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Contents

Articles

- 1 Microplastics and cosmetics: Problems and solutions**
Pierfrancesco Morganti, Maria-Beatrice Coltelli, Gianluca Morganti
- 10 The impact of land use and cover changes on river flows in Wundanyi Catchment of Taita Hills, Kenya (1970–2030)**
Joy A. Obando, Cush N. Luwesi, Rose Adhiambo Akombo
- 32 Demographic conditions and territorial development of Torre de Moncorvo (North of Portugal)**
Mendonça João
- 40 A research on the people's perception and expectations and the behaviours of the cooperative partners in Balıkesir**
Hayati Başaran, Ebru Irmak
- 53 Patriarchy in Southern Africa and war in West Africa: Twin impediments to sustainable social development in Africa**
Dudziro Nhengu
- 70 Optimizing tourist flows through operative carrying capacity assessment: The case of Bakkhali coastal tourism, W.B., India**
Suchandra Bardhan, Soumik Sarkar
- 90 FIKR (Facet, Insight, Knowledge, and Resilience) personality profile for employee development: Literature emphasizes personality characteristic evaluation**
Chee Kong Yap, Chee Seng Leow, Wing Sum Vincent Leong

99 Developing a model for digital adoption in family business: A proposed research framework

Nyayu Lathifah Tirdasari, Wawan Dhewanto, Neneng Nurlaela Arief

Commentaries

108 Sustainable progress: Art-tech and inclusive education transforming virtual learning for equity and long-term impact

Diego Bernaschina

112 New reflections and strategies for social sustainability through the climate change crisis within inclusive participation and school

Diego Bernaschina

Reviews

117 Towards concentric spatial systems for sustainable social development: Beyond western ethnocentric diametric spatial opposition and empty space

Paul Downes

126 Troubled waters? The disproportionate impact of lead water pollution: Evidence from three American communities

Robert W. Peters, Gail Wallace, Christobel Asiedu, Ghislain N. Gueye, Teresa A. Murray

Article

Microplastics and cosmetics: Problems and solutions

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Abstract: Plastic waste and microplastics are invading lands and oceans, creating problems for animals, human health, and the environment. Packaging, building and construction, textiles, and cosmetic sectors are the main industries that utilize these non biodegradable materials. Thus, there is a necessity to find a new way of producing and consuming skin- and eco-compatible' goods. For this purpose, it's important to remember that the cosmetic and diet supplement markets are continually increasing, due also to the introduction of "Beauty from within," based on the contemporary consumption of cosmeceuticals applied to the skin and nutraceuticals taken by oral route. Moreover, both of these products are made by emulsions or solutions based on a great consumption of water with the use of carriers rich in chemicals, which often cause allergy and sensitization problems. Thus, the proposed solution to use smart tissue carriers, which are embedded with natural ingredients, is based on the use of raw materials and biopolymers obtained from food and agroforestry waste. These new carriers, with a structure similar to the Extra Cellular Matrix, may be used to realize smart cosme-nutraceuticals useful to reduce water consumption, producing innovative products free of emulsifiers, preservatives, colors, fragrances, and other chemicals. So, it will be possible to save human health and the environment by maintaining natural raw materials and the biodiversity of the earth for future generations.

Keywords: cosmeceuticals; nutraceuticals; chitin nanofibrils; nano lignin; waste; microplastics; cosmetic market; diet supplement market; water consumption; skin and mucous barriers

1. Introduction

As known, production and consumption of cosmetics contribute to the microplastics released into the oceans as microbeads by materials used for making buildings and producing foods, cosmetics, packaging, and tissues, all impacting the environment and human health (**Figure 1**) [1]. Microplastics are defined as plastic fragments with a size lower than 5 mm. They released into the oceans have reached the number of 24.4 trillion with a weight between 82 and 578 million tons and an estimated increase of 4.8 to 12 million tonnes yearly (**Figure 1**) [2,3]. This great quantity of plastic microparticles, ingested by fish and marine mammals, enters the food chain up to the human food. In fact, microplastics have been recovered into tea cups, placentas, blood, and drinking water [4–7]. It is suspected that they can act as vectors for potentially toxic elements such as Fe, Mn, Si, S, Pb, Cu, Ag, and Zn and contaminants, including polychlorinated bisphenols and phthalates utilized to make some kind of plastic packaging [8,9]. Textiles can be considered the primary source of microplastics because they are generated during their washing. While the presence

of plastic items in land and ocean can be limited by increased education and new technologies, the microplastics due to the textiles' use cannot be eliminated easily, hence an increased use and consumption of fashionable clothes based on biobased fibres (degradable in water) are promoted day by day [10].

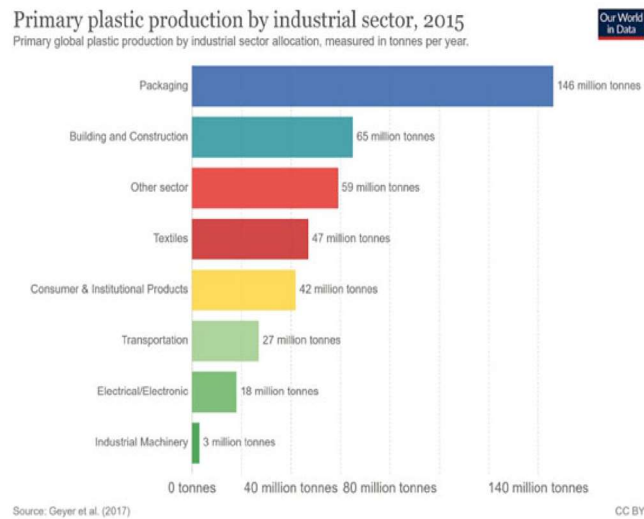


Figure 1. Plastic industrial production cause of the microplastics' release (courtesy of Richie and Roser-Our World in Data [3]).

Regarding the cosmetic products, the global market was valued at USD 375.30 billion in 2022, and it is expected to expand to USD 560.50 by 2030 with a compound annual growth rate (CAGR) of 5.1% from 2021 to 2030 (**Figure 2**) [11]. The principal key factors driving the market are the global aging population and the rapidly changing lifestyle with the adoption of skin care and personal care products by aged and young consumers, driven by social media and the increasing e-commerce [11,12].

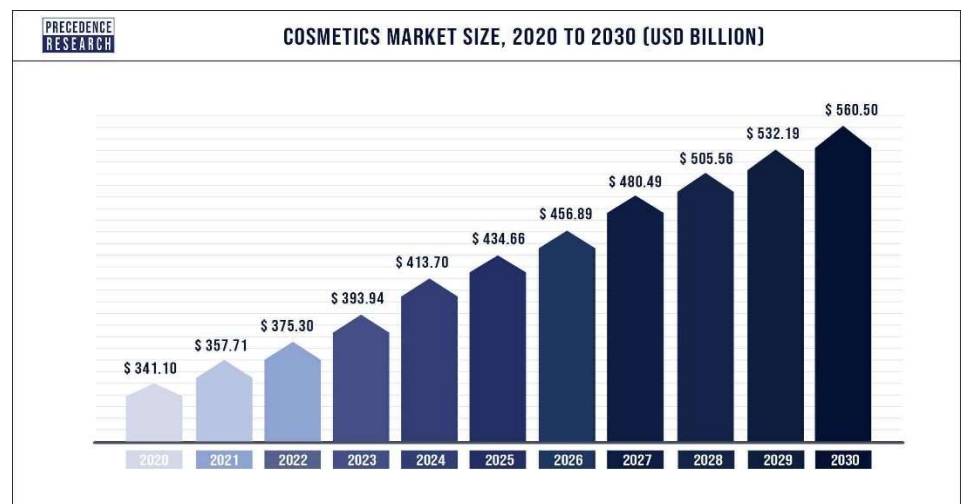


Figure 2. Global cosmetic market (courtesy of Precedence Research Company) [12].

Moreover, for maintaining the actual health and beauty, the so-called “Beauty from within” has born, based on the integration of cosmeceuticals applied to the skin with nutraceuticals (functional food) taken by oral route. Thus, it will be possible to obtain the global health and beauty of the body, acting contemporarily from inside and

outside, by the use of the so-called nutricosmetics [13]. Consequently, it could be useful to add the cosmetic market size (USD 376) to the nutraceuticals ones (USD 493) (**Figure 3**) [9] for understanding the real value of the global beauty healthy market, which, from USD 870 billion in 2022, has been valued to range from USD 1553 billion by 2030 [12,14].



Figure 3. The global nutraceutical market (courtesy of Research and Markets [14]).

At this purpose, it is important to underline that both these products may contain and are packed by plastic polymers such as polyethylene and polypropylene, remembering that the beauty industry only produces more than 120 billion units of not recyclable plastic packaging every year [12,15].

Consequently, it has been valued that the global bottles into which cosmeceuticals and nutraceuticals are filled up will range around 480 billion units by 2029, from the actual 240 billion ones. Moreover, the bottles' fossil origin and limited recyclability due to their incineration and contamination with the product also result in further greenhouse gas emissions.

Therefore, there is the urgent necessity to increase production and use of biobased and biodegradable polymers for realizing innovative skin- and eco-friendly cosmeceuticals and nutraceuticals by sustainable productive processes, reducing the great micro nanoparticles invading the oceans also [1–3,15].

2. Cosmeceuticals & nutraceuticals needs

As a consequence, the consumer request for cosmeceuticals and nutraceuticals that are skin- and eco-friendly is continually increasing. These specific products, in fact, are considered made by natural and biodegradable ingredients, carriers, and packaging and therefore characterized for their high effectiveness and safety [16–19]. However, to be effective, both ingredients and carriers must be capable of passing throughout the keratin-lipid matrix of the skin lamellar membranes as well as the glycoproteic polymer and fibers forming the mucous barrier, possibly maintaining balance in the physiological activity of the microbes living on their surface (**Figure 4**) [19–21]. At this purpose, in fact, it results of fundamental importance not only the active ingredients' selection but also the different carriers (vehicles) used because, driving the penetration of the active molecules through the skin and mucous

membrane' barriers, have the possibility to give effectiveness and texture to the final formulation [19–21].

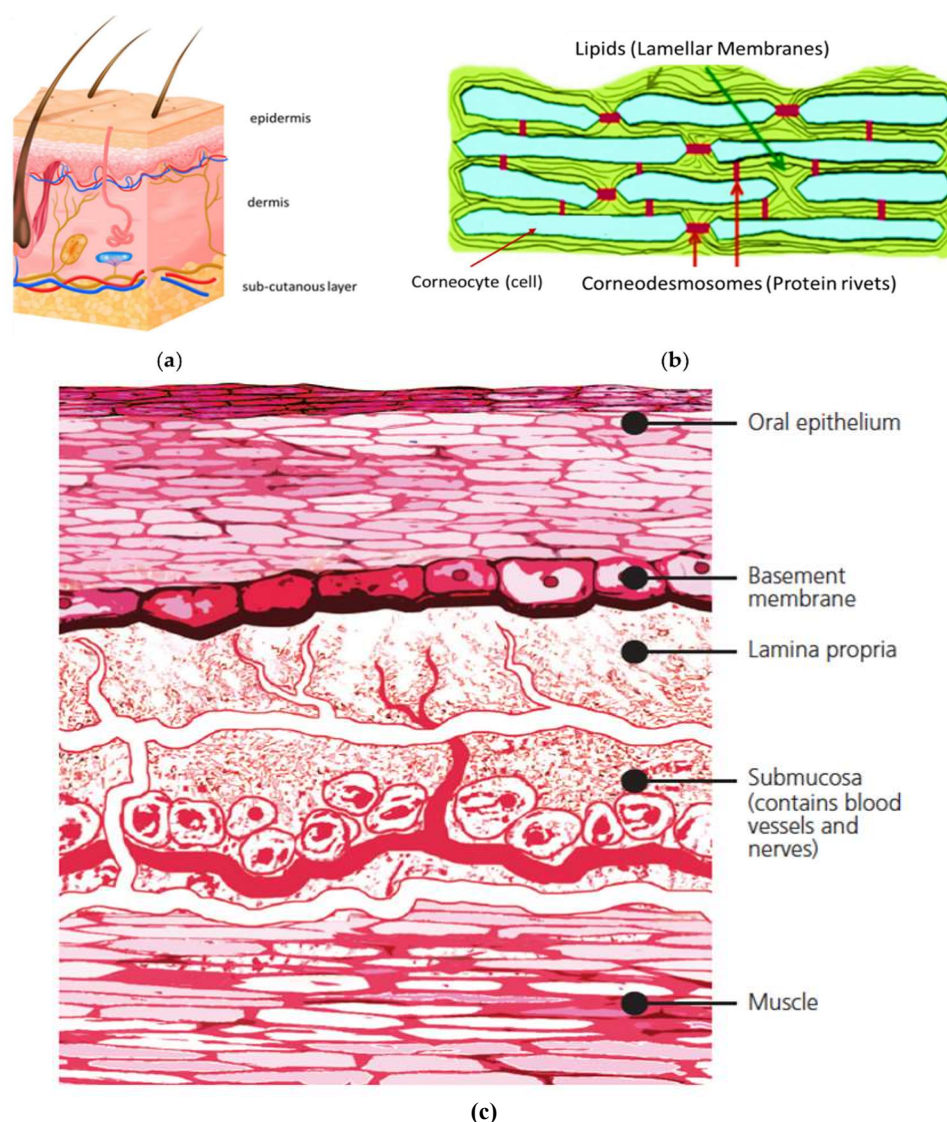
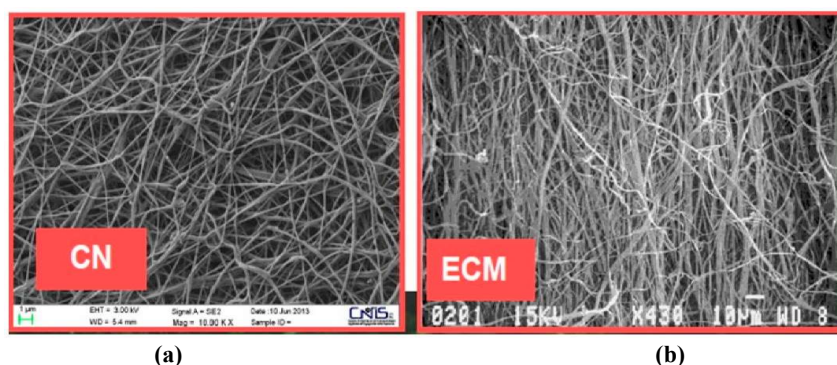


Figure 4. (a) skin structure; (b) corneocytes organized by lipid lamellae; and (c) the mucous membrane.

Skin lipid lamellae and oral epithelium, in fact, modulate the penetration of active ingredients depending on the carrier used naturally; all the selected ingredients have to be biodegradable and obtained possibly by food and agro-forestry waste for maintaining the natural sources and the planet's biodiversity for future generations [22].

It is important to remember, in fact, that “nature and biodiversity loss is a material risk to climate stability, economy and financial increasing and to the global development”. Therefore, protection of biodiversity safeguards climate too, avoiding planet disasters [22]. Unfortunately, the great problem of the biodegradability of both cosmetics and nutraceuticals’ packaging is practically not solved, and the use of non-biodegradable plastic polymers increases year by year. Consequently, polyethylene (PE) dominates the composition of plastic waste at lands and oceans, followed by

1. *Journal of the American Medical Association*, 1997; 277: 1039-1043.



By our technology, the electrospun tissues have been functionalized by embedding the fibers with chitin nanofibril-nanolignin or chitin nanofibril-yaluronan block polymeric complexes (**Figure 6**). These complexes have the possibility to encapsulate different active ingredients, necessary to characterize the final product: cosmeceutical or nutraceutical [32–34]. It is interesting to underline that these smart tissues, made by biodegradable water-soluble or water-insoluble polymers embedded by selected active bio-ingredients, may be applied on the skin and/or on oral mucous membranes, acting as tissue-regenerative products [32–35]. Moreover, the usual non-biodegradable polypropylene support, normally utilized for the non-woven tissues made by the electrospinning technology, has been substituted by a biodegradable bamboo tissue, rendering globally biodegradable the final product for both the ingredients used and the packaging materials [36,37].

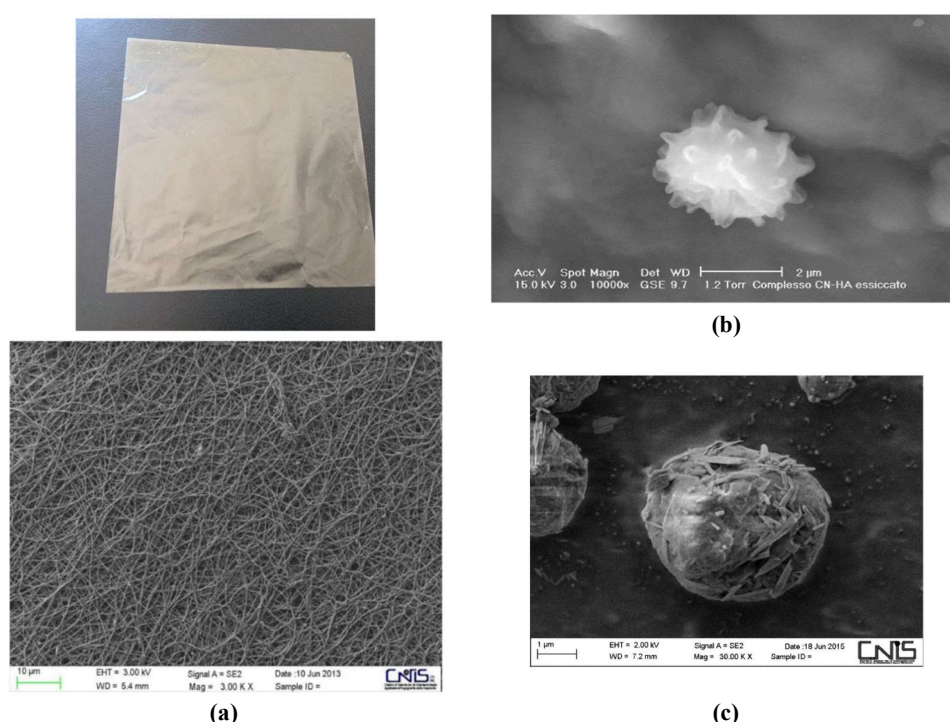


Figure 6. (a) tissue structure (up) and at SEM (down); (b) chitin nanofibrils yaluronan; (c) chitin nanofibrils-nanolignin.

