well as by the behaviour and environment in which the learning takes place. According to Hutchinson the most significant factor in teaching is setting the condition or environment for learning (Hutchinson, 2003). It is crucial to ensure that the academic activities in the institution are adequate and of high quality by assessing the students' perception of their relationship with the staff. Teachers' cultural sensibilities, body language, presentation skills, and their presentation skills are just a few of the factors that shape a teacher-student bond. It is critical to create a good teacher-student relationship. A teacher-student bond may be defined as a caring relationship that encourages a sense of kinship or ongoing healthy communication between a youth and a school staff member. These relationships may be regarded as a crucial element contributing to the healthy social and emotional development of students in addition to creating resilience to challenges and obstacles that students may face (Strawhun et al., 2013).

Universities in Kenya (Chepchieng et al., 2006) reports that students and faculty members come from a wide range of religious, political, socio-cultural, and racial

backgrounds. This diversity, accompanied by an appropriate faculty-student relationship, results in a campus environment that prepares students and faculty members to live and work in a culturally diverse society. In addition to being able to meet the demands of a more complex global environment, they are able to generate, develop, and spread knowledge as a result of the diversity in interpersonal relations, which is an important aspect of higher education worldwide (Chepchieng et al., 2006). Appropriate and standard relationships between students and professors determine their academic, personal, and social integration into university education. This could be attributed to the fact that lecturers engagement with students both inside and outside of the classroom is very critical to student motivation and engagement in all aspects of life (Chepchieng et al., 2006). Another study takes a look at investigated instructional effects, relationships among university college students' perceptions of their instructional surroundings, and their tactics to have a look at each college and school ranges. The results confirmed college students' view of increasing both 'hard' (instructional achievement) and 'gentle' (pride, improvement of crucial competencies) getting to know results, each without delay and slightly via their strategies to examine. Perceptions of the excessive content material of works and irrelevant evaluation directed students toward surface, and perceptions of accurate teaching towards deep, methods to study. College students' perceptions of their current mastering surroundings had been a more potent predictor of learning outcomes at university than prior fulfilment at school. Protocols are proposed to guide greater fine-grained evaluation of students' perceptions (Lizzio et al., 2002).

There are one-of-a-kind methods that body of workers can enhance relationships with students and build resiliency involve several statistics, which include open communication, trainer availability, sense of closeness, emotional safety and consider and the high-quality emotional involvement (Leitao & Waugh, 2012) have engaged those factors into 3 more significant categories of connectedness, availability, and verbal exchange. They provided examples of precise trainer or workforce behaviors that compose in these 3 constructs of their model of instructor-scholar relationships (Leitao & Waugh, 2012).

Challenges

Concerning the demanding situations which have to face by using college students it approaches that the situation this is being confronted with something that requires brilliant mental or physical effort to carry out correctly and consequently tests a person's ability. The first challenge they have to face is the transition. After that there are so many challenges they should face successfully. Mostly for the medical students the main challenge is the English language. Most of them learning in Sinhala medium for their A/Ls and they are not familiar with English terminologies. Other than that, there are cultural challenges, relationship challenges and adaptation also. The study of (Doygun & Gulec, 2012) mention that the problems faced by today's university youth under 4 main categories. These are concerns about food and shelters, habits, and orientation, worries about future and profession and quality education.

According to Samarasekera et al., n.d. study, providing feedback to the academic authorities regarding the effectiveness, success of goals and popular setting is essential. Therefore, this study aimed to evaluate the final year undergraduates' perception on academic atmosphere at the Faculty of Health-Care Sciences (FHCS), Eastern University Sri Lanka (EUSL).

METHODOLOGY

In 2022, FHCS carried out a descriptive study using a qualitative methodology. Students in their final year of medical school made up the study population. Data was gathered via a self-administered survey with open-ended questions using Google Forms. Data analysis was carried out utilizing a thematic analytic approach on their impressions from the first to the last year, and emergent themes were identified. Open coding was used by the researchers to interpret students' responses. Two authors analyzed all the comments and categorized them based on the similar patterns. Other two authors reread and confirmed the categories. The thematic analysis was done using a framework developed by Braun et al. (2006). This framework consists of six steps.

Step 1: The first step enables the investigator to get familiar with the data. This step involves with reviewing the data in means of reading and re reading.

Step 2: This step involves with creating the codes for the data. The data will be organized in a meaningful way.

Step 3: In this step, the codes will be reviewed and based on their similar patterns they will be collated into themes.

Step 4: The themes identified in step 3 will be reviewed and reexamined by the investigator and it will be modified.

Step 5: The final fine-tuning of the themes will be done in this step.

Step 6: Final step of the thematic analysis is stating the results obtained from this analysis.

RESULTS

We categorized and summarized the data we extracted from the open-ended as necessary. Three core themes which emerged across data sets were indented. The themes are Transition, Relationship with the staff and Challenges.

Transition

The first theme of our study is transition. Undergraduate students need to face the transition period in their first year of study. It was evident by our study by the

following statement of the student.
"Phase I was very difficult period"

Sudden transition from learning in mother tongue to English language put them into the difficult situation. One student expressed his language transition as follow.
"Difficult to study in English. Can't understand some words"

These statements revealed that they felt difficulties in the beginning of their study and the first year period was the complicated period for them. Even though they felt difficulties, they positively faced the transition status with the help of their teachers. A wonderful statement was notes as,
"Although it was a new experience, with the help of all the phase 1 academic staff. I was able to adapt to the change. Thank you very much, my dear teachers. You are the people who made the foundation"

Therefore, the teachers are the major pillar for the students to support and help them to adopt their self in transition. This statement is strongly pointed by the following expressions of the students.
"The period which polished the knowledge we have gathered. It was really a nice experience. Thank you, all Sirs and Madams,"
"It was a very good experience. Had a great time"
"Very good exposure and excellent teaching from all the staff"
"It was well organized and well-motivated part of the MBBS programme"
"Phase 1 exam and that 2nd years were very good. Covered all main objectives, and did tutorials, and practicals"

The finding of this analysis indicated that the medical undergraduates were able to successfully adopt themselves to the transition with the support of their teachers and facilitators.

Relationship with the staff

Staff should be able to maintain healthy relationship with the students to enhance the teaching-learning activities. Teachers are the mentors and facilitators for them as they enter into the higher education system. In our study, we found that the staff maintain strong rapport and relationship with the students and, it was evidenced by the students' statements.
"All the staff were very supportive and helpful. Had a great time"
"Thank you, teachers, you helped us lot"

Not only inside the university, outside of the university also students were able to maintain strong relationship with the staff. As the final year medical students spent their majority of the time in the clinical settings, they had good relationship with the consultants and other health-care professionals. Some of the examples of students' expression are follow:
"In all the appointments, the consultants and other staff were so involved and helpful"

"Staff are very much supportive in the hospital"
"SICU nurses are very friendly"
"Overall, the staff were so helpful and the clinical sessions were truly great Thank you so much"

In contrast one final year student stated that
"Some consultants are very rude and they blame us in front of the patients"

Challenges

Majority of the study participants satisfied with the staff, resources and the learning environment which they have. The statements of the students were below about their satisfaction on teaching learning activities.
"There was a good environment"
"I am satisfied about learning resources in our faculty"
"I am satisfied about learning environment that we have"
"I am satisfied with learning activities and clinical clerkships"
"We gained most of the clinical knowledge in phase III. Went really well. Especially the medicine appointment was so organized and well scheduled"

Also they are very happy about their library and its facilities and they expressed their view as
"Library books were really a treasure for us. We could find most books in both physical and e libraries"
"Best and freely available all the time"

Like a two side of the coin some of the students faced some challenges in the faculty as well as in their clinical setting. They expressed their frustrations by pointing the below statements.
"Our batch also lacked many minor appointments like oncology, OPD, urology, nephrology, emergency etc."
"It was good. Some appointments were more than good but unfortunately some were worst Some patients did not supportive during the exam"
"No student room facilities were available in all appointments"
"Dissection periods were meaningless"

Also, the participants discussed ways to improve the shortcomings for better academic achievements. The summary of the students' expressions was stated below;
"Please arrange the study area in the hospital if possible"
"It would be great if the students are given a particular time to carry on the research.'
"It's better if we get to know the end appointment assessment marks before final exams as it would help plan and to know which level, we are in. Thanks a lot"
"Arrange tutorials and quizzes often"
"Students need a separate student's unit in the hospital which is actually well spaced, hygienic with a hygienic washroom for resting, eating and to keep bags"

"No student room facilities were available in all appointments. It's an important negative thing to mention as we cancelled so many discussion classes of our consultants and registrars because of this."

DISCUSSION

Transition

The analysis of the findings of our study identified three themes under the perceptions of the students on academic atmosphere at FHCS, EUSL. This study revealed that the students positively faced the transition status during the beginning of their study period and adopted themselves for the transition with the help of their lecturers. Similarly, the ability of Chinese international students to adapt for the American universities is also found amazing. A study by Oramas & Mitchell (2018) received a positive comment from a participant regarding the transition as follows: "To succeed, you must have a strong motive. Additionally, it involves a great degree of tenacity and perseverance, as well as assurance in one's capacity to "flow and adapt,".

In this study all the students were faced the transition in the first year of the university life. Similarly, in Wolaita Zone, Ethiopia, the female students in high school and university discovered that high school female students had a knowledge of the transition and had gained insights into the experiences during their first semester at the university. The question of what kind of help they would anticipate during the transition period was put to the students. Two-thirds of the students thought that their immediate families were the most helpful and significant during the adjustment. Less pupils said that parents are the most helpful, and a tiny percentage mentioned family, friends, instructors, senior students, and senior students as sources of support (Thuo et al., 2017).

A study done in Sidney shows that the decision to arrive and actual arrival was built around a set of competing and restrictive conditions for older students. All the students came to the university with their expectations, hopes and future goals. In some cases, these were unfulfilled and at times, the reality of this experience was completely overwhelming. As the interviewees reflected on this decision to arrive and then the actual arrival, their narratives were characterized by resilience and determination. As an interviewer, I found myself questioning whether I would have the same level of motivation if many such barriers are encountered, perhaps this process will become clearer as we explore more deeply the true meanings of the university which held for these women, especially the older students (Shea, 2008)

Challenges

In this study most of participants were faced to the challengers in their clinical environment. Accordingly, the study published in the journal of international students reveals that learners discovered that the academic demands, social demands, and emotional responses of their new lifestyles presented challenges.

Students employed both behaviors that could help them adapt to the new culture and behaviors that could hinder adaptation to solve their concerns. Coping mechanisms, utilizing helpful individuals, observing, and imitating others, and reflecting are examples of facilitative behaviors. Expecting others to adjust, complaining, and retreating are actions that are seen as blocking adaptation (Gebhard, 2012).

Another Chinese study shows that it is challenging for Chinese students studying in the United States to adjust to the interactive learning environment and subculture of universities. All of these difficulties may have a significant impact on their academic performance, emotional health, and overall university experience. However, they are eventually successful in successfully adjusting to their future lifestyle (Oramas & Mitchell, 2018).

In terms of challenges, the study conducted in Sydney shows that all the women in this study faced challenges at different stages of the year in both public and private domain. For some, students the most critical challenge was just staying and persisting at university. But the challenges experienced by the students were not always clearly defined or mentioned (Shea, 2008).

According to a study on challenges conducted at a Japanese college, students' entire lives can be made better by having a high level of perceived difficulties and abilities. Additionally, given the higher level of Jujitsu-kan that was seen in the flow condition and at the higher level of the flow channel, it suggested that balanced high-challenge/high-skill conditions were essential for the Japanese to maintain their psychological health (Asakawa, 2004). In this study the university student has the challenge to adapt to the English medium degree programme and terminologies. Similar difficulties are encountered by Tidar University students who are learning English as a foreign language. Lack of communication, low or uneven engagement, and use of mother tongue are the issues. In this situation, students are more concerned about using proper English, avoiding mistakes, and avoiding criticism. Students worry about their pronunciation, grammatical structure, and vocabulary because they are scared that the other students will criticize them. However, despite their worries, many students are quite ease speaking English (Riadil, 2020).

Relationship with the staff

In this study, Students have more positive perception on relationship with the staff. The participants stated that the lecturers helped them a lot to adopt their selves for the university settings and to gain good knowledge. Similarly, the study conducted in UK medical schools identified several instances of competent, approachable role models and valued qualified teachers help the students to achieve their academic performance. They spoke of a hierarchical and hostile environment in the medical school, where unscheduled instruction and teaching by humiliation frequently take place, particularly in the clinical setting (Lempp & Seale, 2004). Another study conducted in the UK reveals that there is a causal link between changes in students' evaluations of their academic environment and changes in their academic

performances (Richardson, 2006). The expectations of the students at the University of East Anglia Medical School were higher than their actual judgments of learning, teachers, and their own academic and social personalities. Expected and actual perceptions of the atmosphere were identical (Miles & Leinster, 2007) Similar to the Australian study, which found that students' perceptions of a good teaching environment influence their deep approaches to learning, students' perceptions of a negative teaching environment influence their preference for superficial ways to learning. The effectiveness of the instruction and the suitability of the evaluation serve as reliable indicators for the students' in-depth study methods. Learning results are influenced by views of the teaching environment both directly (perceptions to outcomes) and indirectly (perceptions to approaches to outcomes). Therefore, despite not necessarily influencing students' learning techniques, changes in teaching environments may have an effect on students' learning outcomes. Academic achievement is strongly influenced by positive teacher perceptions, but more crucially, so are the quality of learning results. It is believed that learning environments defined by excellent teaching and independence are the greatest places for the development of general academic and workplace abilities (Lizzio et al., 2002). According to a study conducted in Kenya, relationships between students and lecturers need to be improved in higher education. It is advised that academics be given a suitable working environment, which involves, among other things, the provision of offices, adequate teaching facilities, and better remuneration. Due to their commitment to their parent institutions and higher income, lecturers and professors are more accessible to their students during working hours (Chepchieng et al., 2006).