4. Conclusion

As reported by many scientific papers, plastics and microplastics' invading lands and oceans became a great problem to be solved for saving human health and the environment. Thus, the necessity to change the way of living ameliorates our actual economic and social approaches, transforming the current linear model of economy based on “take-make-consume-throw away” in a circular economy. This new producing circular methodology, in fact, keeping in use products and materials of post-consumption waste rich in high-value natural resources, might achieve and facilitate a greater level of social and environmental sustainability [38–43]. Therefore, the proposed use of smart biodegradable tissues as new vehicles able to carry natural active ingredients through the skin layers and/or the mucous membranes could be useful to make innovative cosmeceuticals and nutraceuticals [19,29,30,44–47]. These

new carriers seem also able to slow down the actual worldwide side effects (i.e., allergic and sensitizing phenomena), being free of water, preservatives, emulsifiers, fragrances, colors, and other chemicals normally contained in the actual in-use emulsions. In conclusion, these natural-made tissues could be useful to realize innovative and sustainable products that are skin- and environmentally-friendly and packed in biodegradable plastic-free containers [9,19,48–50]. Moreover, by this new way of producing, it will be possible to partially reduce the great quantity of plastics and microplastics invading lands and oceans, safeguarding the natural raw materials and the planet's biodiversity for future generations.

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References

1. Ziani K, Ionita-Mindrican CB, Mititelu M, et al. Microplastics: A real global threat for environment and food safety: A state of the art review. *Nutrients*. 2023; 15(3): 617. doi: 10.3390/nu15030617
2. Isobe A, Azusa T, Cordova MR, et al. A multilevel dataset of microplastic abundance in the world's upper ocean and the Laurentian Great Lakes. *Microplastics and Nanoplastics*. 2022; 1(1): 1-14. doi: 10.1186/s43591-022-00013-z
3. Richie H, Roser M. Plastic pollution, Our World in Data. Available online: <https://ourworldindata.org/plastic-pollution> (accessed on 25 January 2024).
4. Hernandez LM, Xu EG, Larsson HCE, et al. Plastic tea bags release billions of Microplastics and nanoparticles into tea. *Environmental Science and Technology*. 2019; 3(21): 12300-12310. doi: 10.1021/asc.est.9b02540
5. Ragusa A, Svelato A, Santacroce C, et al. Plasticenta: First evidence of microplastics in human placenta. *Environment International*. 2021; 146: 106274. doi: 10.1016/j.envint.2020.106274
6. Leslie HA, van Velzen MJM, Brandsma SH, et al. Discover and quantification of plastic particle pollution in human blood. *Environment International*. 2022; 163: 107199. doi: 10.1016/j.envint.2022.107199
7. Shen M, Zheng Z, Wen X, et al. Presence of microplastics in drinking water from freshwater sources: The investigation in Changsha, China. *Environmental Science and Pollution Research International*. 2021; 28(31): 42313-42324. doi: 10.1007/s11356-021-13769-x
8. Verla AW, Enyoh CE, Verla EN, Nwarnorh KO. Microplastics-toxic chemicals interaction: A review study on quantified levels, mechanism and implication. *SN Applied Sciences*. 2019; 1: 1400. doi: 10.1007/s42452-019-1352-0
9. Morganti P, Morganti G, Gagliardini A, Lohani A. From cosmetics to innovative cosmeceuticals—Non-woven tissues as new biodegradable carriers. *Cosmetics*. 2021; 8(3): 65. doi: 10.3390/cosmetid8030065
10. Bianchi S, Bartoli F, Bruni C, et al. Opportunities and limitations in recycling fossil polymers from textiles. *Macromol*. 2023; 3(2): 120-148. doi: 10.3390/macromol3020009
11. Westbrook G, Angus A. Top 10 global consumer trends 2021. Available online: <https://go.euromonitor.com/white-paper-EC-2021-Top-10-Global-Consumer-Trends.html> (accessed on 25 January 2024).
12. Precedence Research. Cosmetics market trends and forecast 2021-2030. Available online: <https://www.precedenceresearch.com/> (accessed on 25 January 2024).
13. Morganti P. Natural products work in multiple ways. In: Tabor A, Blair RM (editors). *Nutritional Cosmetics: Beauty from Within (Personal Care and Cosmetic Technology)*, 1st ed. William Andrew; 2009.
14. RM. *Nutraceuticals Global Market Report*. Research and Markets; 2023.

15. Plastic Pollution Coalition. The ugly side of beauty: The cosmetics industry's plastic packaging problem. Available online: <https://www.plasticpollutioncoalition.org/blog/2022/1/25/the-ugly-side-of-beauty-the-cosmetics-industrys-plastic-packaging-problem> (accessed on 25 January 2024).
16. Tolnay A, Koris A, Magda R. Sustainable development of cosmetic products in the frame of the laboratory market. *Visegrad Journal on Bioeconomy and Sustainable Development*. 2018; 7(2): 62-66. doi: 10.2478/vjbsd-2018-0012
17. Fisher A. Sustainable skincare in 2021 and beyond. Available online: <https://www.mintel.com/beauty-and-personal-care-market-news/sustainable-skincare-in-2021-and-beyond/> (accessed on 25 January 2024).
18. Dini I, Laneri S. The new challenge of green cosmetics: Natural food ingredients for cosmetic formulations. *Molecules*. 2021; 26(13): 3921. doi: 10.3390/molecules262
19. Montero-Rivière NA. Structure and function of skin. In: Monteiro-Riviere NA (editor). *Toxicology of Skin*. CRC Press; 2010. pp. 1-18.
20. Wertz PW. Roles of lipides in the permeability barriers of skin and oral mucous. *International Journal of Molecular Sciences*. 2021; 22(10): 5229. doi: 10.3390/ijms22105229
21. Lee HJ, Kim M. Skin barrier function and the microbiome. *International Journal of Molecular Sciences*. 2022; 23(21): 13071. doi: 10.3310/ijms232113071
22. The World Bank. Securing our future through biodiversity. Available online: <https://www.worldbank.org/en/news/immersive-story/2022/12/07/securing-our-future-through-biodiversity> (accessed on 25 January 2024).
23. Auta HS, Emenike CU, Fauziah SH. Distribution and importance of microplastics in the marine environment: A review of the sources, fate, effects and potential solutions. *Environment International*. 2017; 102: 165-176. doi: 10.1016/j.envint.2017.02.013
24. Martins MS, Ferreira MS, Almeida IF, Sousa E. Occurrence of allergens in cosmetics for sensitive skin. *Cosmetics*. 2022; 9(2): 32. doi: 10.3390/cosmetics902003
25. Herich D. What consumers want from beauty in 2023. Available online: <https://www.gcimagazine.com/consumers-markets/news/22512091/what-consumers-want-from-beauty-in-2023> (accessed on 25 January 2024).
26. Berg A, Davillard S, Balchandani A, et al. *Apparel, Fashion & Luxury 2022*, McKinsey Report. Available online: www.MacKinseyandcompany.com (accessed on 25 January 2024).
27. NielsenIQ. *The Blurring Lines of Beauty*. Health & Wellness; 2022.
28. Cosmetics Italia. *Cosmetic Industry: Manufacture. Market and Foreign Trade*; 2022.
29. Morganti P, Coltelli MB. A new carrier for advanced cosmeceuticals. *Cosmetics*. 2019; 6(1): 10. doi: 10.3390/cosmetics6010010
30. Morganti P, Morganti G, Colao C. Biofunctional textiles for aging skin. *Biomedicines*. 2019; 7(3): 51. doi: 10.3390/biomedicines7030051
31. Morganti P, Morganti G, Coltelli MB. Skin and pollution: The smart nano-based cosmeceuticals-tissues to save the Planet's ecosystem. In: Nanda A, Nanda S, Nguyen TA, et al. (editors). *Nanocosmetics: Fundamentals, Applications and Toxicity*. Elsevier; 2020. pp. 287-304.
32. Coltelli MB, Morganti P, Castelvetro V, et al. Chitin nanofibril-nanolignin complexes as carriers of functional molecules of skin contact applications. *Nanomaterials*. 2022; 12(8): 1295. doi: 10.3390/12081295
33. Danti S, Trombi L, Fusco A, et al. Chitin nanofibrils and nanolignin as functional agents in skin regeneration. *International Journal of Molecular Sciences*. 2019; 20(11): 2669. doi: 10.3390/ijms20112669
34. Morganti P, Morganti G, Yudin VE, Chen HD. Chitin and lignin: Old polymers and new bio-tissue-carriers. *Dermatology and Dermatitis*. 2021; 6(3). doi: 10.31579/2578-8949/083
35. Morganti P, Morganti G, Memic A, et al. The New Renaissance of Beauty and Wellness through the Green Economy. *Latest Trends in Textile and Fashion Designing*. 2021; 4(2); doi: 10.32474/LTTFD.2021.04.000185
36. Cimini C, Gagliardini A, Di Fazio V. Bamboo-fibers: Physicochemical characteristics, biological properties and production process. *Nanoscience & Nanotechnology*. 2022; Unpublished Work.
37. Morganti P, Chen HD and Morganti G. Nanocosmetics: Future Perspective. In: Nanda A, Nanda S, Nguyen TA, et al. (editors). *Nanocosmetics: Fundamentals, Applications and Toxicity*. Elsevier; 2020. pp. 455-481.
38. Laurenti R, Singh J, Frostell B, et al. The Socio-economic embeddedness of the circular economy: An integrative framework. *Sustainability*. 2018; 10(7): 2129. doi: 10.3390/su10072129

39. Padilla-Rivera A, Russo-Garrido S, Merveille N. Addressing the social aspects of a circular economy: A systematic literature review. *Sustainability*. 2020; 12(19): 7912. doi: 10.3390/su12197912
40. Liu L, Ramakrishna S. *An Introduction to Circular Economy*. Springer Singapore; 2021.
41. EU. Circular economy: Definition, importance and benefits. Available online: <https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits> (accessed on 25 January 2024).
42. UN. The circular economy, cooperatives and the social and solidarity economy. Available online: <https://www.un.org/development/desa/cooperatives/2021/08/02/the-circular-economy-cooperatives-and-the-social-and-solidarity-economy/> (accessed on 25 January 2024).
43. EMAF. The circular economy in detail. Available online: <https://ellenmacarthurfoundation.org/the-circular-economy-in-detail-deep-dive> (accessed on 25 January 2024).
44. Morganti P, Morganti G, Memic A, et al. The new renaissance of beauty and wellness through the green economy. *Latest Trends in Textile & Fashion Design*. 2021; 4(2). doi: 10.32474/LTTFD.2021.04.000185
45. Morganti P, Morganti G, Danti S, et al. Biodegradable nanomaterials for cosmetic and medical use. In: Kumar V, Guleria P, Dasgupta N, et al. (editors). *Functionalized Nanomaterials. II Applications*. CRC Press; 2021. pp. 62-73.
46. Morganti P, Morganti G, Coltelli MB, et al. Non-woven tissues as novel cosmetic carriers for a green beauty. *Advances in Environmental and Engineering Research*. 2022; 3(2): 21. doi: 10.21926/aeer.2202021
47. Morganti P, Morganti G, Gao X. Cosmeceutical-tissues as anti-aging active carriers. In: Morganti P (editor). *Biofunctional Textiles for an Aging Skin*. Lambert Academic Publishing; 2022. pp. 696-733.
48. Morganti P, Morganti G, Palombo M. Research & innovation for sustainable products: Polysaccharides for a smart circular economy at zero waste. *Clinical Research and Clinical Trials*. 2021; 3(3): 37. doi: 10.31579/2693-4779/037
49. Panariello L, Vannozzi A, Morganti P, et al. Biobased and eco-compatible beauty films coated with Chitin nanofibrils, nanolignin and Vitamin E. *Cosmetics*. 2021; 8(2): 27. doi: 10.3390/cosmetics8020027
50. Coltelli MB, Morganti P, Lazzeri A. Sustainability assessment, environmental impact, and recycling strategies of biodegradable polymer nanocomposites. In: Deshmukh K, Pandey M (editors). *Biodegradable and Biocompatible Polymer Nanocomposites*. Elsevier; 2023. pp. 699-737.

Article

The impact of land use and cover changes on river flows in Wundanyi Catchment of Taita Hills, Kenya (1970–2030)

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Abstract: Taita Hills are one of the most important biodiversity hotspots of Kenya but are experiencing a high rate of deforestation due to the conversion of its original forestland to agriculture and settlement during the last century. These landscape dynamics, coupled with rainfall fluctuations in these critical ecosystems, may significantly affect water resource distribution and food security in Taita Taveta County and its environs. This study aimed to establish the trends of land use/cover change (LUCC) in the Wundanyi catchment from 1970 to 2030 and predict their specific and combined effects on surface runoff and stream flow in the same period. The analysis was based on statistical trend analysis and dynamic landscape modeling using both historical and primary data from the Wundanyi catchment and Landsat TM and ETM+ imagery of Taita Hills for 1990, 2000, and 2010. Results show highly variable mean seasonal and annual values of discharge in Wundanyi catchment, probably attributed to environmental changes affecting Taita Hills in general and Wundanyi catchment in particular. Compared to 1990, major land use/cover changes in 2010 were featured by the expansion of built-up area (250%), plantation forest (23.7%), broadleaved forest (17.4%), and thicket (15.9%). It was also notable the decrease in woodland (−30.3%), cropland (−21.6%), and shrubland (−0.8%). Dynamic spatial trends by the year 2030 will be evidenced by increased thicket by 0.41% per annum ($R^2 = 81.6\%$) and by decreased plantation forests (−0.13%; $R^2 = 91.3\%$), woodland (−0.10%; $R^2 = 77.6\%$), shrubland (−0.11%; $R^2 = 85.2\%$), broadleaved forests (−0.03%; $R^2 = 56.6\%$) and cropland (−0.09%; R^2 of 84.4). These changes will shape the catchment landscape and influence its hydrology, unless the existing forest and agricultural policy interventions are enforced. Hence, crop diversification, agroforestry, and soil and water conservation structures are recommended to maintain effective control of LUCC on hydrological processes going on in the Wundanyi catchment.

Keywords: catchment management; land-use and land-cover (LULC) change; river flow, seasonality; Taita Hills

1. Introduction

1.1. Background to the study

Access to clean and safe water is a basic human need and is essential for good health and well-being. Yet, worldwide estimates indicate that over two billion individuals live without safely managed water services, more than one billion lack a basic water service level, and close to 0.8 billion reside in countries with high or critical water stress levels [1]. Land use and land cover changes (LUCC) assume vital roles in global water dynamics. Generally, land cover modification through natural and anthropogenic activities has intensified in recent decades and has produced more

far-reaching impacts than they did in the past [2]. These changes are the primary drivers of the unprecedented local, regional, and global shifts in hydrological processes through their effects on infiltration, erosion, and evapotranspiration. Given the role of vegetation cover in modulating infiltration, transpiration, and evaporation, LUCC can significantly influence surface runoff and river discharges [4]. Overall research findings suggest that in many places, anthropogenic activities, especially those resulting on LUCC, tend to be more impactful on streamflow than climate variability. But less is known about the magnitude of LUCC's impacts on hydrological processes, which varies considerably across regions, depending on land use intensity [2].

Empirical evidence from across the globe has demonstrated LUCC impacts on various hydrological processes, including surface runoff and streamflow. For example, Chen et al. [4] conducted a meta-analysis of studies on the impacts of climate and LUCC on stream flow in the Loess Plateau, China. The authors noted significant declines in stream flow rates in the catchment during previous decades. According to their estimates, while climate change contributed to 36% of observed decreases, 64% of the decline was due to LUCC. Comparable findings are reported by Shah et al. [5], who examined stream flow predictors in the Han River Basin, South Korea, using data covering 1978–2014. According to their results, climate variability accounted for 36–56% of shifts in stream flows, while human activities contributed to 45%–64% of the changes.

Sub-Saharan African countries experience some of the most extensive LUCC-related degradation in the world. [6,7] Poor and most vulnerable countries in the region are also the most prone to the adverse impacts of water scarcity. Kenya is one of the most water-scarce countries in sub-Saharan Africa, considering that over a fifth of its residents have no access to a reliable water system [8]. The ever-increasing water scarcity and demand have emerged into one of the notable obstacles to sustainable development in the country and have brought forward the critical need to protect its water towers. Land use and cover practices in the country, especially the conversion of forestland for agriculture and settlement, have resulted in water catchment destruction and significant alterations of key hydrologic processes [3,9]. Kipchumba and Cornu [8] reported that climate change's impacts on water availability in Kenya are compounded by various land use activities, such as large-scale deforestations and unsustainable agricultural practices.

The Eastern Arc Mountains (EAM) is a critical water tower, a biodiversity hotspot, and one of the world's most important areas for endemic wildlife conservation [10]. Taita Hills of Taita-Taveta County are Kenya's sole representative of the EAM. The hills are an important water tower in Kenya, serving as a catchment for the expansive Tsavo ecosystem [11]. Despite its vital role in the country's hydrology, Taita Hills is among the most degraded EAM areas, having lost over 98% of its original forest cover during the past two centuries [12]. More recently, Wekesa et al. [9] estimated that the hills' lost over 23% of their forest cover between 1973 and 2016, implying an annual deforestation rate of approximately 0.5% during the period. Much of this loss is attributed to unsustainable land use and land cover changes (LUCC) in the hills' catchments [13]. Long-term deforestation and other land use activities have produced significant impacts on the water resources of the areas served by the hills

[14]. Empirical evidence from various studies points to large-scale water catchment degradations due to unsustainable land use activities around Taita Hills [15]. However, there is limited research on the extent to which these changes have influenced the East African region's hydrology.

Empirical evidence on the effects of LUCC on the East Africa region's water systems reveals mixed findings. In one of the most extensive reviews covering East Africa, Guzha et al. [2] found that although field and modelling studies revealed that land cover loss in the region is accompanied by increased stream discharges and surface runoffs, trend analyses revealed that in most cases, the loss in forest cover had no significant impacts on discharges and streamflows. There were weak correlations between forest cover and mean discharge, peak discharge, and runoff. Such inconsistencies call for additional highly controlled studies to offer further insight into hydrological responses to a catchment's LUCC. The study employs a statistical multivariate trend analysis embedded in the Soil and Water Assessment Tool (SWAT) to assess LUCC impacts on surface runoff and river discharges. Statistical models, such as multivariate trend analyses, predict LUCC by establishing mathematical links between a set of explanatory factors and an outcome variable [16].

The SWAT model developed by Arnold et al. [17] is one of the most robust models available for watershed modelling. When used to model hydrological processes in large watersheds, SWAT considers water storage in different layers, as well as surface runoff, infiltration, soil moisture redistribution, evapotranspiration, lateral subsurface flow, storage in reservoirs and ponds, transmission losses in the stream, and return flow [18]. A statistical multivariate trend analysis is embedded in the SWAT model to assess the various LUCC forms and their correlations with the catchment's hydrological processes. The analysis uses the modified curve number (MCN) approach, which is the core mechanism for determining excess rainfall [17]. The SWAT model can be used in ungauged catchments and, hence, allows evaluation of hydrology changes resulting from LUCC in areas without gauges [19].