CONCLUSIONS

The study showed a range of opinions, with more encouraging findings regarding adjusting to the Transition and relationships with the staff. The resources that are on hand in the clinical setting are of more concern to students. They have differing opinions about the educational opportunities presented in theoretical and clinical settings. Therefore, with the assistance of the staff, the medical undergraduate students successfully managed the transition status while highlighting the difficulties encountered in the clinical setting.

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Comparison of unpurified and purified *Kanthakam* (Sulphur) on the basis of mineral content and particle size

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ABSTRACT

Kanthakam (Sulphur) is used for industrial purpose and medicinal preparation from ancient time even though Sulphur possesses toxic effect. More over Siddhas and alchemists created detailed information about utilizing Sulphur, with its supreme curable effects. But Sulphur preparation developed with specified purification process. The study started with the question why did the Siddhas establish numerous different ways to purify Sulphur? Therefore, five samples were prepared (S1 Sulphur, S2 poured to milk once, S3 poured to Plantain stem Juice ten times, S4 *pudam* with Henna leaves and curd seven times, S5 poured to milk thirty times) with four different methods of purification and underwent particle size comparison, and ICP OES analysis, because knowledge of elements with its concentrations and particle size of drug is important in determining the efficacy of medicine. The results gave considerable changes before and after purification process as well as during every method of purification. From the ICP OES, the amounts of carbon, calcium, sodium, and phosphorus increased with each purification. Whereas Iron, Manganese, and Sulphur decreased compared to unpurified samples. In addition, levels of As, As, Cd, Cl, Cu, Hg, Pb, and Si were below detection limit in all five samples. Every

method of purification was effective for treating disease even when there were trace amounts of heavy metals present. Particle size decreased significantly in this sample S5, decreasing from 1247 dnm to 468.0 dnm. Particle size of drug determines specific degree of pharmacokinetic. As a result, the purification methodology should be selected according to siddha statements were mandatory for medicine preparation.

Keywords: ICP-OES, *Kanthakam* (Sulphur), Particle size, Purification

INTRODUCTION

Nonmetallic bright yellow and crystalline solid Sulphur (*Kanthakam*) (Sampasivam Pillai, 1998) historically known as brimstone, which means "Burning stone" (Earnshaw & Greenwood, 1997) and Sulphur is referred as "the smelly" (Sanskrit: Gandhaka) in the applied alchemy tradition (White, 1996). Even though Sulphur has a poisonous effect, Sulphur has been utilized for therapeutic preparation for a very long time. Natural Sulphur compounds can be found in sulfide minerals including cinnabar- which has mercury sulfide, pyrite- which has iron, and sphalerite- which has zinc. Others include sulfate minerals like gypsum- which includes calcium, and barite- which contains barium. (Steudel, 2003). Even the inert element iridium interacts with sulfur to produce iridium disulfide (Munson, 1968).

Industrial uses of Sulphur include the production of sulphuric acid, dyes, agrochemicals, fertilizers, fungicides, pesticides, and bactericides, as well as the production of wine and food preservation. The usage of Sulphur compounds in modern medicine includes the antibacterial sulfonamides (Cremlyn, 1996) Magnesium sulfate (Epsom salts) as a laxative and medication for seborrheic dermatitis, etc. and in siddha mild (Skin rashes, itching, allergic), moderate to severe (Leprosy, arthritis, skin aliments etc.) were managed.

A toxic consequence of sulphur caused by an unpurified and excessive quantity of Sulphur. The poisonous symptoms range from mild eye and throat irritation to severe vascular damage in the brain, heart, and kidney, hypothalamic dysfunction, blood circulation problems that cause heart damage, effects on the eyes and eyesight, reproductive failure, immune system damage, and teratogenic effects (Nehb et al., 2006).

Since the eight century AD, siddhas have written extensively about the use of Sulphur (Ramasamy, 2016) in alchemical processes using mercury (Madhavan, 2009). The Siddha medical system has improved Sulphur preparation by using the appropriate purifying method (Aahib, 2007). Thus, the detoxification process eliminates physical and chemical contaminants, improves brittleness, and boosts the effectiveness of medicine (Mohan, 2019) while having synergistic effects with other metals (Gurusironmani, 1999). The investigation began by asking why the Siddhas created so many distinct processes for purifying sulphur (Murugesa muthaliyar, 2003). As a result, four distinct widely utilized methods of purification were used to test the particle size and mineral content (by ICP OES-Inductively coupled plasma optical emission spectrometry). Understanding these components and their quantities in the drug is crucial for evaluating its efficacy. Particle size also plays a significant impact in the pharmacokinetics of medicine.

METHODOLOGY

Preparation of study samples

Sulphur brought from raw drug retail shop Tirunelveli, India and got authentication by Animal and Mineral Origin Drug Research Laboratory (AMDRL) of Siddha Central Research Institute Chennai purified by four different methods. As mentioned in Figure 1, S1 (Sample I) - unpurified Sulphur, S2 (Sample II) - Sulphur melted and poured into milk this procedure was done only one time, S3 (Sample III) - Sulphur melted and poured into Plantain stem (*Musa acuminata*) juice and this procedure was repeated ten times, S4 (Sample IV) - Sulphur has undergone the *pudam* process (*Lawsonia inermis* leaves and curd were utilized as the basis for *pudam*) and carried out this step seven more times, and S5 (Sample V) - thirty times, Sulphur was melted and then poured into milk (Thiyagarajan, 2009).

Description	S1 (Sample I)	S2 (Sample II)	S3 (Sample III)	S4 (Sample IV)	S5 (Sample V)
Sulphur (*Kanthakam*)					

Figure 1. Prepared samples for study

Analysis by Inductively coupled plasma optical emission spectrometry (ICP-OES)

ICP-OES is widely employed for the estimation of metals and metalloids at trace, minor and major concentrations. The elemental composition of a sample is often an important part of the information needed to assess its properties. ICP-OES study was done in The Sophisticated Analytical Instruments Facility (SAIF), Indian Institute of Technology Madras (IITM), Chennai. Perkin Elmer Optima 5300 DV was used for standard ICP-OES analysis. ICP OES, operates by subjecting a sample to a high – temperature argon plasma, causing the atoms in the sample to become ionized and emit characteristic wavelengths of light. A spectrometer then measures the emitted light to determine the elemental composition and concentration of the sample, making it a powerful technique for precise and simultaneous analysis of multiple elements in various samples.