The SWAT model has been successfully applied in various studies across the globe to assess the impacts of changes in land use and management practices on water quantity and quality at different scales and environmental conditions, even in areas with limited data [18–20]. The model is also capable of simulating various hydrologic processes of a catchment, such as runoff and stream flow. Digital Elevation Models (DEMs), ERDAS, ILWIS, and ArcGIS were used to analyse historical LUCC patterns. Similar to SWAT, these tools have been successfully used to analyse and classify LUC patterns [21,22]. The findings sometimes reveal unexpected shifts in the landscape's LUC, including changes that have had notable impacts on the catchment's hydrological processes.

1.2. Research scope and rationale

The main purpose of this study is to assess the effects of land cover changes on the hydrological processes in the Wundanyi catchment of Voi catchment, within the Taita Hills of Kenya. Specifically, the study aims to:

- a) assess past and future patterns of land use/cover changes in Wundanyi catchment from 1970 to 2030; and to

- b) determine the effects of forest cover change in Wundanyi catchment's surface runoff and streamflow.

In fact, Wundanyi, like other catchments within Taita Hills, is experiencing rapid deforestation-related environmental deterioration [23]. The catchment is also experiencing a vicious drought-flood cycle, which may have impacted its hydrological processes remarkably. Part of the prolonged droughts and frequent floods in the catchment may be attributed to sustained land use-related environmental degradation. Assessing how land use changes affect Wundanyi's hydrological processes may help develop informed policies to alleviate water stress levels among the populations served by the catchment. Yet, few studies have evaluated specific LUCC impacts on Wundanyi's surface runoff and streamflow.

Yes! There is insufficient knowledge of the implications of human activities on hydrological processes in the Wundanyi catchment under the changing climate scenarios. Besides, the available studies in Wundanyi catchment are based on old data and may not reflect the present scenario, given that the catchment's population and land use activities are rapidly changing [24]. In addition to supplementing existing studies, this study also simulates future changes in the Wundanyi catchment. The study simulates Wundanyi's past and future land use and/or cover (LUC) scenarios for 1970–2030 using a dynamic landscape model of satellite images of the catchment. Various studies have been conducted on environmental degradation in Taita Hills [12,13,25]. This study models and predicts seasonal runoff and discharges using a set of LUCC parameters, such as area under cultivation, area under forest cover, and seasonal rainfall, using statistical multivariate trend analysis. The choice of these models was justified by their ease of implementation and the capacity to create a general LUCC representation where data, time, and other resources are scarce [16,26]. However, these statistical models ideally need to be combined with spatial models to display LUCC, especially for catchments with scarce data such as Wundanyi, and possibly project their impacts on the whole regional hydrology.

2. Materials and methods

2.1. Description of the study area

The study was conducted in Wundanyi, a medium catchment of about 190 km², in Taita Hills' upper elevation, within Taita-Taveta County of Kenya. Taita Hills cover an area close to 1000 km², which is located in South-Eastern Kenya at latitude 03°020' S and longitude 38°20' E (**Figure 1**), about 150 km off the Indian Ocean's coastline and isolated from other mountainous areas by the Tsavo plains. The elevations range from 700 to 2208 m a.m.s.l. (above mean sea level). Due to the altitudinal differences, the area has very variable rainfall, vegetation cover, and land use practices. The population in the catchment was estimated to be about 370,000 and 280,000 people in 2023 and 2010, respectively; that's an increase of nearly 517% (2023) and 370% (2010) since the 1960s [23,24,27]. The rapid population growth is considered the main driver of biodiversity loss and environmental degradation in the catchment [9,28].

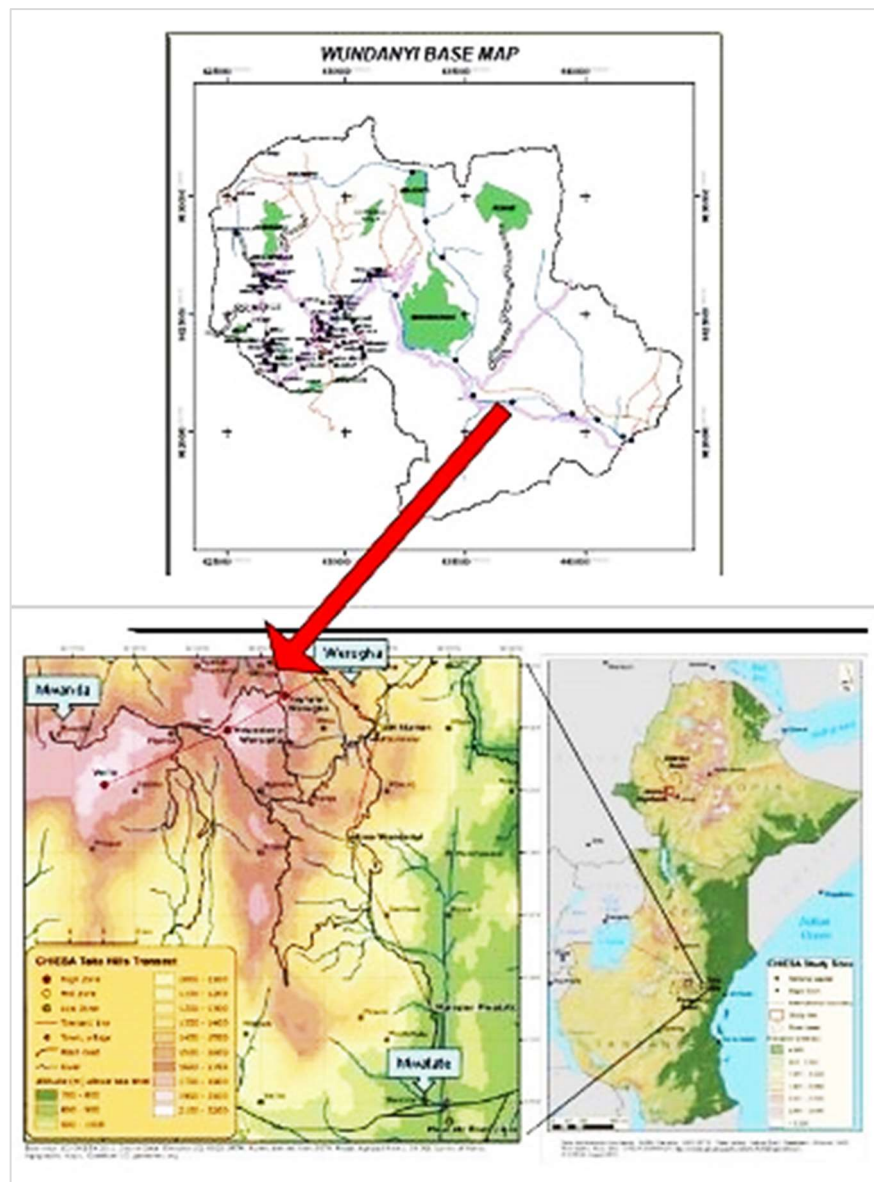


Figure 1. Map of Wundanyi catchment drawn from soak and chiesha maps (Source: Data analysis by authors from KNBS) [27].

Wundanyi catchment belongs to a semi-arid climate influenced by the Inter-Tropical Convergence Zone and differences in altitude and relief. The topography affects rainfall distribution significantly both vertically and horizontally. Annual precipitation in Taita-Taveta ranges from approximately 1000 mm to 1750 mm [14]. There are some variations throughout the country, with the hills around Wundanyi experiencing slightly wetter conditions [23]. Wundanyi's rainfall distribution is bi-modal, with longer rainy seasons occurring from March to May and short rains from October to December (**Figure 2**). The bi-modal pattern determines the growth of all vegetation and agricultural practices. Temperatures range between 23 °C and 27 °C, with slightly cooler conditions experienced around Wundanyi than in other parts of the county [14]. The potential evaporation is about twice the annual rainfall in the semi-arid area, while in the humid upper basin, rainfall exceeds potential evaporation in most parts of the year [24].

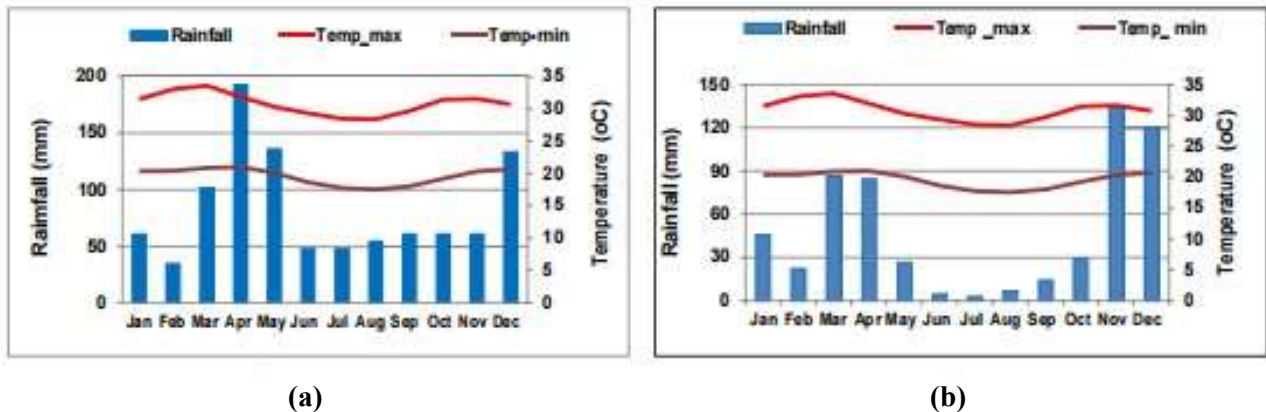


Figure 2. Climate diagrams of (a) Wundanyi dc's office; (b) Voi station (Source: Data analysis by authors).

The major soils in the study area are of volcanic origin. They are young and have weak, unstable structures, making them vulnerable to physical degradation. The catchment's soils and major rocks are on undifferentiated basement system rocks, predominantly gneisses. They are generally well-drained, moderately deep to deep, reddish brown to brown, stony, friable sandy clay loam to clay, with humic topsoil (1.2–1.8 m) and vary from dark reddish brown to dark brown, clay loam to loamy soils with thick acid humic topsoil in shallow to moderately deep and rocky places [29].

Land cover/use types are determined by the hydro-climatic and ecological zonations of Taita Hills. The hills have seven agroecological zones, each characterized by distinct land use activities. Wundanyi catchment is within a zone characterized by a transition from a semi-arid to a semi-humid climate depending on the altitude [30]. The upper highland zone has 115 to 145 growing days and means a temperature of 15–18 °C, while the lower highland zone has 75 and 104 growing days and means annual temperatures of 21–24 °C. The lowland around the hills has a different landscape, mostly flat with limited rainfall and savannah vegetation. The climatic conditions and soils support intensive cultivation, while the landscape mosaic is constructed of abundant small-scale farms, exotic tree species patches such as *Cupressus lusitanica*, *Pinus* spp., *Eucalyptus* spp., and *Grevillea robusta*, and indigenous forest patches (1% of total land area). Only three larger hilltop indigenous forest remnants exist: Mbololo (ca. 179 ha), Ngangao (ca. 136 ha), and Chawia (ca. 94 ha) [29].

Hydrologically, Wundanyi falls within the Athi River catchment, one of the six major basins in Kenya. The area is considered semi-arid and dependent on erratic rainfall patterns that fall within the two rainy seasons. With an annual per capita renewable water resource of 464 m³, Athi River has less water than the 1000 m³ per capita global benchmark [31]. Wundanyi has a single river (Wundanyi/Voi River) and many small stream tributaries. Lagale and Rahai are the river's main tributaries. Wundanyi has ten sub-catchments: Wesu, Shigaro/Wushimbo, Suguluu. The study was conducted within the recommended Climate Change Impact on Ecosystem Services and Food Security in Africa (CHIESA) project sites in the EAM. Wundanyi catchment was purposefully selected because of the complexity of hydro-geomorphologic processes going on in that part of the EAM. Yet, this catchment is

one of the critical water towers and biodiversity hotspots of Taita-Taveta County. This study enabled the building of water availability scenarios vis-a-vis climate variability and land use/cover change, which have been subjected to sustained LUCC and are in the semi-urban stage, characterized by intensive agriculture and a rapid increase in construction activities.

2.2. Sampling strategy

The study was conducted within the recommended Climate Change Impact on Ecosystem Services and Food Security in Africa (CHIESA) project sites in the EAM. Wundanyi catchment was purposively selected because of the complexity of hydro-geomorphologic processes going on in that part of the EAM. Yet, this catchment is one of the critical water towers and biodiversity hotspots of Taita-Taveta County. This study enabled the building of water availability scenarios vis-a-vis climate variability and land use/cover change.

2.3. Data collection technique

Several primary and secondary geophysical and hydrological data were collected to address the research objectives. Computational LUCC data was abstracted from remotely sensed satellite images and their ground truthing. Landsat images were acquired from the Kenya Forest Service (KFS), the Department of Remote Sensing and Resource Surveys (DRSRS), and the Institute of Resource Assessment (IRA). An inquiry was performed on the ground to ascertain the results of the satellite imagery conducted earlier in the Wundanyi catchment. These activities were conducted simultaneously in five administrative, six forest, and ten water catchment areas.

The Theta Probe ML2x meter was used to sample and measure in situ the moisture of 44 specific soil points along river banks and 54 farming field points, mostly during Wundanyi's long, dry season (JJAS). For streamflow, the Hydrometer current meter was utilized to measure ten river discharges across ten (10) discharge points sampled from six (6) sub-catchments within the Wundanyi catchment between September and October 2023. Secondary time series data on river discharge (2011–2013) were obtained from the various stations installed by the CHIESA Project. A long series of streamflow data (1970–2010) was collected from the neighbouring Musau WRMA gauging station for regionalization purposes.

2.4. Key techniques of data analysis

2.4.1. Detecting past patterns and predicting future trends of LUCC (1970–2030) in Wundanyi

The first objective involved developing spatial simulation models for temporal LUCC patterns in the catchment. Three Digital Elevation Models (DEMs) (ERDAS, ILWIS, and ArcGIS) helped generate streamlines, flow direction, accumulation, slope, catchment boundary, and other relevant catchment attributes. Topographic maps (scale = 1:250,000) were used to geo-reference the images, while satellite image processing involved geometric rectification and radiometric normalization. Past and future LUCC scenarios were then simulated using statistical trend analyses of the satellite images.

For LUCC classification, FAO's Land Cover Classification System (LCCS) [32]

was used. Based on the collected data, different LUCC types were identified and verified using various DRSRS-produced maps and corrected following a ground-truthing conducted in September to October 2013. Ground control points were selected based on easily identifiable features (e.g., junctions, bridges, and prominent buildings) to re-geo-reference the images. A dynamic landscape model was then built to analyze historical LUCC trends, assess LUCC driving forces and simulate future scenarios.

To evaluate the driving forces, remote sensing and GIS tools were integrated with explicit dynamics in Wundanyi's landscape and hydrology using LUCC maps and ancillary data from ArcGIS 10.1. The dynamic landscape model was embedded in the IDRISI software with the following key inputs: land use transition rates, landscape parameters, and selected LUCC variables. Other factors linked to explanatory variables (i.e., distance from riverbanks, croplands, and roads) were included. Finally, a confusion matrix was used to assess the accuracy of the classification. Overall, producer and user accuracies and kappa coefficients were obtained from the ENVI/QGIS manual and other remote sensing and image analyses.

2.4.2. Simulating the effects of LUCC on Wundanyi's surface runoff and streamflow

For the second objective, dynamic trend analyses were utilized to simulate the effects of LUCC on Wundanyi's surface runoff and streamflow. For the second objective, dynamic trend analyses were utilized to simulate the effects of LUCC on Wundanyi's surface runoff and streamflow. A Soil and Water Assessment Tool (SWAT) model was used to subdivide Wundanyi into sub-catchments, which were linked by a river system network and further delineated into Hydrologic Response Units (HRUs). The HRUs comprised unique land cover-soil combinations within each of the ten (10) sub-catchments of Wundanyi. But the model failed to conclusively simulate surface and sub-surface flows using commonly available parameters due to limited data. This technique was not ideal for small catchments like Wundanyi. Hence, a multivariate statistical trend analysis was conducted to simulate the effects of LUCC on Wundanyi's surface runoff and streamflow. Estimated best fitting models used a univariate Weighted Least Squares (WLS) regression without a constant term (Weighting factor: River Distance_To_Forest), following the simplified model design below:

$$Y_s = bx \quad (1)$$

or,

$$Y_s = \beta t \quad (2)$$

where Y_s , the regression dependent variable, is represented by a seasonal runoff/discharge linear or exponential model (validated by a coefficient of determination (R^2) and a F statistical test at 1% significance level); $\log Y_s$, the regression dependent variable, is represented by a seasonal runoff/discharge logarithmic or power model (validated by a coefficient of determination (R^2) and a F statistical test at 1% significance level); x = land use/cover size (area); t = time with j = JJAS and o = OND; b and β , regression parameters (validated by a t -test at 1% statistical significance level).

Different linear and nonlinear regression models were tested for specific effects of LUCC variables on Wundanyi's surface runoff and discharges. Model parameters

were estimated based on partial correlations and partial auto-correlation functions. The models allowed for estimating surface runoff and discharge variations during the OND, JF MAM, and JJAS seasons.

3. Results of the study

3.1. Study sample description

The first step in data analysis involved identifying key land use and cover (LUC) categories that play influential roles in Wundanyi's hydrological cycle. Principal Component Analysis (PCA) and the homogeneity of variance test were used to this end. Previous research has established that Wundanyi's micro-climate and hydrology are mostly influenced by the catchment's forestry and agricultural activities [14]. Several such factors were included in the initial extraction. Levene's homogeneity test helped cluster the extracted factors as independent and dependent variables based on Levene's *F* statistic and using the heuristic method. *F*-values below 2.6 were interpreted to indicate the presence of homogeneity.

A quick outlook of Wundanyi's landscape from a vantage point showed that the catchment had some fragments of natural forest along with extended hydrographical and road networks. Landsat TM and ETM+ satellite images of Taita Hills for 1990, 2000, and 2010 were used to enable categorization of land use/cover types thereof. In addition to these satellite images, topographical maps, DEM, and other field data were used to ensure the accuracy of this classification. Based on these spatial data and the FAO land use/cover classification system [32], a spatial raster modeling extracted 12 major classes of land use/cover (LUC) types from the three-epoch satellite images. These 12 LUC classes encompassed: (i) cropland; (ii) shrubland; (iii) thicket; (iv) woodland; (v) plantation forest; (vi) broad-leaved forest; (vii) grassland; (viii) bare soil; (ix) bare rock; (x) water body; (xi) burnt area; and (ii) built-up area (**Figure 3**).

According to the ENVI software suggested rules for the ranges of class signatures' separability values, a "good" signature separability was achieved for each image classified, the average Bhattacharyya distance ranging from 1.979 to 1.987. This classification got an overall accuracy of 82.3% for the 1990 Landsat TM image, 83.4% for the 2000 Landsat ETM+ image, and 89.5% for the 2010 Landsat TM image. The lowest values of accuracy corresponded to shrubland, thicket, woodland, and broad-leaved forest categories. These four groups were very similar in terms of spectral signatures assigned to these categories. They may have resulted in misclassifications due to similar stages of development. However, we decided to classify them as such using an algorithm that easily differentiated all categories of vegetation.

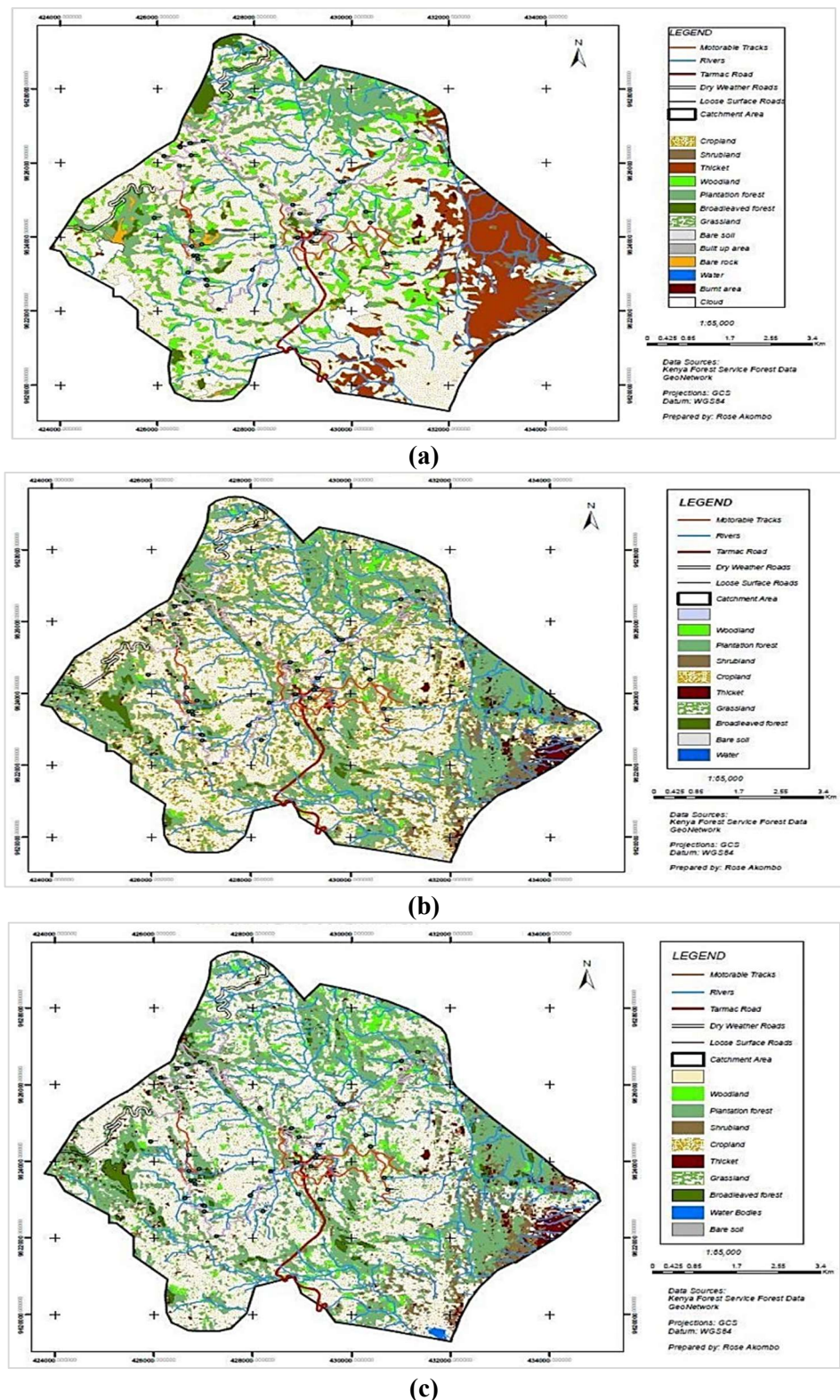


Figure 3. Wundanyi's land use/cover classes for (a) 1990; (b) 2000; and (c) 2010 (Source: Data analysis by authors).

To validate this classification accuracy, a ground control point (GCP) procedure was applied in the field alongside a user/producer classification accuracy assessment. According to **Table 1**, the average percentage of correctly classified pixels (Apcc)

were 95%, 86%, and 96% for 1990, 2000, and 2010, respectively, with Kappa coefficient statistics of 0.96, 0.82, and 0.95. The user's accuracy for individual classes ranged from 85% to 98%, and the producer's accuracy ranged from 87% to 99%. These values were all greater than 75% (or 0.75 ratio), which is the lowest limit for a good classification system, thus validating the accuracy of the classification.

Table 1. Producer and user accuracy of the classification (Source: ENVI/QGIS image processing, data analysis by authors).

Years	Image	Apcc	Overall Kappa
1990	Landsat TM	95	0.97
2000	Landsat ETM+	86	0.82
2010	Landsat TM	96	0.95

3.2. Predicting land use/cover changes in Wundanyi (1970–2030)

Spatial modeling identified plantation forests and cropland as the major LUC types in Wundanyi in 2010 (**Table 2**). However, the catchment has undergone notable changes in the areas under specific LUC types since 1990. As of 2010, plantation forests had overtaken cropland as the leading LUC type, having experienced a growth in its share from 25.7% (1990) to about 31.8%. In contrast, cropland decreased from 37.7% to 29.1%. This reforestation may have positively impacted broadleaved forests, whose share grew by 17.4%. Other LUC types whose acreage increased were thicket, grassland, bare soil, built-up area, and burnt area. Woodland and cropland registered the highest declines, while shrubland's share decreased slightly.

Table 2. Land use/cover types distribution in Wundanyi (1990–2010) (Source: Data analysis by authors).

Land use/cover	1990		2000		2010		Growth (%)
	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	
Cropland	3248.21	37.1%	2615.17	29.9%	2543.52	29.1%	−21.6%
Woodland	577.38	6.6%	457.11	5.2%	401.46	4.6%	−30.3%
Plantation forest	2245.54	25.7%	2788.85	31.9%	2780.18	31.8%	23.7%
Broadleaved forest	199.26	2.3%	137.53	1.6%	231.77	2.7%	17.4%
Shrubland	1172.79	13.4%	1394.78	16.0%	1164.48	13.3%	−0.8%
Thicket	1204.40	13.8%	1225.67	14.0%	1401.48	16.0%	15.9%
Grassland	4.53	0.1%	31.54	0.4%	31.49	0.4%	300%
Bare soil	14.96	0.2%	12.31	0.1%	46.19	0.5%	150%
Bare rock	47.58	0.5%	45.32	0.5%	41.74	0.5%	0.0%
Built up area	18.32	0.2%	23.20	0.3%	65.40	0.7%	250%
Water	1.65	0.0%	0.54	0.0%	1.53	0.0%	0.0%
Burnt area	9.92	0.1%	12.53	0.1%	35.31	0.4%	300%
Total Area	8744.55	100.0%	8744.55	100.0%	8744.55	100.0%	-

Statistical modelling (**Figure 4**) confirmed that plantation forests had overtaken cropland and grassland, while woodland, broadleaved forests, and built-up areas

showed slight stability. Shrubland decreased substantially, while the other LUC classes exhibited no major acreage shifts. Projected scenarios (**Table 3**) showed that areas under all LUC types will decrease (in absolute terms and relative proportions) by 2030, except thicket. Thicket's acreage is expected to grow by 0.41% annually ($R^2 = 0.816$), while plantation forests, shrubland, and woodland will witness the largest declines. The high R indicated that the model accounted for a substantial proportion of variations in LUC. However, dynamic modeling (**Table 4**) showed that Wundanyi will undergo tremendous increases in acreages of its grassland (+1613.2%), plantation forest (+293.7%), and thicket (+97%) by 2030, while woodland broadleaved forests, shrubland, and cropland will experience substantial declines.

Table 3. Statistical trend analysis of land use/cover in Wundanyi (2010–2030) (Source: Data analysis by authors).

Land use/cover	2010		2030		R^2
	Area (ha)	Percent (%)	Area (ha)	Percent (%)	
Cropland	2543.52	29.09%	2384.18	27.26%	0.844
Woodland	401.46	4.59%	233.04	2.66%	0.776
Plantation forest	2780.18	31.79%	2552.32	29.19%	0.913
Broadleaved forest	231.77	2.65%	176.78	2.02%	0.566
Shrubland	1164.48	13.32%	980.58	11.21%	0.852
Thicket	1401.48	16.03%	2121.67	24.26%	0.816
Other LUC	221.66	2.53%	295.98	3.38%	-
Total area	8744.55	100%	8744.6	100%	-

Table 4. Percentage of land use/cover change by 2030 (Baseline: 1970) (Source: Data analysis by authors).

Land use/cover	Year						
	1970	1980	1990	2000	2010	2020	2030
Cropland	-	+3.8%	-5.3%	-22.8%	-24.9%	-27.7%	-29.6%
Woodland	-	-24.8%	-29.7%	-44.3%	-51.1%	-65.3%	-71.6%
Plantation forest	-	+61.0%	+246.4%	+330.2%	+328.8%	+304.4%	+293.7%
Broadleaved forest	-	-34.1%	-48.3%	-64.3%	-39.9%	-48.7%	-54.1%
Shrubland	-	-9.1%	-47.6%	-37.7%	-48.0%	-51.4%	-56.2%
Thicket	-	+1.1%	+12.1%	+14.0%	+30.4%	+73.6%	+97.4%
Grassland	-	+1.2%	+54.2%	+234.8%	+234.3%	+711.8%	+1613.2%
Bare soil	-	-3.8%	-78.9%	-82.6%	-34.8%	-63.3%	-69.1%
Bare rock	-	+0.6%	+113.4%	+103.2%	+87.2%	-8.9%	-25.9%
Other lands	-	+6.3%	+33.5%	-58.1%	+18.1%	+70.2%	+14.0%
Built up area	-	+6.2%	-66.9%	-58.1%	+18.1%	+14.2%	+10.6%
Water body	-	+5.4%	+26.9%	-58.5%	+17.7%	-13.1%	-34.6%

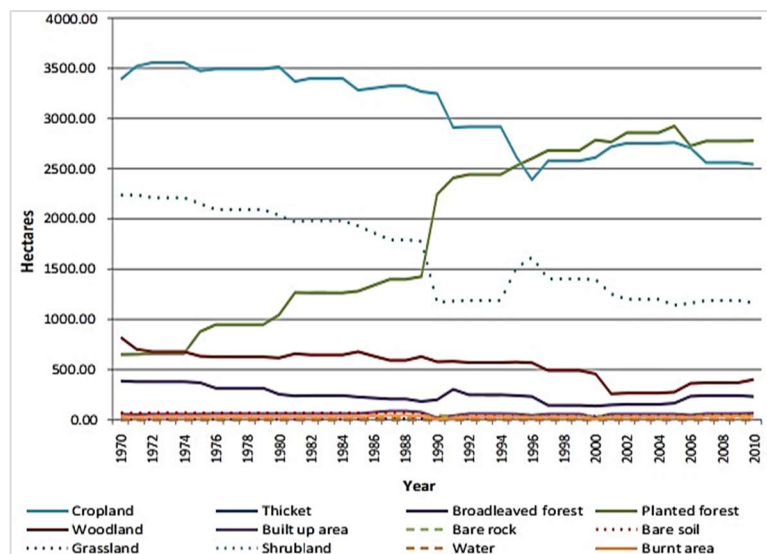


Figure 4. Statistical trend of land use/cover transition (1970–2010) (Source: Data analysis by authors).

3.3. Analysing the effects of forest cover change on seasonal surface runoff

Different regression models (**Table 5**) were tested for the effects of specific LUC categories on Wundanyi's surface runoff based on 1970–2010 JJAS data. All models, except woodland and thicket, explained over 70% of surface runoff variations based on the *R*-squared statistic. Expansions in all LUC types were associated with significant runoff increases ($p < 0.001$). The coefficients indicated that cropland and shrubland produced the largest runoff changes, while broadleaved forest, plantation forest, and woodland had the lowest impacts.

Table 5. Modelling land cover change effect on JJAS runoff in Wundanyi (Source: Data analysis by authors).

Model	Adjusted <i>R</i> Square	Factor/covariate	Unstandardized coefficients		Standardized coefficients	<i>t</i>	Sig.	<i>F</i>	Sig.
			<i>B</i>	Std. error					
Linear	0.562	Thicket	0.362	0.059	0.728	6.107	< 0.001	37.297	< 0.001
Linear	0.699	Woodland	0.226	0.025	0.841	8.933	< 0.001	79.801	< 0.001
Power	0.984	log(Shrubland)	0.640	0.014	0.992	45.297	< 0.001	2052.066	< 0.001
Linear	0.724	Broadleaved_Forest	0.068	0.007	0.855	9.485	< 0.001	89.968	< 0.001
Power	0.970	log(Cropland)	0.735	0.022	0.986	33.361	< 0.001	1112.923	< 0.001
Power	0.971	log(Planted_Forest)	0.204	0.006	0.986	33.668	< 0.001	1133.990	< 0.001

Notes:

^aBest fitting models estimated using univariate Weighted Least Squares (WLS) regression without a constant term-Weighting factor: River Distance_To_Forest.

^bThe Dependent variable (Y_j) is JJAS_Runoff for linear and exponential models, and log (JJAS_Runoff) for logarithmic and power models.

^cModel design: $Y_j = bx$, where x = land cover area.

Figure 5 depicts runoff built-up scenarios from bare land (1970) to large forest covers (2030). Logarithmic cropland (990 mm) and shrubland (810 mm) expansions will produce the highest runoffs in 2030. The effects of other LUC types on runoff

will generally be low, ranging from 350 mm (thickets) to 198 mm (broadleaved forest).

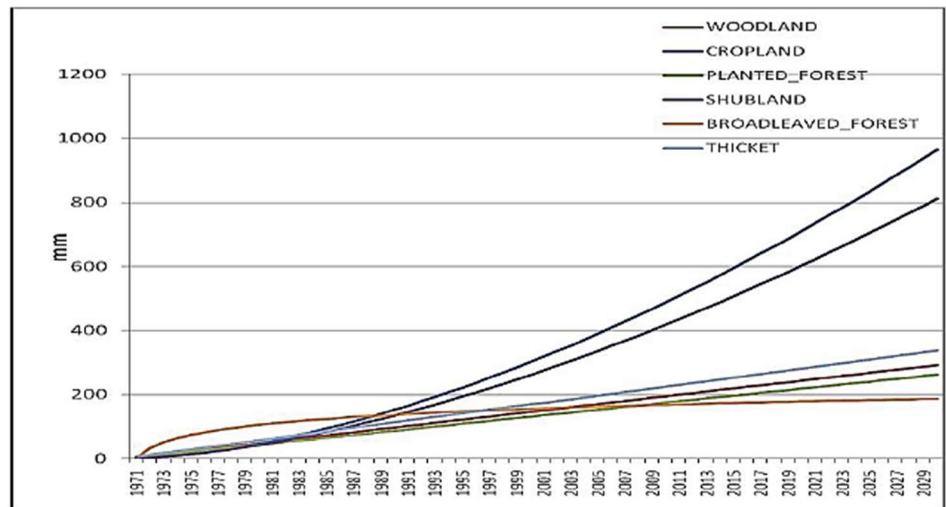


Figure 5. Expected JJAS runoff under specific effects of land cover change in Wundanyi by 2030 (1970 = 0) (Source: Data analysis by authors).

Note: Model design: $Y_j = bt$, where Y_j = JJAS_Runoff, t = time.

Models predicting LUCC effects on OND runoffs based on 1970–2010 data are in **Table 6**. A unit cropland rise increased the runoff by about 99.3%. Other LUC categories with large effects on OND runoff were thicket and shrubland, while the shifts due to broadleaved forest were negligible.

Table 6. Statistical prediction of land cover change effects on OND runoff (Source: Data analysis by authors).

Model	Adjusted <i>R</i> square	Factor/covariate	Unstandardized coefficients		Standardized <i>t</i> coefficients		Sig.	<i>F</i>	Sig.
			<i>B</i>	Std. error	Beta				
Power	0.990	log(Cropland)	0.993	0.017	0.995	59.12	< 0.001	3495.142	< 0.001
Linear	0.836	Planted_Forest	0.484	0.037	0.917	13.188	< 0.001	173.913	< 0.001
Power	0.992	log(Shrubland)	0.737	0.012	0.996	63.285	< 0.001	4005.310	< 0.001
Linear	0.727	Woodland	0.133	0.014	0.857	9.558	< 0.001	91.350	< 0.001
Power	0.955	log(Thicket)	0.837	0.031	0.978	27.036	< 0.001	730.946	< 0.001
Power	0.988	log(Broadleaved_Forest)	0.002	3.14×10^{-5}	0.994	54.031	< 0.001	2918.951	< 0.001

Notes:

^aBest fitting models estimated using univariate Weighted Least Squares (WLS) regression without a constant term—Weighting factor: River Distance_To_Forest.

^bThe Dependent variable (Y_o) is OND_Runoff for linear and exponential models, and log (OND_Runoff) for logarithmic and power models.

^cModel design: $Y_o = bx$, where x = land cover area.

Forecasts of LUCC impacts on OND runoff showed that cropland (2510 mm), shrubland (2250 mm), and thicket (2225 mm) will produce the largest seasonal runoff increases by 2030 (**Figure 6**). Thus, in both JJAS and OND scenarios, much of Wundanyi's runoff changes will be due to shifts in forest covers. Cropping practices will have minimal impacts.