Sample preparation for ICP–OES

Separately weigh 0.25 g of Unpurified Sulphur(S1), Purified Sulphur (S2), Purified Sulphur (S3), Purified Sulphur (S4) and Purified Sulphur (S5) samples separately and transmit into the linear provided by the instrument. In order to prevent any sample from sticking to the slide, 9ml of sulfuric or nitric acid should be added slowly. Allow it to react for a while after thoroughly mixing. Put the lining into the inner jacket. Turn the screw cap as you turn it in a clockwise manner. Place the rotor fixed in a microwave and then seal the container. Set the thermostat to 180^{o}C and maintain it there for at least 10 minutes.

Permit the vessels to cool below 60°C and surface temperature (IR) below 50°C. A Millipore water solution was used to dilute the digested material in to 100 ml. The Whitman filter paper was used to filter the solution to get rid of the visible insoluble particles. Put the digested solution in labeled plastic containers (Sharma et al., 2020).

Particle size

Particle size study was done in the center for Advanced Research in Indian System of Medicine (CARISM), SASTRA, Thanjavur. To establish the average particle size of the Sulphur, zeta sizers were used. The study was conducted at temperature of 25°C with water as a dispersion media. The count rate was 213.4 Kcps, and the measurement location was 5.5 mm. (Sigfridsson, 2009).

RESULTS AND DISCUSSION

ICP-OES

The sample S1 (0.35075 g), S2 (0.25075 g), S3 (0.11075 g), S4 (0.23075 g) and S5 (0.23075 g) reveals the ICP–OES test result of all sample shown in the Table 1. The Sulphur, Carbon, Calcium, Iron, Potassium, Manganese, Sodium, Phosphorus and Zinc were quantified. There were additional components present at levels below detection.

Table 1. Concentration of elements detected in samples by ICP-OES

No	Element	Wave length(nm)	Concentration -mg/L				
			S1	S2	S3	S4	S5
01.	Al- Aluminium	396.152	BDL	BDL	BDL	BDL	BDL
02.	As- Arsenic	188.979	BDL	BDL	BDL	BDL	BDL
03.	C- Carbon	193.030	05.350	10.350	32.350	55.350	95.350
04.	Ca-Calcium	315.807	02.180	40.180	45.180	95.180	105.180
05.	Cd- Cadmium	228.802	BDL	BDL	BDL	BDL	BDL
06.	Cl- Chlorine	725.670	BDL	BDL	BDL	BDL	BDL
07.	Cu- Copper	327.393	BDL	BDL	BDL	BDL	BDL
08.	Fe- Iron	238.204	00.376	00.176	00.106	00.106	00.106
09.	Hg- Mercury	253.652	BDL	BDL	BDL	BDL	BDL
10.	K- Potassium	766.491	1.821	00.821	00.101	02.101	02.101
11.	Mn- Manganese	257.610	01.104	00.104	00.104	00.104	00.104
12.	Na- Sodium	589.592	24.320	20.320	70.320	75.320	70.320
13.	Pb- Lead	220.353	BDL	BDL	BDL	BDL	BDL
14.	P- Phosphorus	213.617	26.341	36.341	66.341	96.341	120.341
15.	S- Sulphur	180.731	811.254	800.254	750.254	700.254	650.254
16.	Si- Silicon	251.611	BDL	BDL	BDL	BDL	BDL
17.	Zn- Zinc	206.200	01.018	01.018	01.018	01.018	01.018

*BDL: Below detection limit

ICP-OES provide evidence that carbon is present and increase the amount of all purification methods S1, S2, S3, S4 and S5 respectively in the amount mg/L 5.350, 10.350, 32.350, 55.350 and 95.350 in the wave length of 193.030 nm. Calcium also increased with the method of purification S1, S2, S3, S4 and S5 respectively 2.180, 40.180, 45.180, 95.180 and 105.180 in wave length 315.807 nm. Iron slightly reduced after purification from S1 - 0.376 to S2 0.176 and 0.106 in S3, S4 and S5 with the wave length of 238.204 nm. Potassium present in the amount of S1 - 1.821, S2 - 0.821, S3 - 0.101 then S4 and S5 - 2.101**.** Manganese reduced in purified all samples (S2, S3, S4, S5) to 0.104 from 1.104. Sodium increased in the samples S1, S2, S3, S4 and S5 respectively 24.320, 20.320, 70.320, 75.320 and 70.320. Phosphorus also increased to the rate of S1 - 26.341, S2 - 36.341, S3 - 66.341, S4 - 96.341 and S5 - 120.341. Sulphur show reduction S1- 811.254, S2 - 800.254, S3 - 750.254, S4 - and S5 - 120.341. There were no changes in the amount of Zinc**.** Finally, Al, As, Cd, Cl, Cu, Hg, Pb and Si presented below the limit of detection (Anonymous, 1987; Rajalakshmi et al., 2010; Rajalakshmy, 2017). Every mineral is very essential for human physiological and biochemical activities. From the analysis with Sulphur adding other mineral would be more beneficial for medicinal field.

Particle Size

The mean particle size of S1, S2, S3, S4 and S5 were analyzed using zeta sizer. The particle size has been significantly reduced in the S5 sample compared to other samples. S4 particle size more or less similar to the S1.

All samples had smaller particles, which aided in the drug's integration into the body and eased absorption. S1 Z-Average (d.nm):1247 this size reduced after purification 640.2 d.nm, 608.4 d.nm, 1127 d.nm and 468.0 d.nm respectively in S2, S3, S4 and S5. Among samples S5 Particle size was significantly reduced. Smaller particles are more bioavailable, have a bigger surface area, and absorb substance more quickly. In order to maintain pharmacological capability over time, the stability of the nanoparticles is essential (Sigfridsson, 2009).

S1 - Sample 1

			Size (d.nm):	% Intensity:	St Dev (d.n...
Z-Average (d.nm):	1247	Peak 1:	563.5	100.0	95.31
PdI:	0.756	Peak 2:	0.000	0.0	0.000
Intercept:	0.819	Peak 3:	0.000	0.0	0.000

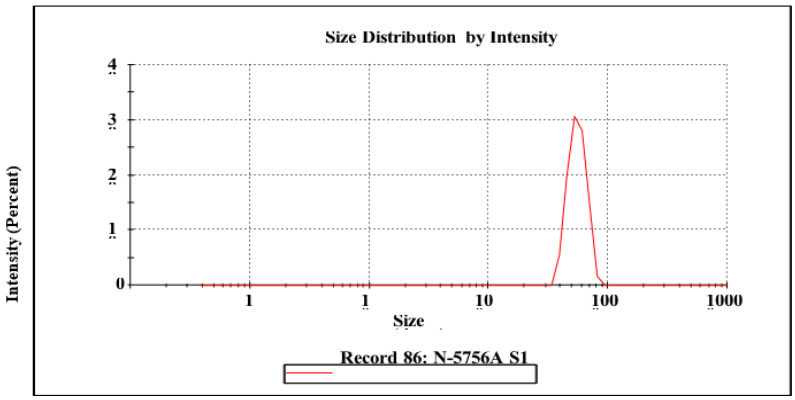

Figure 2. S1 – Particle size

S2 - Sample

		Size (d.nm):	% Intensity:	St Dev (d.n...
Z-Average (d.nm): 640.2	Peak 1:	511.7	100.0	152.3
PdI: 0.473	Peak 2:	0.000	0.0	0.000
Intercept: 0.765	Peak 3:	0.000	0.0	0.000

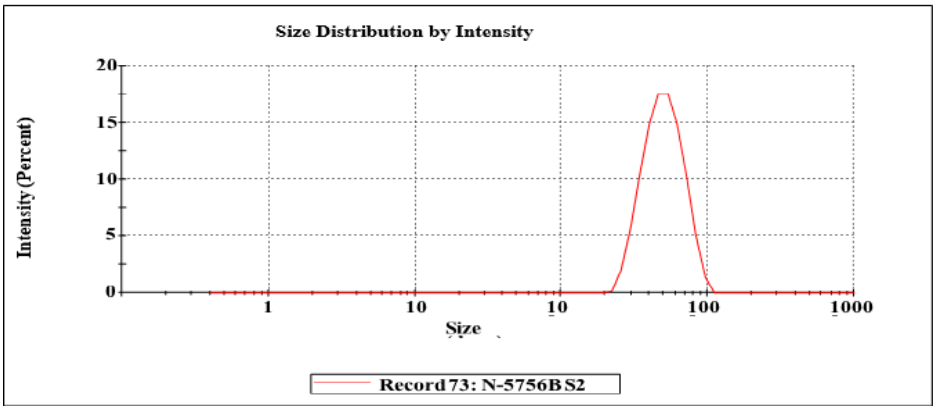

Figure 3. S2 – Particle size distribution graph

S3 - Sample 3

		Size (d.nm):	% Intensity:	St Dev (d.n...
Z-Average (d.nm): 608.4	Peak 1:	335.2	91.2	66.44
PdI: 0.542	Peak 2:	71.50	8.8	10.81
Intercept: 0.845	Peak 3:	0.000	0.0	0.000

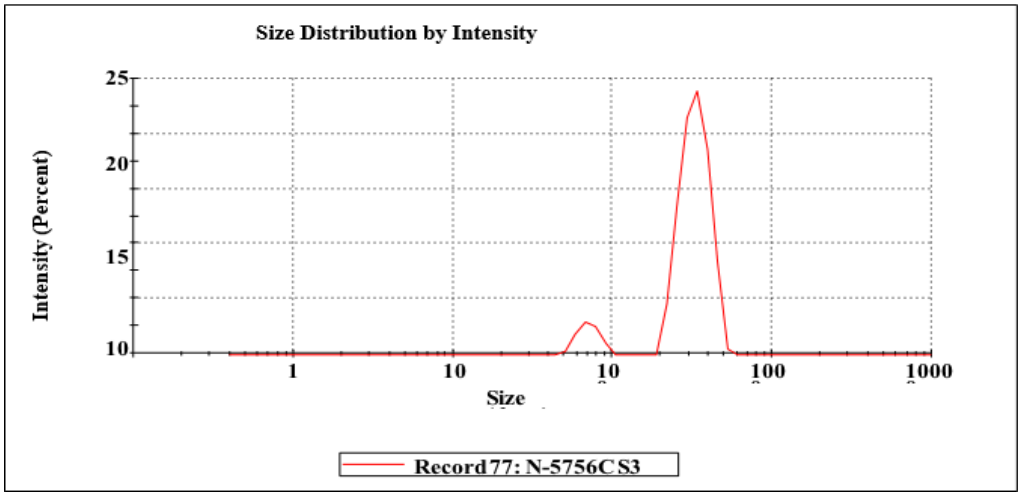

Figure 4. S3 – Particle size distribution graph

S4 - Sample 4

			Size (d.nm):	% Intensity:	St Dev (d.n...
Z-Average (d.nm):	1127	Peak 1:	578.7	100.0	80.76
PdI:	0.613	Peak 2:	0.000	0.0	0.000
Intercept:	0.802	Peak 3:	0.000	0.0	0.000

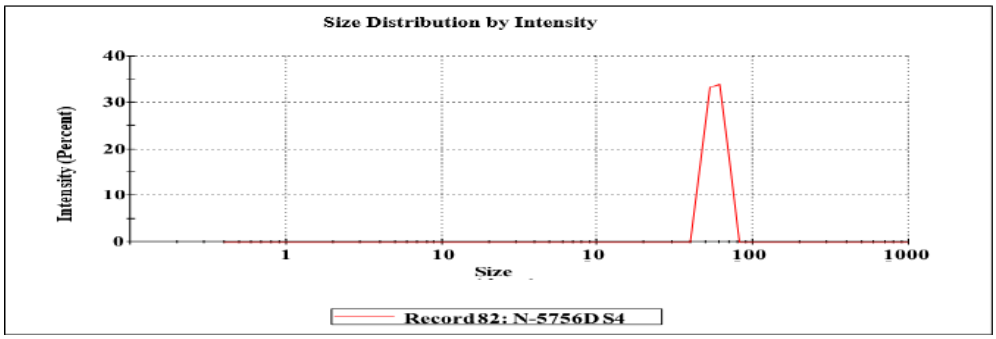

Figure 5. S4 – Particle size distribution graph

S5 - Sample 5

Z-Average (d.nm):	468.0	Peak 1:	548.0	87.1	184.9
PdI:	0.413	Peak 2:	102.2	9.8	21.78
Intercept:	0.796	Peak 3:	5376	3.0	325.1
Result quality :	Good				