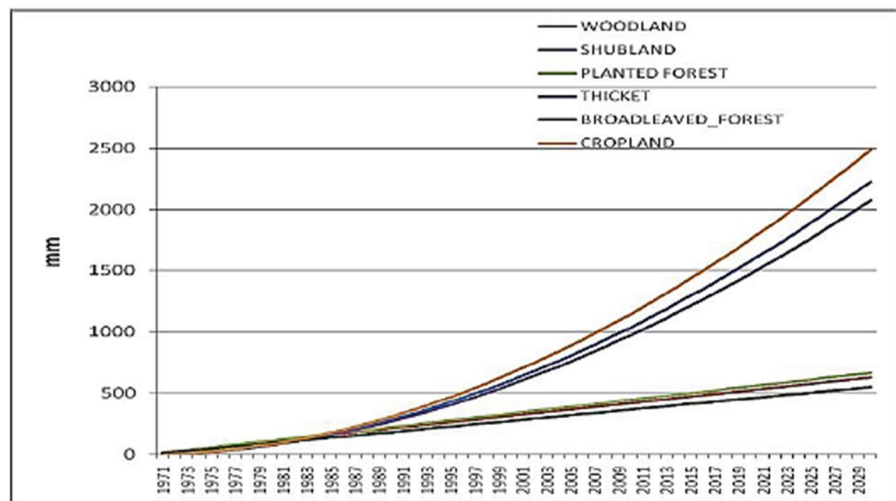


Figure 6. Predicted OND_runoff in 2030 under effect of land cover change in Wundanyi (Source: Data analysis by authors).

Note: Model design: $Y_o = bt$, where t = time, Y_o = OND_Runoff.

3.4. Analyzing the effects of forest cover change on river discharge

A homogeneity test of the study variables revealed that only plantations and broadleaved forests correlated significantly with Wundanyi's river discharges. **Table 7** shows that from 1970 to 2010, a unit change in plantation forest during the JJAS season increased/decreased river discharges by 27.4% against 0.5% for a unit increase/decrease in broadleaved forest.

Table 7. Statistical models for effects of land cover change on JJAS discharge (Source: Data analysis by authors).

Model	Adjusted R square	Factor/covariate	Unstandardized coefficients		Standardized coefficients	t	Sig.	F	Sig.
			B	Std. error	Beta				
Linear	0.546	Broadleaved_Forest	0.005	0.001	0.748	6.466	< 0.001	41.806	< 0.001
Logarithm (base e)	0.644	log(Planted_Forest)	0.274	0.035	0.809	7.909	< 0.001	62.553	< 0.001

The situation is likely to reverse by 2030, with broadleaved forests overtaking forest plantations (**Figure 7**). Then, broadleaved forests are expected to grow linearly, with Wundanyi's discharges increasing by about 3.3 m³/s in the JJAS of 2030, a leap from the zero-discharge observed in 1970. In contrast, logarithmic plantation forest cover growth will result in a total discharge of 2.6 m³/s by 2030.

Similar effects of forest cover change were also evident in OND discharges. From 1970 to 2010, a unit plantation forest expansion increased/decreased Wundanyi's OND discharges by 22.3% against a 0.5% discharge increase/decrease due to a unit change in broadleaved forests (**Table 8**). Discharges will be 3.75 m³/s by 2030 under an assumption of a linear broadleaved forest expansion and 2.15 m³/s under a logarithmic plantation forest expansion (**Figure 8**). These results emphasise the importance of natural forest protection and conservation for sustainable water ecosystem services in Wundanyi.

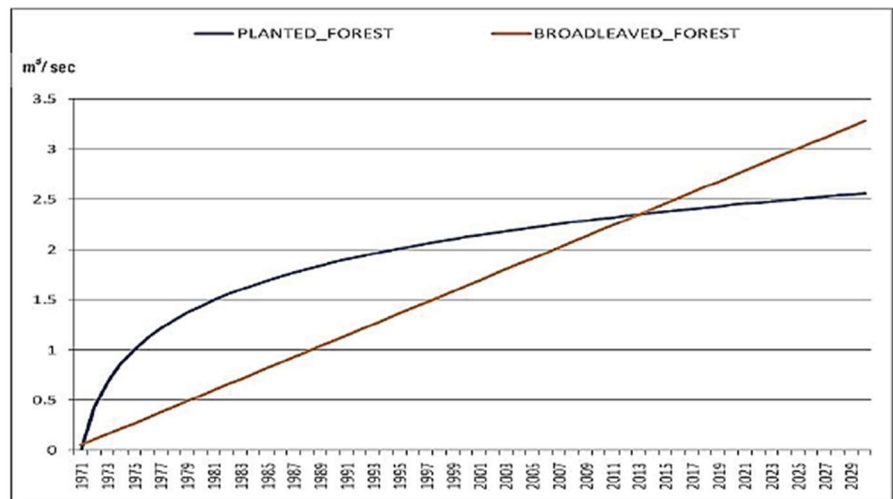


Figure 7. The impact of land cover change on JJAS discharge in Wundanyi (Source: Data analysis by authors).

Model design: $Q_j = \beta t$, where Q_j = JJAS_Discharge, t = time.

Table 8. The impact of forest cover change on OND discharge in Wundanyi (Source: Data analysis by authors).

Model	Adjusted R square	Factor/covariate	Unstandardized coefficients		Standardized coefficients	t	Sig.	F	Sig.
			B	Std. error	Beta				
Linear	0.570	Broadleaved_Forest	0.005	0.001	0.764	6.792	0.000	46.130	0.000
Logarithm (base e)	0.609	log(Planted_Forest)	0.223	0.030	0.788	7.341	0.000	53.889	0.000

Notes:

^aBest fitting models estimated using univariate Weighted Least Squares (WLS) regression without a constant term (Weighting factor: River Distance_To_Forest).

^bThe Dependent variable is OND_Discharge for linear and exponential models and log(OND_Discharge) for logarithmic and power models.

^cModel design: $Q_o = bx$, where Q_o = OND_Discharge, x = land cover area.

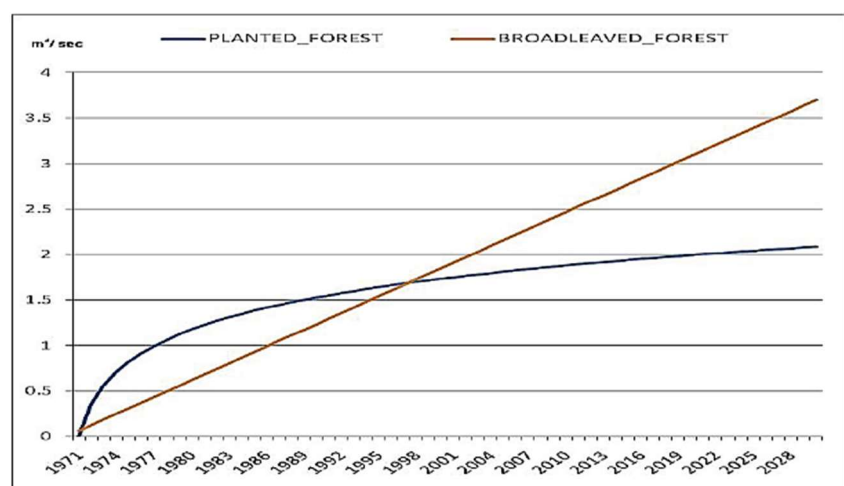


Figure 8. The impact of land cover change on OND discharge in Wundanyi (Source: Data analysis by authors).

Model design: $Q_o = \beta t$, where Q_o = OND_Discharge, t = time.

Similar effects of forest cover change were also evident in OND discharges. From 1970 to 2010, a unit plantation forest expansion increased/decreased Wundanyi's

OND discharges by 22.3% against 0.5% for broadleaved forests (**Table 8**). Discharges will be 3.75 m³/s by 2030 under a linear broadleaved forest expansion assumption and 2.15 m³/s under a logarithmic plantation forest expansion assumption (**Figure 8**). These results emphasise the importance of natural forest protection and conservation for sustainable water ecosystem services in Wundanyi.

4. Discussion of the findings

4.1. Discussion on the changing LUC patterns predicted in Wundanyi (1970–2030)

The above analysis has established drastic increases in Wundanyi's afforestation and agro-forestry practices, while other LUC types, including cropland, have slightly decreased over the years. These shifts could be attributed to the conversion of broadleaved forests into plantation forests and the adoption of agroforestry practices in croplands in the catchment [9,29]. The increased forest cover may have positive long-run impacts on Wundanyi's micro-climate and hydrology [4,5].

Land-cover changes due to reforestation and forest plantation have resulted in increased forest cover in the Wundanyi catchment, thus reducing surface runoff and soil erosion. Consequently, the amount of soil organic carbon that could otherwise be lost to land clearance and cultivation is retained in the catchment to increase 'green water' flows [33,34]. Therefore, increased forest cover in the Wundanyi catchment will certainly have a positive impact on its micro-climate and hydrology in the long run. Water resource stakeholders need an integrated approach to acknowledge the interactions between water, forest, other land uses, and socio-economic factors in this complex catchment.

Enhanced knowledge on integrated management of water resources and the multi-functionality of forested watersheds in addressing water scarcity, water quality, and flood control in the light of a changing environment is inevitable. The upper catchment of this area is inhabited by subsistence farmers dependent on rain-fed agriculture for livelihoods, which results in increased surface runoff and enhanced soil erosion as they engage in poor farming practices. There are limited soil and water conservation measures to minimize water runoff and soil loss, maintain soil fertility, and improve land productivity in these hills.

Hydrological processes in a catchment are influenced by many factors, such as climate, human activities, and the physical characteristics of the catchment. Therefore, changes in any of these factors or their variables (rainfall and forest cover) are likely to affect surface runoff and stream flow, as evidenced in the results above. Forest cover modification due to harvesting or planting alters the water balance of the site and eventually the catchment hydrologic regime. Hence, a significant reduction in the forest cover is likely to alter the flow path of precipitation and cause an increase in surface runoff, erosion, and sedimentation of water bodies. This complex interaction between climate and human activities makes it very difficult to quantify individual effects on changes in runoff and stream flow [35].

Taita Hills comprises two main parts: the hilly one rising abruptly in a series of ridges with the highest peak of 2208 m.a.s.l. at Vuria; and the surrounding plains with

an elevation of 600 to 900 m.a.s.l. mist and cloud precipitations occur almost throughout the year, while orographic rainfall plays an important role in this micro-climate change as most of the hills form the first significant barrier to marine moisture-laden air coming from the Indian Ocean, nearly 150 km away [24]. This annual precipitation, though highly variable by nature, is also greatly influenced by the movement of the Intertropical Convergence Zone, thus leading to a bimodal rainfall pattern, with long rains during March–May (MAM) and short rains in October–December (OND).

4.2. Discussion on the effects of LUCC on Wundanyi's hydrological processes

Studies in various parts of the world have shown that, in general, climate variability, slope gradient, and LUCC have a significant bearing on stream flow variations through interaction between urbanization, vegetation, soil, and rocks, upon which precipitation is being translated into surface runoff, stream flow, and groundwater recharge (baseflow) in larger basins (over 100,000 ha) and medium catchment areas between 5000 and 500,000 ha [2–4,10]. Changes in rainfall patterns associated with climate change and storm duration during rainy seasons may have a significant impact on runoff and soil erosion in larger catchments rather than smaller ones [33,34]. Hence, surface runoff and river discharges in smaller catchment areas (of less than 100 ha) may be altered by natural vegetation or the influence of man, such as significant forest cover removal and water abstractions upstream, rather than by significant effects of climate change. Furthermore, large coverage of natural vegetation dominated by large canopy forests prevents and/or decreases considerably runoff depth from high-risk areas [2]. Hence, in the short run, higher surface runoff and discharges are expected from deforested areas with high soil loss rates [8]. However, most forested areas may experience high evapotranspiration rates, leading to low groundwater generation and thus lower water tables, which in turn result in lower river discharges. In time, these dynamics change with high rates of soil erosion in deforested areas leading to the sedimentation of the river channels, while forest cover reduces soil erosion rate and, therefore, increases river discharges.

The situation may be different for medium catchments (between 5000 and 500,000 ha). Studies have shown that during the dry seasons (JF or JJAS), a decrease of forest cover in such catchments results in an increase of surface runoff with decreasing infiltration rates, thus leading to lower baseflow and stream flow downstream of between 50% and 75%. This situation is explained by the removal of organic matter (humus), which serves as a sponge in the soil and enhances soil porosity. Once removed, soil absorption capacity will decrease along with infiltration, percolation, and groundwater recharge. The latter results in decreasing baseflow and river discharge and increasing surface runoff. During the rainy seasons (OND or MAM), high rainfall inputs result in higher surface runoff, as well as discharge in forested areas rather than on cropland and deforested areas.

A different scenario would be experienced in areas with large forest cover (over 100,000 ha) during the dry seasons. High rainfall inputs do not result in significant changes in the water balance in vegetated areas, except in areas where almost all forest

cover has been cleared. Also, sharp surface runoff and discharges are experienced in areas where half of cropland has been removed. Consequently, surface runoff and stream flow in large forest areas are affected by both climate and vegetation cover. In either case, researchers concur that changes in surface runoff and river discharges occur within specific types of vegetation cover cut and/or replaced [36,37]. Therefore, crop selection and management are vital for maintaining stream flow and reducing runoff in Taita Hills.

The rainfall fluctuations coupled with LUCC over time may lead to decreased stream flow in the river basin [9,38]. Thus, the hydrological benefits could be threatened by land use/cover changes and climate variability. Land use/cover changes in the catchment impact water quality and quantity in streams [38]. It is postulated that the rapidly increasing population in the upper parts of the catchment has influenced changes that result in an increased inflow of sediments and nutrients in the river basin. For instance, a decreased water infiltration rate in a catchment may influence runoff and soil erosion patterns as observed.

5. Conclusion

The study assessed the effects of LUCC on Wundanyi's hydrological processes, focusing on surface runoff and streamflow. The findings show that Wundanyi has a highly fragmented LUC landscape. A spatial LUCC modelling of three-epoch satellite images (1990, 2000, and 2010) generated 12 LUCC categories within Wundanyi based on FAO's classification. The catchment's LUC landscape has undergone sustained modifications, which will continue up to 2030. Plantation forest has overtaken cropland as the largest LUC category; the former's share is increasing, while the proportion of the catchment's area under crops is declining, suggesting that part of the area previously used for crops is being converted to forest plantations. Significant LUC changes will occur in the future as the areas under grassland, plantation forests, and thickets increase tremendously, while woodland, broadleaved forests, shrubland, and cropland will reduce by up to half their area in 1970 by 2030. Wundanyi's LUCC has significant specific impacts on its surface runoff and streamflow, and different LUC types have had varied effects on the catchment's hydrological processes.

6. Recommendations

As a recommendation, the government and other stakeholders should implement interventions with direct and/or indirect relevance to climate change adaptation and mitigation. The interventions could cover several sectors, including agriculture, water, energy, and infrastructure. In the agriculture sector, for example, the government should promote irrigated and conservation agriculture and value addition to agricultural products. In the energy sector, the government could promote alternative energy, including geothermal, wind, solar, and mini hydropower generation, to minimize reliance on wood for fuel. The government should implement or enforce policies encouraging intensified afforestation, agroforestry-based alternative livelihood systems, alternative energy sources, community forest management, REDD+ initiatives, and reduced mono-species plantation stands. Such strategies may help reduce Wundanyi's LUCC and the associated impacts on the catchment's

hydrology.

Author contributions: Conceptualization, RAA and CNL; methodology, JAO; software, CNL and RAA; validation, RAA, JAO and CNL; formal analysis, RAA; investigation, RAA; resources, RAA; data curation, CNL; writing—original draft preparation, RAA; writing—review and editing, JAO; visualization, CNL; supervision, JAO and CNL; project administration, RAA; funding acquisition, RAA. All authors have read and agreed to the published version of the manuscript.

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References

1. UN. Sustainable Goals Report 2022. Available online: <https://unstats.un.org/sdgs/report/2022/The-Sustainable-Development-Goals-Report-2022.pdf> (accessed on 11 January 2024).
2. Guzha AC, Rufino MC, Okoth S, et al. Impacts of land use and land cover change on surface runoff, discharge and low flows: Evidence from East Africa. *Journal of Hydrology: Regional Studies*. 2018; 15: 49-67. doi: 10.1016/j.ejrh.2017.11.005
3. Velastegui-Montoya A, Montalván-Burbano N, Peña-Villacreses G, et al. Land Use and Land Cover in Tropical Forest: Global Research. *Forests*. 2022; 13(10): 1709. doi: 10.3390/f13101709
4. Chen H, Fleskens L, Baartman J, et al. Impacts of land use change and climatic effects on streamflow in the Chinese Loess Plateau: A meta-analysis. *Science of The Total Environment*. 2020; 703: 134989. doi: 10.1016/j.scitotenv.2019.134989
5. Shah SA, Jehanzaib M, Lee JH, et al. Exploring the Factors Affecting Streamflow Conditions in the Han River Basin from a Regional Perspective. *KSCE Journal of Civil Engineering*. 2021; 25(12): 4931-4941. doi: 10.1007/s12205-021-0151-5
6. Guzha AC, Rufino MC, Okoth S, et al. Impacts of land use and land cover change on surface runoff, discharge and low flows: Evidence from East Africa. *Journal of Hydrology: Regional Studies*. 2018; 15: 49-67. doi: 10.1016/j.ejrh.2017.11.005
7. Kipchumba L, Cornu E. Climate Change Action in the Water Sector in Kenya: Status Review. Available online: <https://publications.aecom.com/media/files/ClimateActionWaterSectorKenyaStatusReview.pdf> (accessed on 11 January 2024).
8. UNICEF. 2017 Impact Report. Available online: <https://www.unicef.org/kenya/media/471/file/Kenya-0000062.pdf.pdf> (accessed on 11 January 2024).
9. Wekesa C, Kirui BK, Maranga EK, et al. The Fate of Taita Hills Forest Fragments: Evaluation of Forest Cover Change between 1973 and 2016 Using Landsat Imagery. *Open Journal of Forestry*. 2020; 10(01): 22-38. doi: 10.4236/ojf.2020.101003
10. Hassan Z, Shabbir R, Ahmad SS, et al. Dynamics of land use and land cover change (LULCC) using geospatial techniques: a case study of Islamabad Pakistan. *SpringerPlus*. 2016; 5(1). doi: 10.1186/s40064-016-2414-z
11. KTWA. Distribution of Water Towers in Kenya. Available online: <https://watertowers.go.ke/water-towers/> (accessed on 11 January 2024).
12. Maeda EE. The future of environmental sustainability in the Taita Hills, Kenya: Assessing potential impacts of agricultural expansion and climate change. *Fennia*. 2012; 190 (1): 41–59. ISSN 1798-5617
13. Pellikka PKE, Heikinheimo V, Hietanen J, et al. Impact of land cover change on aboveground carbon stocks in Afromontane landscape in Kenya. *Applied Geography*. 2018; 94: 178-189. doi: 10.1016/j.apgeog.2018.03.017