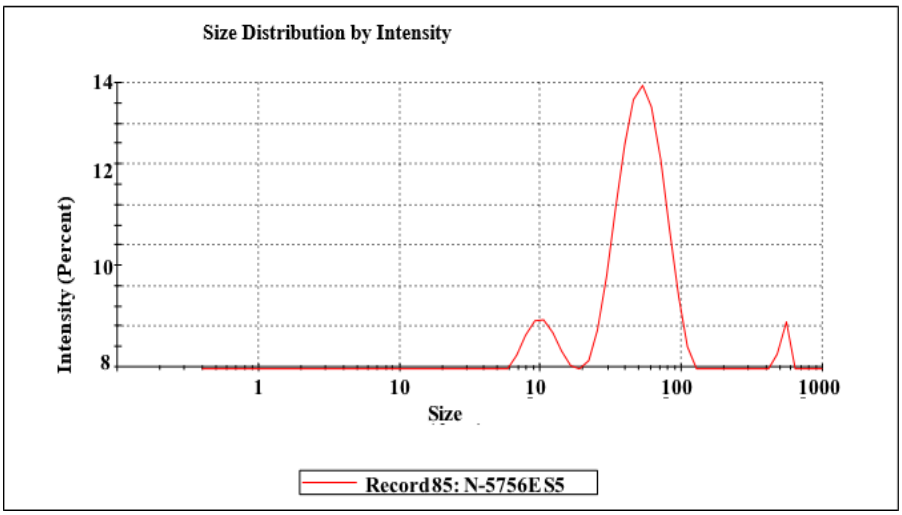

Figure 6. S5 – Particle size distribution graph

Table 2. Particle size comparison

S.No.	Test Parameters	Result	Limit of Detection or Specification	Reference of Testing methods
S1	Particle size	1247 d.nm	NA	CARISM/TP/CHE/33
S2	Particle size	640.2 d.nm	NA	CARISM/TP/CHE/33
S3	Particle size	608.4 d.nm	NA	CARISM/TP/CHE/33
S4	Particle size	1127 d.nm	NA	CARISM/TP/CHE/33
S5	Particle size	468.0 d.nm	NA	CARISM/TP/CHE/33

All samples had smaller particles, which aided in the drug's integration into the body and eased absorption. S1 Z-Average (d.nm):1247 this size reduced after purification 640.2 d.nm, 608.4 d.nm, 1127 d.nm and 468.0 d.nm respectively in S2, S3, S4 and S5. Among samples S5 Particle size was significantly reduced. Smaller particles are more bioavailable, have a bigger surface area, and absorb substance more quickly. In order to maintain pharmacological capability over time, the stability of the nanoparticles is essential (Sigfridsson, 2009).

CONCLUSIONS

The results revealed significant changes before and after the purification procedure, as well as for each purification method, according to the current comparative study. From the ICP OES data, the amount of Carbon, Calcium, Sodium, and Phosphorus increased with each method, whereas Iron, Manganese, Sulphur, and Zinc decreased compared to unpurified samples and remained constant throughout. For all five samples, however, the level of Al, As, Cd, Cl, Cu, Hg, Pb, and Si are below detection limits. In addition, Sulphur with other minerals in samples are beneficial for medicine preparation based on the indication. Particle size decreased, notably among these samples S5 Particle size decreased from 1247 d.nm to 468.0 d.nm. Its bio availability and effect are altered by smaller particle size. Therefore, the purifying technique should be chosen in accordance with Siddha's statements, which were necessary for the preparation of a particular medicine.

RECOMMENDATION FOR FUTURE RESEARCH

All sulphur purification techniques should be done and analyzed with other modern techniques for the purposes of scientific validity and comparison. To test the toxicity, a toxicological investigation using animals should be done after the chemical analysis. In future the toxicological effect of different purified sample will reveal the histopathological changes under this different purification methods.

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Analysis of nutritive value of indigenous livestock feed ingredients in Sri Lanka

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ABSTRACT

Feed cost is a prominent challenge in livestock industry in developing countries. The present study seeks to emphasis locally available and low-cost feedstuffs with a specific focus on fishery and agricultural by-products. Eight by-products were selected based on their availability, consumption avoidance by human, and cost. The samples were assayed by the standard AOAC method for dry matter (DM), ash, crude protein (CP), ether extract (EE), gross energy (GE), and crude fiber (CF). The highest DM was found in broken red rice. Highest CP percentage was recorded in sesame cake, 43.26±0.44. The highest gross energy value was recorded in rice polish, 5271±3.2 kcal/100g. The CP found in different feed ingredients was fall between the ranges of 0% - 43.26%. The obtained EE for ingredients were in the ranges of 0.19% to 9.13% whereas maximum EE was recorded in coconut cake. Among the investigated feed stuffs, sesame cake found to be the best protein source for animal feed. Highest ash content was found in animal based feed ingredient such as shrimp shell (33.78±0.38). Utilization of sesame cake along with black gram husk, coconut cake and rice polish as animal feed ingredients would be more advantageous from the perspective of nutritional value, eco-friendly by-products and cost effectiveness.

Keywords: Crude protein, Feed stuffs, Locally available, Low cost, Proximate composition

INTRODUCTION

Livestock production became a focus point worldwide especially in developing countries as a means of improving animal based protein production that is presently have a big challenge due to the higher production cost. The contribution of animal production to the GDP of Sri Lanka is about 0.6% in 2020 which have shown a decline than 2019, where the contribution was 0.7%. The poultry, aquaculture and dairy subsectors mainly contribute to animal production of the country. Poultry meat production and aquaculture production decreased in 2020 by 3.5% and 5.3%, respectively (Central Bank of Sri Lanka, 2020) which can be attributed to several factors including the availability of feed materials and limited importation of feeds and feedstuffs.

In most cases, the feed cost constitutes 60-70% of the total cost of the poultry production. The compound poultry feed industry profoundly depends on imported feed raw materials such as maize, fish meal, and soya bean meal which makes the feed formulation expensive. Simultaneously the poultry industry has rapidly increased during the last decades, and the total compound feed production also increased. However, owing to higher compound feed cost, there has been a growing tendency for poultry farmers to formulate the animal feed in their own (Premarathne & Samarasinghe, 2020).

The traditional sources of protein and vitamins used in livestock feed production such as soya bean meal, ground nut cake, and bone meal are becoming expensive in developing countries and increasing the feed production cost (Thirumalaisamy et al., 2016). In order to ensure sustainability and efficiency of feed stuffs, there is a necessity to find out the alternative cost- effective agriculture and fishery by-products and establish the nutritional value of available feedstuffs. Proper scientific knowledge for utilizing low-cost, locally available animal-based and plant originated products and by-products is an attempt to reduce the feed cost, it may lead to a considerable reduction in the total cost of poultry production (Babikeret al., 2009; Thirumalaisamy et al., 2016).

Feed ingredients such as rice and rice polish are available for feeding animals in many parts of Asia. Rice polish is the major by-product of rice obtained during the milling process. Red rice flour can be obtained by finely grinding the rice.