14. MoALFC. Kenya County Climate Risk Profile: Taita Taveta County. Nairobi; 2021.
15. Ndalilo LA, Maranga EK, Kirui BK. Land Use and Land Cover Change along River Lumi Riparian Ecosystem in Kenya: Implications on Local Livelihoods. *Open Journal of Forestry*. 2021; 11(03): 206-221. doi: 10.4236/ojf.2021.113014
16. Gaur S, Singh R. A comprehensive review on land use/land cover (lulc) change modeling for urban development: Current status and future prospects. *Sustainability*. 2023; 15(2): 903. doi: 10.3390/su15020903
17. Arnold JG, Williams, JR, Srinivasan R, et al. Soil and Water Assessment Tool Manual. USDA Agricultural Research Service, Texas; 2000.
18. Janjić J, Tadić L. Fields of Application of SWAT Hydrological Model—A Review. *Earth*. 2023; 4(2): 331-344. doi: 10.3390/earth4020018
19. Anaba LA, Banadda N, Kiggundu N, et al. Application of SWAT to Assess the Effects of Land Use Change in the Murchison Bay Catchment in Uganda. *Computational Water, Energy, and Environmental Engineering*. 2017; 06(01): 24-40. doi: 10.4236/cweee.2017.61003
20. Ware HH, Chang SW, Lee JE, et al. Assessment of Hydrological Responses to Land Use and Land Cover Changes in Forest-Dominated Watershed Using SWAT Model. *Water*. 2024; 16(4): 528. doi: 10.3390/w16040528
21. Islam K, Jashimuddin M, Nath B, et al. Land use classification and change detection by using multi-temporal remotely sensed imagery: The case of Chunati wildlife sanctuary, Bangladesh. *The Egyptian Journal of Remote Sensing and Space Science*. 2018; 21(1): 37-47. doi: 10.1016/j.ejrs.2016.12.005
22. Lemenkova P. Modelling Landscape Changes and Detecting Land Cover Types by Means of the Remote Sensing Data and ILWIS GIS. Available online: https://www.researchgate.net/publication/337559838_Modelling_Landscape_Changes_and_Detecting_Land_Cover_Types_by_Means_of_the_Remote_Sensing_Data_and_ILWIS_GIS (accessed on 1 May 2024).
23. ICPAC. Report on Historical Climate Baseline Statistics for Taita Taveta, Kenya. Available online: https://www.icpac.net/documents/265/Kenya-Climate_baselines_Report_ACREI-Print_Copy_sVprJAJ.pdf (accessed on 11 January 2024).
24. Nyambariga FK, Opere AO, Kituyi E, et al. Climate change scenario projections and their implications on food systems in Taita Taveta County, Kenya. Benkeblia N, ed. *PLOS Climate*. 2023; 2(6): e0000114. doi: 10.1371/journal.pclm.0000114
25. Mkaya DM, Mutua BM, Kundu PW. Evaluation of The Impact of Land Use Change on Catchment Hydrology: The Case of Wundanyi River Catchment in Taita Hills, Kenya. Egerton University; 2013.
26. Sun B, Robinson D. Comparisons of Statistical Approaches for Modelling Land-Use Change. *Land*. 2018; 7(4): 144. doi: 10.3390/land7040144
27. KNBS. 2019 Kenya Population and Housing Census Results. The Regal Press Kenya Ltd; 2019.
28. Obunga G, Siljander M, Maghenda M, et al. Habitat suitability modelling to improve conservation status of two critically endangered endemic Afrotropical forest bird species in Taita Hills, Kenya. *Journal for Nature Conservation*. 2022; 65: 126111. doi: 10.1016/j.jnc.2021.126111
29. Mkuzi HT. Assessment of Land Tenure, Land Use and Land Cover Changes in Taita Hills Forest Fragments: A Case Study of Ngerenyi Forest Fragments in Taita Taveta County, Kenya. Pwani University; 2020; Unpublished work.
30. Jaetzold R, Schmidt H, Hornetz B, et al. Coast Province: Taita-Taveta County. *Farm Management Handbook of Kenya*. Ministry of Agriculture; 2012. p. 46
31. Kithiia SM. A Critical Analysis of the Water Quality Impacts on Water Resources in the Athi River Drainage Basin, Kenya. *Water Quality—Factors and Impacts*. 2022. doi: 10.5772/intechopen.99667
32. FAO. Global Forest Resources Assessment 2005, Main Report. Progress Towards Sustainable Forest Management. FAO Forestry; 2006.
33. Leul Y, Assen M, Damene S, et al. Effects of Land-Use Dynamics on Soil Organic Carbon and Total Nitrogen Stock, Western Ethiopia. *Applied and Environmental Soil Science*. 2023; 2023: 1-12. doi: 10.1155/2023/5080313
34. Li Y, Liu W, Feng Q, et al. Effects of land use and land cover change on soil organic carbon storage in the Hexi regions, Northwest China. *Journal of Environmental Management*. 2022; 312: 114911. doi: 10.1016/j.jenvman.2022.114911
35. Kumar M, Denis DM, Kundu A, et al. Understanding land use/land cover and climate change impacts on hydrological components of Usri watershed, India. *Applied Water Science*. 2022; 12(3). doi: 10.1007/s13201-021-01547-6
36. Chu X, Lu Z, Wei D, et al. Effects of Land Use/Cover Change (LUCC) on the Spatiotemporal Variability of Precipitation and Temperature in the Songnen Plain, China. *Journal of Integrative Agriculture*. 2022; 21(1): 235-248.

37. Dogan FN, Karpuzcu ME. Effect of land use change on hydrology of forested watersheds. *Ecohydrology*. 2021; 15(1). doi: 10.1002/eco.2367
38. Arantes LT, Carvalho ACP, Carvalho APP, et al. Surface runoff associated with climate change and land use and land cover in southeast region of Brazil. *Environmental Challenges*. 2021; 3: 100054. doi: 10.1016/j.envc.2021.100054

Article

Demographic conditions and territorial development of Torre de Moncorvo (North of Portugal)

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Abstract: The development of some rural areas, such as most municipalities in the Portuguese interior, is completely dependent on the maintenance and retention of their population. The strengthening and qualification of a minimum number of inhabitants are necessary for the local dynamization processes. In this paper, it is proposed a theoretical approach and the data presentation for a case study—the municipality of Torre de Moncorvo in the Douro Valley region (northern Portugal). The main objective of this contribution is to demonstrate that population maintenance is crucial to local development. The social, economic, and territorial aspects are mutually dependent and determine the sustainability and the future dynamics of this kind of rural territory.

Keywords: population; rural areas; sustainability; local development; social development

1. Introduction

The development dynamics of socially and economically peripheral areas, such as most municipalities in the Portuguese interior, are completely dependent on the maintenance and retention of their population or, at least, on the strengthening and qualification of a minimum number of inhabitants, necessary for the local dynamization process. The main literature related to this subject outlines, in the case of the rural¹ area, the importance of agriculture, mainly the studies of Kayser et al. [1] and Varela [2].

It's our aim to underline that all the different topics (demographic, social, economic, and environmental) are mutually related and are very important to the development of this territory. For that reason, it will be considered not only a revision of the bibliography², but also the population database and the analysis of the economic and social activities and their recent dynamics.

To describe the recent demographic evolution of the municipality of Torre de Moncorvo (Douro valley region—northern Portugal) and its consequences in the topics of the local economy, namely in the agricultural sector of wine and almond cultivation and in the dynamization of the activity regional tourism and the municipality itself. The three domains are even mutually dependent, as pointed out by Mendonça [3,4] or Teresa et al. [5].

2. The problem of local development in rural areas

Although it is not the primary objective of this contribution, it is important to reflect a little, in theory, on the design of rural areas in the interior of Portugal in a process of demographic shortage of population. Academic studies on issues of local development in rural areas usually address the contributions and variables that lead to the development of these types of areas. Below we can refer to a summary diagram

that allows us to visualize these dimensions:

Economic recovery, based for the most part on direct and indirect employment generated by activities in the primary sector, namely agricultural and livestock production, reveals a strong dependence on natural conditions, which, due to their variability, do not always guarantee productive and profitable agricultural years. In contrast, the close connection between agricultural and agroforestry cultivation and the maintenance and enhancement of the landscape make these activities essential for their multifunctional enhancement (for example, the possibility of maintaining the natural diversity of these spaces, the capacity for tourist use of the territory in question, and the maintenance or otherwise valorization of the local demographic contingent).

The environmental component is closely related to landscape issues and the natural resources present. Forest and agricultural settlements, surface and underground water tables, and their necessary preservation and safeguarding (even through their agricultural use and human and animal/plant supply), as well as others related, for example, to mining extraction or energy production, are all elements to consider in this field.

Social: this attribute can include the local inhabitants and those who visit the municipalities in question, aspects that are very dependent on diversity and mainly on the quality of existing public services. Consider the provision of healthcare and the field of education for children and young people. Still in this item, it is also important to guarantee good local and regional accessibility, among other aspects. In summary, demographic maintenance is a primordial condition for each of the previous aspects of the development of this type of area (economic, environmental, social), since without it all these components of development can be put into cause. Even if they have virtues and comparative advantages compared to other more competitive areas on the coast (a natural environment that is more protected from human overuse, just to mention one example), the shortage of population can condition and even endanger all of them (the aspects of development). Transposing this type of approach to the territory of Torre de Moncorvo (in the Douro region—north of Portugal) is the next objective of this contribution.

3. Geographical setting of Torre de Moncorvo

Torre de Moncorvo belongs to the northern region, district of Bragança, and flanks the Douro valley to the north in its upper section of the Portuguese part. Some of its parishes even belong to the Vale do Douro Wine Region, therefore combining technological, social, and economic traditions, to which can be added the physical or natural aspects of the landscape of this famous river valley (**Figure 1**).

This wine-growing region is unique, and that led to classifying the Douro as a living evolutionary cultural landscape of importance for humanity (by UNESCO). Regarding the Douro Demarcated Region, we should remember two of the basic concepts of the classification: integrity and authenticity, as ways of valuing material and immaterial aspects that require extensive efforts to preserve and regulate the culture of the vineyard, villages, and other constructive elements, as well as the landscape itself.



Figure 1. Torre de Moncorvo municipality.

It is important here to focus on the issue of regional tourist use and the development of the municipality of Torre de Moncorvo. It can be said that there are multiple advantages resulting from the tourist use of this type of area. Among them, it should be highlighted the possibility of promoting the wine region with a consequent possible increase in sales volume; new business opportunities linked to tourism emergence; settling population in low-density areas; and preserving and valuing traditions linked to vineyard cultivation and wine production. In fact, the National Strategic Plan for Tourism (PENT) highlights the topic of gastronomy and wine as particularly important for the strategic axis of a territory, destinations, and products³. The territories and destinations result from the fact that wine tourism units, spread across a large part of the national territory⁴, are mostly linked to wine routes and inserted in demarcated regions. According to PENT, gastronomy and wine are one of the ten strategic tourism products to be developed and will have a high contribution to the value proposition of the destination Portugal (**Figure 2**).



Figure 2. “Pinhão” Village—The Douro Wine Region (Credits by the author).

Wine tourism is a form of social and economic revitalization of some territories since, in addition to traditional wine routes, vineyards and wine museums, stays on farms with agritourism, visits to cellars, wine courses have emerged in recent years, oenology and tasting centres linked to wine, wine-growing villages, visitor and interpretation centres, new hotel units linked to health and well-being tourism (wine therapy), to name just a few examples.

This activity functions in many regions and for their population as an alternative to improve their quality of life (see in this regard many of the ideas contained in the preparatory work for the classification of the Alto Douro Wine Region as World Heritage), and it also allows to improve the awareness of residents for the high heritage value of traditions linked to vineyards and wine.

It is on the agricultural slopes of the Douro valley that the predominance of vineyards is overwhelming. However, at higher elevations, places that we can now classify as the “sub-plateau Douro”, on steeper slopes, there is forestry and sub-Atlantic bush occupation in discontinuous portions, which at certain times of the year stand out for their strong colour. In May, the yellow tufts of the broom stand out between the valley bottoms, typically Mediterranean in appearance, and the plateau region (**Figure 3**).



Figure 3. Image of the Douro wine region classified as world heritage by UNESCO (Credits by the author).

Its intermediate nature allows the coexistence of an arboreal layer in which species such as oak (*Quercus Robur L.*), cork oak (*Quercus Suber L.*), maritime pine (*Pinus Pinaster Aiton*) come together, and in the shrub layer, the already mentioned

broom, gorse (*Ulex Spp.*), the strawberry tree (*Arbustus Wedo L.*), the “Estêvão” (*Cistus Populifolius L.*), etc.

The succession of rounded peaks dominates in the lands closest to the Douro valley, generally belonging to the schist complex, and which gives it a certain landscape regularity, changes when we move to granite soils. In certain contact areas, the differences in level are more abrupt, which results in sharp breaks in river slopes or in the presence of considerable elevations, places suitable for the establishment of hermitages and viewpoints (in the case of Torre de Moncorvo, the Reboredo Mountain range). Although there may be local variations, the massifs are generally divided by a series of orthogonal divisions, which forms a succession of rounded blocks of varying size but which become striking in the landscape, especially in areas that are most devoid of vegetation. The contrast between the Douro Demarcated Region and the granite area with an Oro-Atlantic appearance that lies to the south is visible.

To the south and southeast extends the extensive plateau area where fruit crops, in this case, almond trees, prevail, although in the foreground they coexist with vineyards. Few spaces are not occupied by some of these two crops. Small patches of arboreal vegetation with darker foliage, corresponding mainly to maritime pines (*Pinus Pinaster Aiton*) and more rarely to small oak chestnuts (*Quercus Robur L.*), appear amidst a lighter green, corresponding to orchards and vines (**Figure 4**).



Figure 4. Image of the Douro wine region classified as world heritage by UNESCO “Pinhão” village (Credits by the author).

If along the Douro River the houses dotted along the valley (“Solar’s” and “Quinta” houses), in this area isolated houses rarely appear; they are grouped in clusters of different configurations: linear, following the road communication routes, population centres relatively dense in which housing is grouped around a central square, or even dispersed and without a well-defined geometric order.

Vineyards mark the landscape of the Douro region, whether in its cities and towns or punctuating rural buildings, as they played and continue to play an important role in the processes of modernization and restructuring of viticulture and tourism. Its role is especially important in the process of disseminating and valuing regional wines, particularly those with greater projection in terms of national and international sales, linked to the most recognized grape varieties. The greater economic capacity and dynamism of some of its owners, such as producer-bottlers, are not unrelated to this

phenomenon. At the same time, its prestige and the renown of its houses are also linked to embarking on wine tourism activities linked to the Port and Douro Wine Route. The important role that this activity can play in the conservation and promotion of wine properties and their architectural and heritage legacy is unquestionable, and at the same time, tourism contributes to the appreciation of the local environment and its traditions, disseminating to those who visit these units and the region a whole set of material and immaterial resources of undeniable value.

In summary, the hypsometric sketch of the region allows us to roughly describe the distribution of the various types of agricultural crops and the organization of the settlement. Using a “figurative” image of the morphology of Torre de Moncorvo, it resembles a hand, with the douro running along the ends of the fingers. The interdigital space represents the main tributaries of this portion of the north bank. The part corresponding to the parishes included in the Douro Demarcated Region occupies the southernmost portion, where the slopes are slightly steeper and the altitudes are between 250 and 600 m.

4. Demographic dynamics in Torre de Moncorvo

The demography of the municipality of Torre de Moncorvo does not contrast with the dynamics of population loss (decrease in the resident population, increased dependence on young people in the face of an increase in the elderly population) that is seen in most rural areas in the interior of mainland Portugal (**Figures 5 and 6**). Therefore, it can be concluded that all parishes have lost population, including the municipal main village, and that the aging rate is high, more significantly in parishes with greater rurality. In all the parishes, the percentage of population decline goes from 9.75 to 33.65, with the highest values corresponding to the less dynamic ones in terms of economic strength (**Figure 5**). The number of aging population goes from 925 (in the Torre de Moncorvo main centre) to 2665 in the less dynamic parishes (**Figure 6**).

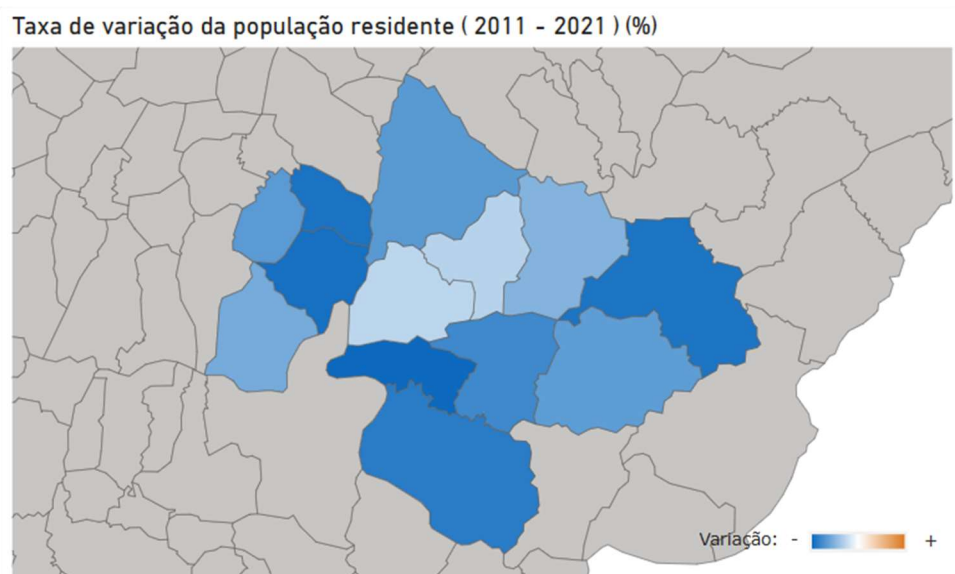


Figure 5. Population declines in the municipality 2021/2011 (%).

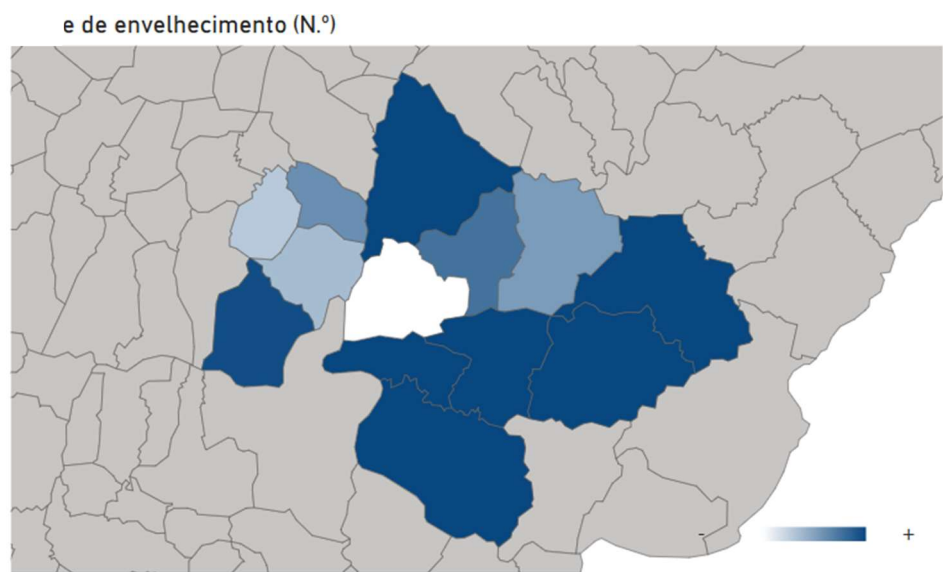


Figure 6. Ageing population in the municipality (number).