Shrimp shell has been identified as protein source in animal feed and these crustacean shells provide various minerals such as calcium, magnesium, potassium, sodium, and phosphorous (Adeyeye & Aremu, 2016). In the Northern part of Sri Lanka, these by-products are mostly underutilized and discarded as industrial waste from seafood factories.

Maize is an important cereal crop grown in Sri Lanka, locally produced maize has lower price and a major part of the yield is used in animal feeds rather than human consumption (Natesan & Jogaratnum, 1997). Coconut cake is a high-protein and high-energy by-product derived from the coconut oil extraction process (Jácome et al., 2002). Coconut cake is rich in protein and commonly used feed ingredient in poultry

feed in Asia (Mondal, 2008). Sesame cake is the by-product of oil extraction from sesame seeds which is rich in protein and considered as ingredient in poultry feed formulation (Fitwi & Tadesse, 2013). Husk of black gram, a waste by-product from seed splitting mill has no commercial value (Saeed & Iqbal, 2003). Palmyrah molasses is a liquid waste material obtained from the production of palmyrah sugar candy (Sinnarasa et al., 2019).

To develop efficient formulated feed, analysis of nutrient composition of feed ingredients is the basic step and typically available test such as crude protein, crude fat, moisture, ash could be performed. Energy content of final feed is an important factor taken into consideration as crude protein, therefore, analysis of energy content of ruminant feedstuffs is essential for a better final output (Chumpawadee, 2002).

The present research work was carried out to evaluate the chemical composition such as crude protein, ether extract, moisture content, ash content, crude fiber, and energy content of locally available low-cost feed ingredients.

METHODOLOGY

The selection of feedstuffs to be covered within this study was based on their non-use for human consumption, availability, and cost. Shrimp shell was obtained from the processing plant and sun-dried. Palmyrah molasses was obtained from palmyrah sugar candy producers while the remaining samples were collected from the local market in Jaffna, Sri Lanka. The collected samples were brought to the laboratory of Department of Fisheries, Faculty of Science, University of Jaffna and ground finely. Proximate analyses of the ingredients were done using the following standard methods.

Dry matter (DM) content

The dry matter content was calculated as the remaining weight of the original sample after kept in Hot air Sterilizer at 104°C and expressed as percentage dry matter content (AOAC, 2005)

Ash content

The dried sample was incinerated overnight at 600^{o}C in a muffle furnace. The weight of the residual ash was calculated (AOAC, 2005).

$$\text{Ash content (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100$$

Crude protein (CP)

The crude protein was determined by the Kjedhal method. The percentage of nitrogen was calculated and multiplied by 6.25 to obtain the value of the crude protein (AOAC, 2005).

Crude fat

The Soxhlet extraction technique described by Redfern et al. (2014) was used for the determination of the oil content of samples. Crude fat can be extracted by solvent extract method and the most commonly used solvent is petroleum ether. Therefore, crude fat can be referred to as ether extract (EE) (Min & Steenson, 1998).

$$\text{Crude fat/ Ether extract (EE)} = \frac{\text{Weight of fat (g)} \times 100}{\text{Sample weight}}$$

Determination of gross energy (GE)

The gross energy was determined by E2K Bomb Calorimeter (Miller & Payne, 1959).

Crude fiber (CF)

The sample after crude fat determination was used to determine the fiber content according to AOAC (2005) method.

$$\text{Crude fiber \%} = \frac{\text{loss in weight of sample on incineration (g)} \times 100}{\text{Initial weight of sample (g)}}$$

Statistical analysis

All data generated were analyzed using one-way analysis of variance (ANOVA) using R version 4.0.3. The significance difference level of 0.05 was applied to all statistical analyses.

RESULTS AND DISCUSSION

In Sri Lanka large variety of fishery and agriculture wastages and by-products are wasted without any utilization. In the present study, the locally available feed ingredients were found to be red broken rice, rice polish, maize, sesame cake, coconut cake, black gram husk, shrimp shell, and palmyrah molasses and their proximate analysis and gross energy of all ingredients are presented in Table 1.

Table 1. Nutrient composition of feed ingredients available in Jaffna, Sri Lanka (g per 100 g dry weight basis, mean ± SD, n=3)

Ingredients	DM (%)	CP (%)	EE (%)	Ash (%)	GE (kcal kg^{-1})	CF (%)
Broken red rice	98.97±0.41	7.46±0.61	1.47±0.83	2.4±0.054	4069±7.4	10.99±0.41
Maize	93.62±0.69	9.42±0.57	3.2±0.04	2.76±0.21	4417±4.1	6.04±0.69
Sesame cake	97.64±0.55	43.26±0.44	8.67±0.09	10.05±0.11	4679±6.7	2.41±0.55
Coconut cake	90.71±0.62	14.73±0.78	9.13±0.05	11.97±0.17	4836±6.1	12.38±0.62
Rice polish	94.27±0.52	11.51±0.42	7.37±0.08	9.37±0.24	5271±3.2	9.28±0.52
Black gram husk	95.5±0.83	19.6±0.28	2.5±0.07	13.24±0.47	3980±5.9	21.50±0.83
Shrimp shell	90.54±0.96	17.21±0.53	2.8±0.04	33.78±0.38	3017±5.1	8.53±0.71
Palmyrah molasses	37.46±1.24	0	0.19±0.03	5.44±0.08	3421±6.7	0

The DM content of the assessed ingredients was significantly different ($p<0.05$) and ranged from 37.46% to 98.97%. High DM was found in red rice followed by sesame cake and lower DM was found in palmyrah molasses. Except palmyrah molasses, all the other feedstuffs have shown a higher DM level above 90% (Table 1). Moisture content is a crucial factor to consider when choosing ingredients, as greater than 12% (lower than 88% DM) moistness accelerates decomposition during storage (Akiyama, 1988). No significant difference ($p>0.05$) was found in DM between coconut cake and shrimp shell and also between black gram husk and rice polish. The moisture content of shrimp shell was found to be 9.46% which was higher than the results (12.20%) obtained by Bhuiyan (2018). The DM of coconut cake was in agreement with the findings of Moraes et al. (2020), Moorthy & Viswanathan (2009), and Gunathilake & Abeyrathne (2008).

Protein is a necessary supplement for body support and development. The CP gives the amount of all the reduced nitrogen in the food in the form of amine, ammonium compound, urea, and amino acid (Dawodu et al., 2012). Among the assessed ingredients, crude protein content was found significantly ($p<0.05$) higher in sesame cake (43.26%) while lower in palmyrah molasses (0%). The variation happened due to the different cultivars and crop species (Islam et al., 2021; Islam et al., 2022). The investigated CP of red rice was in agreement with the findings of Dawodu et al. (2012), Oppong et al. (2021), Carceres (2014), and Khan et al. (2005). CP of rice polish (11.51%) in the present study was in agreement with the results obtained by Dawodu et al. (2012). The CP of black gram husk was recorded as 19.6%. This finding was in agreement with the results obtained by Jain (1983) and Arulnathan et al. (2013).

The CP of maize in the present study was found to be 9.42%. Adéyèmi et al. (2020), Qamar et al. (2016) and Ullah et al. (2010) have reported similar results. The CP of sesame cake in the present investigation was found to be 43.26% in agreement with the findings of Babiker et al. (2009) and I.S.L (1961). The CP level of coconut cake

obtained from this study was 14.73% which is slightly lower than the results obtained by Santhiralingam & Sinniah (2018).

The EE content for the experimental feed ingredients ranged from 0.19%-9.13%. The high-fat content sources are better energy sources. Among the assessed ingredients, EE was found significantly ($p<0.05$) higher in coconut cake (9.13%) followed by sesame cake (8.67%) while lower in palmyrah molasses (0.19%). Oil seed cakes such as sesame cake and coconut cake have shown the results of EE, 8.67% and 9.13%. The EE of coconut cake found in the present study was in agreement with the findings of Karandeep (2019). The EE of sesame cake found in the present study was in agreement with the results (9.2%) obtained by Chad et al. (1991). The EE of maize in the present study was 3.2%, which was in agreement with the findings of Adéyèmi et al. (2020) and Qamar et al. (2016). No significant difference ($p>0.05$) was found in EE between black gram husk and shrimp shell. The EE of maize and broken rice found in the present study was in agreement with results obtained by Moniruzzaman & Fatema (2022).

The percentage of ash can be regarded as a general measure of food quality. A high percentage of ash content is correlated with high mineral content. The ash content of the assessed ingredients was significantly different ($p<0.05$) and ranged from 2.4% to 33.78%. The highest ash content was recorded in shrimp shells and the lowest ash content was recorded in red rice (Table 1). The percentage of ash (33.78%) obtained in shrimp shells falls between the results (29.5% and 36.15%) obtained by Adeyeye & Aremu (2016) and Ibrahim et al. (2019). The variation in ash content of shrimp shells might be influenced by several factors such as species, sex, day in a month, water quality, etc.

No significant difference ($p>0.05$) was found in ash content between maize and broken rice. Carceres (2014) & Khan et al. (2005) have analyzed the ash content of red rice, those results were in agreement with the findings of the present study. The ash content of rice polish obtained in the present study was 9.37% which shows resemblances with results obtained by Ambreen (2006). The recorded ash content for maize in the present study marginally deviated from the findings of Qamar (2016). The variation might occur due to different plant varieties and culture conditions. The ash content of sesame cake agreed with the results (10.35%) obtained by Mamputu & Buhr (1995).

The investigated results revealed that the GE of feedstuffs varied from 3017–5271 kcal kg^{-1}. Among the investigated ingredients, the GE was found significantly ($p<0.05$) higher in rice polish followed by coconut cake and sesame cake. These ingredients were found to be the best energy source among other feedstuffs. The lowest GE was observed in the shrimp shell sample due to its high percentage of mineral composition which is not an energy source. The GE of coconut cake was agreed with the findings of Moraes et al. (2020), and Moorthy & Viswanathan (2009). The GE of red rice obtained in this study was 4.06 $kcalg^{-1}$, which is comparable to the findings obtained by Sittiya et al. (2011). The palmyrah molasses has higher gross energy, it can be used as an energy source. However, a further scientific study would help to find the importance of the inclusion of palmyrah molasses in animal feed.

Among assessed ingredients, CF was found significantly ($p<0.05$) higher in black gram husk (21.5%), while lower in palmyrah molasses (0%). No significant difference ($p>0.05$) was found in CF between rice polish and shrimp shell.

The CF of rice polish was 9.28%, the results are in agreement with the observation of Ali & Leeson (1995) who reported that CF of rice polish as 9.0%. The investigated CF of maize in thepresent study was 6.04%, this value was in agreement with the findings of Adéyèmi (2020). Sittiya et al. (2011) reported that the CF of rice polish was 10.84%, and the CF of red rice in the present study was in agreement with this finding. CF of coconut cake obtained in the present study was 12.38%, Moorthy & Viswanathan (2009) and Moraes (2020) have reported similar results. CF of black gram husk found in the present study was 21.5%, which was in close line with the results obtained by Jain (1996). Ravichandran et al. (2009) found that the CF of shrimp shells as 8.7%, which is in agreement with the present study. CF of sesame cake was found to be 2.41%, which is in agreement with the findings of Hasan & Khandaker (2000) and Bukya & Vijayakumar (2013).

The variation in the proximate composition of maize and red rice could have been attributed to variety, soil condition, cultivation practices adopted, and temperature. The variation in nutritional composition of coconut cake and sesame cake may have been attributed to plant variety, environmental factors, and the method employed for oil extraction from the seeds. The plant variety and processing method of the kernel could be attributed to the variation found in the proximate composition of rice polish and black gram husk. Meanwhile, variation in the proximate composition of shrimp shells could have been attributed to variations in species composition and seasonal variation.

Utilization of sesame cake along with black gram husk, coconut cake, and rice polish as feed ingredients would be more advantageous from the perspective of eco-friendly by-products and nutritional value.

CONCLUSIONS

Some locally available ingredients can replace imported feed ingredients in animal feed formulation. Incorporation of these locally available ingredients in animal feed would add more value to fishery and agricultural by-products and will also decrease the cost of feed production. Also, utilization of these feed ingredients may invariably provide a better solution to the environmental pollution problem due to the accumulation of these products in coastal regions and processing plants. Overall, the present study reveals that a diversity of local feed ingredients are available in Jaffna, Sri Lanka, to produce different livestock feeds with adequate nutritional compositions to enable efficient livestock feeding.

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AUTHORS GUIDELINES

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Book:
Campbell, C.L. & Madden, L.V. (1990) *Introduction to Plant Disease Epidemiology*. New York, NY: John Wiley & Sons.

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McIntosh, R.A. (1992) Catalogues of gene symbols for wheat. *Proceedings of the 7th International Wheat Genetics Symposium*, Cambridge, UK. 13–19 July 1992. pp. 1225–1323.

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Lenné, J.M. (1978) *Studies of the biology and taxonomy of Colletotrichum species*. PhD thesis, Melbourne, University of Melbourne.

Online material:
Goudet J. (2001) *FSTAT, a program to estimate and test gene diversities and fixation indices v. 2.9.3*. Available at: http://www2.unil.ch/popgen/softwares/fstat.htm [Accessed 22 November 2022].

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