There are multiple factors explaining this demographic trend: emigration abroad and to the most dynamic areas of Portugal, particularly the city of Porto and its immediate surroundings; double aging that generates a decline in synthetic fertility rates in the municipality; population concentration only in the municipal main village, etc.

These demographic references impact not only the quantitative aspects of the total population residing in the municipality, but also qualitative aspects related to the degree of qualification of the available labor force and consequently the type of productive fabric that can be boosted locally, such as the vineyards. This will be seen in the next chapter on action proposals for the development of this territory.

5. Conclusions

Despite the difficult demographic situation, it is proposed to attract new population groups and requalify existing ones. As proposals for dynamizing the municipality, 3 areas of strategic action are referenced:

A-Territory and tourist product “Moncorvo vineyards”:

Creation of the “Moncorvo vineyards seal” and applying it to different products and tourist offers of a cultural and environmental nature (landscape), including the wine tourism route itself. Reinforce the redevelopment of public equipment along the route.

B-Tourist promotion:

Establish an online platform for disseminating regional and local tourist resources, namely the use of the “Sabor lakes” and the cultural landscape of the Douro vineyards.

C-Institutional and business articulation:

Creation of an interpretative center linked to wine and local cultural traditions and an enoteca in the municipality and the establishment of protocols that allow greater dissemination of the resources of the municipality of Torre de Moncorvo (for example with the Douro Museum, with wine operators Douro River cruises, etc.).

Depending on the territorial framework described and the proposals presented, it

is concluded that the proposals presented are just a few more ways of valuing and revitalizing a rural territory with a weak social and economic base. The historical nature of this region (like the Douro Demarcated Region as a whole) presupposes that particular attention is paid to the distinctive characteristics of its territory and the necessary preservation of its values. From the previous point, resources such as wine tourism must be viewed according to a multifunctional vision of the rural environment.

Conflict of interest: The author declares no conflict of interest.

Notes

- ^{1.} For the French case Kayser, B.; Brun, A; Cavailhès, J.; Lacombe, P. For a chosen rurality (French) (1994) Marseille, Datar/Éditions de l'aube, p. 10–17.
- ^{2.} In several contributions we've written about the Douro region, mainly pointing out the agricultural dynamic and its agrotourism role as in Mendonça, J. (2020) Know-how and agriculture and wine-growing traditions of a monastic community in Proceedings of Cultural Sustainable Tourism Congress (CST) 2nd Edition, 2020, Instituto Universitário da Maia, Maia, 13 out.
- ^{3.} Second most important form of tourism, just after the City Breaks–10%.
- ^{4.} More than 500 economic investors related to wine tourism (C. f. Wine tourism action plan 2019-2021, from “Turismo de Portugal IP”.

References

1. Kayser B, Brun A, Cavailhès J, Lacombe P. For a Chosen Rurality (French). Datar/Éditions de l'aube; 1994.
2. Varela JAS. Agriculture and Rural Space (Portuguese). Ministério da Agricultura; 1992. pp. 115-120.
3. Mendonça J. Know-How and Agriculture and Wine-Growing Traditions of a Monastic Community in Proceedings of Cultural Sustainable Tourism Congress (CST), 2nd ed. Instituto Universitário da Maia; 2020.
4. Mendonça J. Towards a geography of tourism and agrarian initiatives. The case of Lamego and Távora. PASOS Revista de Turismo y Patrimonio Cultural. 2022; 20(5): 1163-1170. doi: 10.25145/j.pasos.2022.20.078
5. Teresa S, Carlos Coelho P, Rui C, et al. Living and Knowing How: Traditional Technologies in the Douro Region: Preliminary Studies (Portuguese). Museu do Douro; 2003. pp. 11-15.

Article

A research on the people's perception and expectations and the behaviours of the cooperative partners in Balıkesir

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Abstract: The study attempts to learn the perceptions of people living in Balıkesir about cooperatives and their expectations from cooperatives. It also aims to learn the thoughts of cooperative members about cooperative activities and the behavior of each member. Within the scope of the research, 724 people from Balıkesir were interviewed. Meetings were held for discussions. The public's perception of cooperatives in Balıkesir is generally positive. However, unsuccessful attempts and the difficulty of establishing a joint business also cause negative criticism. The public expects supervision and educational assistance from the government and financial support from the municipality. There are many reasons to become a member of cooperatives. However, the first thing to do is to facilitate the work related to the activity. Acting in solidarity with other people is also an important motivation for becoming a member. In Balıkesir, it is not regular for cooperative members to attend cooperative general assembly meetings. At the same time, their desire to take part in cooperative management and control bodies is low. The success level of cooperatives varies according to the expectations of the members. In Balıkesir, 36.7% of the members find the technical information provision activity of the cooperative sufficient, while 32.7% find the product marketing activity sufficient. The majority of cooperative members in Balıkesir find the financial aid activities of cooperatives incomplete. At the same time, they generally find the product purchase price of cooperatives inadequate.

Keywords: Balıkesir; cooperation; local solidarity; entrepreneurial activity

1. Introduction

In many languages of the world, 'cooperative' is defined as the expression of solidarity and joint action. When we consider cooperatives in the sense of acting together, solidarity, and finding common solutions to problems, it can be said that the history of cooperatives is as old as the history of humanity [1]. Today, nearly one billion people are members of operating around the world, one of the three million cooperatives in the world [2]. Cooperatives, which base their philosophy on the idea of solidarity and joint action, have today turned into large organizations with commercial, economic, and social activities with broad participation [3].

Due to such activities and behaviors, the notion of cooperative is given too much meaning. Either economic language or social life language, the generally accepted definitions for cooperatives all over the world are 'joint action' and 'spirit of cooperation' [4]. A cooperative is defined as an autonomous organization of people who come together voluntarily to meet their common socioeconomic goals and aspirations through a jointly owned and democratically controlled enterprise.

The emergence of cooperatives as a form of economic organization around the

world dates back to the mid-19th century. The Turkish cooperative movement started with the Memleket Funds, founded by Mithat Pasha in 1863 [5]. Cooperative activities in the modern sense also started in the Republican Period [6]. As of 2022, there are 39 different types of cooperative activities in Turkey, while 8.5% of the population is a partner in approximately 7 million cooperatives.

Balıkesir is among the provinces where cooperative practices are intense in Turkey. Cooperative activities in Balıkesir started in the first years of the Republic, as in many parts of Turkey. While there are 890 cooperative activities in Balıkesir as of 2022, the number of partners registered in these cooperatives is 125.516. According to the date on the number of population and the number of cooperative partners, one in every ten people in Balıkesir will be a cooperative partner in 2022. There are 23 different types of cooperative activities in Balıkesir and they can be found in every district. Approximately 4.5% of the commercial companies who registered with the Chambers of Commerce in Balıkesir are cooperative companies. Approximately 50% of the tradesmen who registered in 85 separate chambers in Balıkesir are partners in cooperatives. 454 of the 890 cooperatives registered in Balıkesir are agricultural cooperatives, and as in Turkey, they stand out in terms of numbers. There are 331 agricultural development cooperatives in Balıkesir. This number is the highest among cooperative types. The number of other types of cooperatives is as follows: housing building cooperatives 226, motor transport cooperatives 79, agricultural credit cooperatives 60, aquaculture cooperatives 28, and tradesmen's credit guarantee cooperatives 23. The type of cooperatives with the highest number of partners in Balıkesir are agricultural development cooperatives. The number of partners of these cooperatives is 27,290 people. The ranking of other cooperatives in terms of the size of the number of members is as follows: Beet growers' cooperatives are 19,388 members, agricultural credit cooperatives are approximately 19,000 members, agricultural sales cooperatives are 16,318 members, tradesmen's credit and guarantee cooperatives are 15,663 members, and housing building cooperatives are 14,143. 339 of the 890 cooperatives operating in Balıkesir are members of a higher union related to their activities. While the participation rate of cooperatives in higher unions in Turkey is 33%, in Balıkesir the participation rate of cooperatives in higher unions is 38% [7]. When the scope of research grows, the depth of findings may decrease. But when the focus of research is limited, the use of specially defined parameters provides in-depth information [8]. In this study, it is aimed at obtaining detailed information about cooperatives in Balıkesir by determining the public's perception and expectations of cooperatives and by making analyses and evaluations on the behaviors of cooperative partners.

2. Methodology

2.1. Research model

The research was designed using the relational scanning model and qualitative research methods. It is stated that qualitative research data (variables such as perception, opinion, and attitude.) can be used to direct quantitative research, and data obtained through qualitative methods can be used as a basis to develop measurement tools suitable for quantitative evaluation [9]. In order to measure the perception of

cooperatives in Balıkesir, different segments of the society were reached through a survey. Questions were prepared by quoting the methods applied to agricultural marketing cooperatives by Yıldırım and Acar [10], who developed survey questions by conducting field studies on cooperatives while taking into account the unique structure of the region.

The survey consisted of 46 questions in 3 sections. All questions were prepared as a closed question type; only the ‘other’ options were arranged in an open question form. There are questions related to age, gender, education level, field of work, source of income, place of residence, and cooperative partnership situation of participants. The second part of the survey consisted of 16 questions about perceptions and expectations about cooperatives, and the third part consisted of 19 questions to determine the opinions of cooperative partners.

2.2. Data collection and analysis

Data collection tools were obtained through survey questions. Survey voice responses by telephone, online application, printed document application under observation, and face-to-face interview methods were used. The online method covered all of the survey questions and was open to participation throughout Balıkesir for twenty days from July 29 to August 17. The printed document application under the observation method also covered all the survey questions and was applied from July 28 to August 2. In the face-to-face interview method, meetings were held with cooperative managers and partners.

The first part of the survey questions was analyzed on 724 participants whose information was reached. In the second part of the survey questions, a total of 461 participants were analyzed, including 166 participants who answered the printed document under observation, 210 participants who used the online method, and 85 participants who were interviewed face-to-face. The third part of the survey questions was analyzed based on the data of a total of 223 participants who were cooperative partners. Information getting the knowledge procurement is summarized in **Table 1**.

Table 1. Data acquisition method.

Method	Total Number of Participants	Rate (%)
Voice calling application	140	19.3
Online survey application	285	39.4
Printed document application under observation	214	29.6
Face to face meeting	85	11.7
Total	724	100.0

Quantitative data were entered into Microsoft’s Excel program; percentages and frequencies were calculated and visualized with tables or graphs depending on their characteristics. Open-ended questions were coded, and then the codes were grouped according to subthemes and main themes. Names and surnames were not used in the application, and participants were represented by codes such as C1, C2, C3, etc. The data obtained were analyzed according to their numerical size, and the findings were summarized in tables [11]. Quantitative and qualitative research methods were used

together to examine and evaluate the perspectives of all participants and cooperative partners. With this method, the perception of cooperatives could be measured through the eyes of the people of Balıkesir, and cooperatives were evaluated through the opinions of their partners.

3. Results and discussion

3.1. Socio- economic characteristics of the research area

More women (59%) participated in the research than men (41%). The fact that women's cooperatives participate in face-to-face meetings and meetings with at least two female managers and that the partners of women's cooperatives show more interest in the printed document application under observation has been effective in the high rate of women's total participation.

In terms of marital status, 78% of the participants are married and 22% are single. The marriage rate is higher for women (83%) than men (71%). 53.4% of Balıkesir population is married [12]. The average age of the research participants is 44.7. The median age of Balıkesir population is 41 [13]. The age to become a cooperative partner in Turkey is 18, and since people under the age of 18 did not participate in the study, the marriage rate and median age were found to be high. 48% of the survey participants live in districts, 30% in Balıkesir center, and 22% in villages.

The majority of the participants in the research are secondary school graduates (37%). The rate of primary school graduates is 17%; the rate of people with an associate degree is 13%; the rate of people with a bachelor's degree is 18%; and the rate of people with a master's degree or doctorate is 7%. The rate of those who say they are illiterate or do not have a diploma is 8%. In Turkey and in most of the research published on determining the common characteristics of cooperatives, it is seen that cooperative partners are moderately educated [6]. Başaran and Irmak [14], in their research titled 'Partnership Structure in Agricultural Cooperatives in Edirne', Evaluation of Cooperative Activities', found that 0.37 percent of the cooperative partners were literate, 51.57 percent were primary school graduates, and 19.06 percent were secondary school graduates. They determined that 21.93% were high school graduates and 7.06% were university graduates. In the Southern Marmara Development Agency Cooperative Report [15], it was shared that in the study area covering Balıkesir and Çanakkale, those who graduated from high school ranked first with 44% of the cooperative partners' graduation status, while those with a bachelor's degree ranked second with 26%. 21% of the survey participants are private sector employees. Other income sources were found to be 19% farmers, 14% public employees, 12% retirees, and 11% tradesmen. The rate of those who do not specify their source of income or report is 23%. 30.8% of the survey participants are cooperative partners. Average partnership duration is, 16 years in tradesmen and craftsmen's credit and guarantee cooperatives, 14.5 years in agricultural sales cooperatives, 12 years in agricultural credit cooperatives, and 1.3 years in women's enterprise cooperatives. It is understood from the history of cooperative partnerships that women's initiative cooperatives have started to operate in recent years.

3.2. Perception of cooperatism

In order to measure the public's perception of cooperatives, an attempt was made to first determine the concept of cooperatives. In this context, the question 'What is the first sentence that comes to your mind when cooperatives are mentioned?' was directed. Participant reactions are grouped as positive approach, negative approach, definition through application, and no answer received (**Table 2**).

Table 2. Perception of cooperatives in Balıkesir.

Situation	Rate (%)
Positive approach	55.7
Negative approach	26.3
Definition through application	5.0
No answer	13.0
Total	100.0

55.7% of the participants in the research expressed the concept of cooperatives with a positive approach. A positive approach is expressed with concepts such as togetherness, solidarity, cooperation's joining forces, joint business culture, socializing, mutual trust, and strong partnership.

26.3% of the survey participants attributed negative meanings to the concept of cooperatives. Negative approaches are expressed with concepts such as favoritism, uninhabitable houses, difficulties in the establishment phase, theft, bad managers, and a place to find jobs for supporters.

5% of the survey participants defined their perception of cooperatives through application areas such as agriculture, markets, and housing. It is considered that the expansion of agricultural credit markets has an impact on the perception of the application area. 13% of the participants did not answer.

The perception of cooperatives varies according to people's expectations:

- While women, who sell the products they produce at home through a cooperative and turn them into income, take a positive approach by taking strength from the existence of the cooperative; women, who turn the products they produce at home into income by opening a stall in the municipal market, also have a negative attitude towards cooperatives, finding the space support provided by Balıkesir Metropolitan Municipality sufficient.
- While tradesmen who have the opportunity to access credit thanks to cooperative partnerships express positive opinions about cooperatives, tradesmen who earn income by workplace they acquired through cooperatives (small industrial site building cooperatives) may have a negative opinion about cooperatives based on other activities of the cooperative (not building housing on KOP lands).
- While the pharmacist who provides the medical product he requested from the warehouse of the cooperative of which he is a partner does not discriminate between cooperatives and other commercial companies in terms of business relations and has a positive opinion about cooperatives, farmers who cannot access chemical fertilizer from the cooperative of which they are a partner in a timely manner may make negative evaluations about the cooperatives.

- d) The approach to associate with the education and experience of managers also affects the formation of perception. As a matter of fact, those who define the same people assuming managerial duties for a long time with the concept of ‘experienced profiteering’ and those who point out that the managers (women) in newly established women’s cooperatives are inexperienced can also express negative opinions about cooperatives.
- e) Cooperatives are associations aimed at protecting common interests around the same purpose. Since they are structures that bring together people with different social statuses and income levels, the behavior and expectations of the partners may not always be the same, and the degree of satisfaction with the cooperative activities also varies. In aquaculture cooperatives, agricultural sales cooperatives, pharmacist cooperatives, and motor transport cooperatives, which have narrower (specific) areas of activity, the suitability of the service can be measured more easily, so the perception of the partners is positive, and it is seen that they embrace the cooperative culture more.
- f) Cooperative managers who find the cooperative under their management successful and make negative evaluations about other cooperatives also serve to create a negative perception.

In recent years, the view on cooperatives has been established on negative thinking due to the unsuccessful practices arising from cooperative management processes, especially housing building cooperatives [16]. The criticisms can sometimes lead to doubts and questioning the cooperative model altogether. In Balıkesir, the social status and income level of cooperative partners affected the expectations in housing cooperatives, and a negative perception about cooperatives was created due to the amount of dues determined by low-income partners and the extension of the construction period.

Believing that individuals’ responsibility-taking and tendencies are important in order to measure a perception within a population, it is asked, ‘Would you like to be the founder/manager or partner of a cooperative to be established in Balıkesir?’ Participant reactions are grouped as I will be a founder/manager, I won’t be a founder/manager, I will not be a founder/manager but I will be a partner, and I am not interested at all. The percentages of the reactions can be seen in **Table 3**.

Table 3. Tendency to be associated with a cooperative.

Feature	Rate (%)
I would be the founder/manager	14.6
I would not be the founder/manager	9.3
I would not be the founder/manager, I will be a partner	45.1
I didn’t interested in at all	12.1
No answer	18.9
Total	100.0

14.6% of the survey participants stated that they would be the founder/manager of a new cooperative to be established in Balıkesir, 9.3% stated that they would not be the founder/manager, and 45.1% stated that they would not be the founder/manager

but could be partners. While 12.1% of the participants answered that they have no interest in cooperatives, 18.9% left the question unanswered.

3.3. Expectations from cooperatives

Today, cooperatives offer a business model that can be applied to all economic activities almost everywhere in the world. Cooperatives also enable social activities to be carried out on the basis of solidarity and equality [6]. For this reason, expectations from cooperatives are diverse. Measurements regarding meeting expectations vary depending on the field of application of the cooperative activity, but are made based on the economic and social results of the activity. In order to measure the expectations of the people from cooperatives in Balıkesir, the participants were firstly asked, ‘In which area do you find cooperative activities lacking in Balıkesir?’. Participant reactions are summarized in **Table 4**.

Table 4. Field where cooperative activity is lacking in Balıkesir.

Field	Rate (%)
No answer	24.5
Agriculture	24.8
Housing production	9.8
Branding	8.8
Endangered arts and crafts	8.2
No shortage	7.6
Youth entrepreneurship	7.0
Banking- Insurance	6.0
Other (education, health, energy)	3.2
Total	100.0

24.5% of the participants didn’t answer the questions. 24.8% of the participants find the agricultural sector, 9.8% housing production, 8.8% branding, 8.2% endangered arts and crafts, 7% youth entrepreneurship, and 6% banking insurance to be lacking. The rate of those who find cooperative activities sufficient is 7.6%.

While the unique characteristics agreement of each region gives the product a ‘local’ meaning, the standards of the regional human factor of production and the characteristics of production techniques give the product a ‘local’ meaning. Local products have an internal content and are generally used to describe products grown where people live. At the same time, the historical process and the local product create a unique story. The length of local product life can sometimes cover centuries, but in any case, it is transferred from generation to generation and is carried out depending on collective memory [7]. Cooperatives all over the world carry out various activities in order to ensure the continuity of local cheap production and protect local values. In order to protect what is locally provided in Balıkesir: the questions ‘Whether there is a need for cooperatives’ and ‘For which products are cooperatives needed?’ are asked. And since the information will be important, it can be obtained from the question ‘For which local expansion production and marketing is cooperative formation needed in Balıkesir?’ was posed. 66.2% of the survey participants say that cooperatives are

needed to protect the local value in Balıkesir and 23% say that cooperatives are not needed. 10.8% of the participants left their questions unanswered. Among local products, ‘hışmerim’ ranked first (65%), while other products included ‘Balıkesir pullusu’ (43%), ‘Kapıdağı purple onion (38%), and ‘yağcıbedir carpet’ (32%).

Although cooperatives are private legal entity institutions, they are sometimes seen as state institutions due to the intensity of their relations with the public. In order to determine the level of knowledge of the people in Balıkesir on this issue and to measure their expectations from cooperatives, the question ‘What are your expectations from the state for the development of cooperative activities in Balıkesir?’ was posed to the participants. Participant reactions are grouped under the headings of education/information, supervision, legislation, support, and independence from government interference (Table 5).

Table 5. Expectations from the state.

Situation	Rate (%)
Education/Information	36.3
Supporting	22.5
Control	21.0
Regulatory update	14.1
No control by government, Independence	6.1
Total	100.0

33% of the survey participants expect the state to provide education/information. While 23% of the participants expect the state to support, 21% expect the state to supervise, and 14.1% expect legislation updates from the state. 6.1% of the participants say that the state should not interfere and cooperatives should be independent.

Expectation of support from the state focuses on raw material support, fair-festival participation support, promotion-advertising support, business networking support, and support for women’s cooperatives. In the South Marmara Development Agency South Marmara Cooperative Analysis Report, it was emphasized that the cooperatives should feel the state behind them completely, and the proposal was shared that the establishment expenses of the cooperatives, especially the virtual environment costs and product raw material purchasing expenses, advertising, and training expenses, should be covered with state support without any bureaucratic obstacles.

The purpose of the emergence of cooperatives is to strengthen local solidarity. The basic principles of cooperatives are extremely important for local development. In particular, the principle of social responsibility directly concerns local development. Due to their social responsibilities, cooperatives contribute to sustainable development on a national and global scale, starting from the local area in which they live. Cooperatives have an effect on increasing the social capital level of that city or region in the regions where they are located. The most reliable organizations where small producers and unprotected consumers organize against monopolies in the market are cooperatives. The positive effects of cooperatives for local development cannot occur spontaneously. Cooperatives need support to demonstrate their expected positive impact on local development. The most important actor of support is the municipality

of the place where the cooperative operates [17].

Cooperation of municipalities with cooperatives can be achieved through different methods. Municipalities can become partners in an active cooperative, or they can cooperate as founding partners of a new cooperative. Cooperatives Law No. 1163 says, 'Public and private law legal entities may assist, lead, and become partners in the establishment of cooperatives in which they are interested in terms of their purposes.' In Balıkesir, some municipalities have become partners in cooperatives [7].

In order to measure local levels of cooperatives, the question 'What are your expectations from the municipality for the development of cooperatives in Balıkesir?' was directed to. Participant reactions focus on support, education's information, finding solutions to the problems of motor transport companies, and the independence of the municipality's participation.

73.8% of the survey participants expect financial support from the municipality. The rate of those who expect the municipality to provide training information is 11.2%, and those who expect the motor transport cooperatives to solve their problems is 5.2%. The rate of those who expect the municipality not to interfere and the cooperatives to be independent is 3.5%. The rate of those who did not answer the question is 6.3%.

Expectation of support from the municipality; financial expectations such as renting open market/sales areas to cooperatives, providing fair-festival participation support, advertising successful cooperatives locally, providing business networking support, cooperating with cooperatives in food supply, and providing rent support by cooperating with women's cooperatives come to the core.

In Balıkesir, municipalities can strengthen local solidarity by collaborating with cooperatives. In this context, to strengthen cooperation with marketers in running a neighborhood market, marketers can establish a business cooperative or become partners. To strengthen cooperation with the slaughterhouse, including animal producers and butchers, animal sales places and slaughterhouse management cooperatives can establish or become partners in recycling service cooperatives to provide effective recycling services and to transfer the income obtained from these to the poor.

Municipalities can also cooperate with cooperatives by providing logistical support and assuming the role of supplier. In this context, while it can mediate the marketing of women's cooperative products, it can also provide direct support by purchasing the products of business cooperatives established by disabled people. Additionally, volunteer firefighting can expand its service area by collaborating with service cooperatives. Depending on the situation of the beneficiaries of fire services, it can also reduce the financial burden of fire services by delegating authority to cooperatives, if necessary.

3.4. Behaviors of cooperative partners

Behavior analysis of cooperative partners was conducted on 223 participants who were cooperative partners. While 42% of the survey participants are partners in agricultural cooperatives, 17% are partners in women's enterprise cooperatives, 12% in tradesmen and craftsmen's credit and guarantee cooperatives, 11% in motor

transport cooperatives, and 10% in housing cooperatives.

33% of the survey participants became partners in the cooperative to make their job easier. 28% of the participants stated that they partnered to do business together, 17% to socialize, and 16% to earn money. 6% of the participants shared the view that 'I became a partner to set up my own business and feel like a boss'. While the majority of women participating in the research (72%) stated that they became partners in the cooperative with the expectation of achieving social goals (achieving, socializing, being in solidarity), the majority of men (59%) became partners in the cooperative with the expectation of achieving economic goals (getting the job done easily and doing business together).

The highest management body in cooperatives is the general assembly. The level of participation in general assembly meetings is important in terms of partner cooperative relations as well as an important indicator of the partners' ownership of the cooperative. In Balıkesir, while 30% of the cooperative partners attend the general assembly meetings regularly, the majority do not attend the general assembly meetings, with 47% attending some years. The discussions held in the general assembly meetings are deemed unnecessary, and the same people being constantly elected as directors are effective in the low attendance at the general assembly meeting in Balıkesir.

Cooperatives provide the opportunity for partners to freely express their opinions and suggestions within the framework of the principle of democratic management. Ensuring the free contribution of the partners to the decisions made at the general assembly meetings is not only the duty of the management but also the partners towards the cooperative. It is possible to be effective in decision-making processes by actually participating in general assembly meetings and providing opinions and suggestions on the activities of the cooperative and other issues. In Balıkesir, 22% of the cooperative partners read the reports of the board of directors and the audit board, and 17% express their opinions at the general assembly meeting and influence the decision.

It is important for cooperative partners to take part in management and control bodies in accordance with the principle of democratic management of cooperatives. Entry into the cooperative in voluntary and legal responsibility begins following the acquisition of partnership status. Within the framework of the self-management principle of cooperatives, each partner has the opportunity to become a manager or auditor. In Balıkesir, 41% of cooperative members have worked as managers or auditors in cooperatives, and 59% have never served in management and audit bodies.

In many types of cooperatives (such as housing cooperatives and business cooperatives), the monthly/annual dues received from the partners constitute the most important income of the cooperative. In order for cooperative activities to function regularly, dues must be collected on time. Paying dues is an important obligation for cooperative partners. In Balıkesir, 82% of cooperative partners pay their dues regularly. It is considered that cooperative relations in Balıkesir are healthy, depending on the regular payment of dues.

The satisfaction level of cooperative partners with cooperative managers is important in terms of joint cooperative relations. In Balıkesir, 35.4% of cooperative partners are satisfied with their managers. 25.6% of the participating cooperative members do not find it appropriate to elect the same person as manager repeatedly.

Cooperatives are corporate structures that provide common benefits. Those who cannot get the benefit they expect from the cooperative partnership can sometimes express dissatisfaction by making evaluations solely on the managers. According to cooperative types in Balıkesir, there are negative evaluations about the same individuals assuming long-term managerial duties in building cooperatives, tradesmen's and craftsmen's credit and guarantee cooperatives, and agricultural credit cooperatives. However, in motor transport cooperatives as aquaculture cooperatives, where manager-partner relations are tighter due to business reasons, the success of the activity increases trust in managers, regardless of their tenure. In women's initiated cooperatives that have just started their operations, the majority of partners are satisfied with their managers.

Cooperatives are businesses that protect the mutual interests of their partners through cooperation. The financial expectations that the partnership will provide come first in the reason for becoming a partner in a cooperative. While 67.7% of the participants responded to the questions asked to the cooperative partners in order to reveal the importance of the cooperative partnership in terms of business activities and that they do not need a cooperative to run their current business, 15.2% of the participants responded that if there is no cooperative, my activity will come to an end.

In order to measure the indicators that meet common expectations, cooperatives asked their cooperative partners, 'Which activity of your partner's cooperative do you find sufficient?' And 'Which activity of the cooperative of which you are a partner do you find inadequate?' While 36.7% of the cooperative members find the activity of providing technical information and informing about the developments of the cooperative of which they are partners sufficient, 32.7% find the product marketing activity sufficient, and 29.1% find the activity of facilitating access to institutions and organizations sufficient. 18.8% of cooperative partners left the question unanswered. The rate of those who find the activity of cooperatives in providing financial support sufficient is 14.3%; the rate of those who find the activity of selling products at good prices sufficient is 13.9%; the rate of those who find the activity of providing production input sufficient is 13.0%.

While 40.8% of the cooperative members found the financial support activities insufficient, 31.3% stated that the activity of providing production inputs was insufficient, 29.5% stated that it was insufficient to sell the products at a good price, and 26.4% stated that the activity of providing financial support was inadequate and finds the product marketing activity inadequate (**Table 6**).

Table 6. Sufficiency of cooperative activities.

Feature	Finding it sufficient (%)	Finding it insufficient (%)
Product marketing	32.7	26.4
Providing technical information/Sharing information	36.7	17.4
Providing Access to institutions' organizations	29.1	14.3
Providing financial support	14.3	40.8
Sell products at good prices	13.9	29.5
Providing production input	13.0	31.3
No answer	18.8	1.8

In conclusions made from face-to-face interviews, the extent to which cooperative members find the activities of the cooperative in which they are a partner sufficient varies depending on whether it meets their individual expectations. While women's cooperative partners find the cooperative's activities in providing technical information and reaching institutions to be highly sufficient, the partners of agricultural sales cooperatives find the product marketing activities of the cooperative, and the partners of tradesmen and craftsmen's credit and guarantee cooperatives find the activities of the cooperative in accessing credit highly sufficient.

While the partners of agricultural credit cooperatives find the product marketing activity of the cooperative insufficient, agreement development cooperation partnerships find the financial support activity of the cooperative more inadequate. Motor transport cooperative partners have left this issue largely unanswered.

4. Conclusion

The perception of cooperatives in Balıkesir is mostly positive. There are also critical approaches based on unsuccessful practices and the difficulty of doing business together.

In Balıkesir, the rate of regular participation of cooperative partners in general assembly meetings is low, and their desire to take part in management and auditing bodies is also low. More than half of the cooperative partners in Balıkesir are not satisfied with their management, and they also neglect the process of determining the management by not attending the general assembly meetings. While this situation shows that the cooperation activity is not sufficiently embraced by the partners, it also shows that the management cannot sufficiently implement the principle of democratic unity.

Election of the same people as managers can sometimes create discomfort between the partner-manager through personal relationships, and sometimes it can create actions through trust and experience.

Women's cooperatives in Balıkesir carry out similar activities, including processing local products and selling them as finished goods. Similar activities focused on local food narrow the field of women's cooperatives. To better demonstrate the importance of cooperatives for women, the activities of women's cooperatives in Balıkesir should be diversified. It is very difficult to ensure that women become partners in legal organizations such as cooperatives, which involve legal liability and financial sanctions [7].

In Balıkesir, the negative attitudes of women who have the convenience of opening a stall in the neighborhood market towards cooperatives should be seen as a concern about legal sanctions and avoidance of financial responsibility.

Expectations from the municipality in Balıkesir regarding cooperatives mainly include financial support. Activities aimed at meeting these expectations will certainly create a financial burden for the municipality. In Balıkesir, open market sales of food and necessities and garbage collection, separation, and recycling services can be provided by cooperatives. Providing these services by cooperatives will reduce the financial burden of the municipality and may also provide additional income opportunities.

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References

1. Rehber E. Cooperatives (Turkish). Ekin Basın Yayın Dağıtım; 2011.
2. ICA. International co-operative alliance. Available online: <http://www.ica.coop> (accessed on 18 February 2024).
3. Başaran H, Zeyrek AE. Social solidarity practices and cooperatives in Turkey's economic and social development (Turkish). In: Proceedings of the 2nd International Congress on Applied Sciences: "Migration, Poverty and Employment"; 23-25 September 2016; Konya, Turkey. pp. 29-37.
4. Başaran H. The importance of solidarity relations and cooperatives in the Covid-19 pandemic impact (Turkish). Karınca Dergisi. 2020; 1001.
5. Kocabaş Yıldırım Ö. The Intellectual Dimension of the Cooperative Movement in Turkey (Turkish). Tebliğ, 20. Milletlerarası Türk Kooperatifçilik Kongresi; 2011.
6. Türkiye Kooperatifçilik Raporu. Available online: <https://ticaret.gov.tr/kooperatifcilik/bilgi-bankasi> (accessed on 18 February 2024).
7. Balıkesir'de Kooperatifçilik. Balıkesir City Council Working Report (Turkish). Balıkesir'de Kooperatifçilik; 2022.
8. Aykaç A. Solidarity Economies: Alternative Approaches to Production and Distribution (Turkish). Metis yayınları; 2018.
9. Polit DF, Beck CT. Essentials of Nursing Research: Appraising Evidence for Nursing Practise, 7th ed. Wolters Kluwer & Lippincott Williams & Wilkins; 2010.
10. Yıldırım İ, Acar İ. Thoughts and Expectations of the Students of the Faculty of Agriculture of Yüzüncü Yıl University towards Agricultural Engineering Education (Turkish). Atatürk Üniversitesi Ziraat Fakültesi; 1998. pp. 1166-1175.
11. Başaran H, Irmak E. Local product production in Devrek and the place of cooperatives in local women entrepreneurship (Turkish). Ahi Evran Akademi. 2022; 3(1): 19-31.
12. TÜİK. Available online: <https://data.tuik.gov.tr/Kategori/GetKategori?p=nufus-ve-demografi-109&dil=1> (accessed on 18 February 2024).
13. TÜİK. Available online: <https://data.tuik.gov.tr/> (accessed on 18 February 2024).
14. Başaran H, Irmak E. Edirne'de Tarımsal Amaçlı Kooperatiflerde Ortaklık Yapısı ve Kooperatif Faaliyetlerinin Değerlendirilmesi. Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi. 2018; 21: 116-122. doi: 10.18016/ksutarimdog.vi.472753
15. Güney Marmara Kalkınma Ajansı. South Marmara Cooperatives Analysis (Turkish). Available online: <https://www.gmka.gov.tr/> (accessed on 18 February 2024).
16. Başaran H. New Approaches in Cooperatives (Turkish). 21. Milletlerarası Türk Kooperatifçilik Kongresi; 2015.
17. Yalçın AZ. Cooperatives and municipal interaction in the context of local development (Turkish). Maliye Araştırmaları Dergisi. 2022; 8(1): 1-20.

Article

Patriarchy in Southern Africa and war in West Africa: Twin impediments to sustainable social development in Africa

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Abstract: Close to 4 decades post-publishing of the Brundtland Report, a global blueprint that emphasised multilateralism and interdependence of nations as the basis for a tenable sustainable development, gender inequalities and untenable development persist in Africa. There is a need to continuously redefine the pathways for eliminating poverty and gender inequalities as the basis for sustainability. A better understanding of the causes of gender inequality as well as an acknowledgement of the fact that gender equality and sustainable development are inseparable is also imperative. This review study, through a desk review of available literature, explored three central issues: why gender inequality and sustainable development must be addressed together in everyday theory and practice, how patriarchy and war cause gender inequalities and untenable sustainability in Africa, and how these twin pandemics must be confronted to ensure achievement of the 17 sustainable development goals (SDGs) and their 86 targets, drawing from case studies of Southern and West Africa. Focusing on a number of social determinants of well-being, including good health for all, sexual and reproductive health services, education for all, quality of employment, gender rights, and basic requirements such as food and portable water, the review study argues that development efforts in Africa have proved gender unequal and thus unsustainable. The review study advanced arguments for a holistic view of sustainable social development, contending that market-focused indicators of development that disregard social determinants of well-being misrepresent reality. Market-focused neo-liberal patterns of growth neglect human needs and compound poverty and undergrowth. On the other hand, integrating a people centred approach to growth helps understand the connections, ruptures, and trade-offs between dimensions of gender equality and sustainability in a way that facilitates holistic growth.

Keywords: gender equality; social sustainability; SDGs; Southern Africa; West Africa

1. Introduction

1.1. Background and theoretical underpinnings

This review study utilised a gender critique of patriarchy and war as a policy entry point for addressing the agenda of social sustainability in Africa, based on a qualitative case analysis of two sub-regions, Southern Africa and West Africa. The case analysis looked beyond mere macroeconomic stability and growth as indicators for social sustainability, arguing that economic growth is indeed a critical but insufficient component of holistic sustainable social development. Adding social economic indicators to the matrix makes an analysis of sustainable social development complete. In this review study, I asked questions on the impacts of patriarchy and gender discrimination on gender relations, as well as on the gendered impacts of war on women and girls. Advancing a pro-marginalised policy agenda, I argued that a sustainable society is not one where the poor work and live a general life, but one that

is able to address the often neglected and subtle, yet so determining social risks to which African people, especially women and girls, are exposed. The said social risks include exclusion, gender-based violence, displacement, poverty, unemployment, poor health outcomes, and poor education outcomes—which are underlining factors for gender inequality. I utilised a gender lens to my research task, focusing squarely on the plight of women and girls in patriarchal Southern Africa and in war-stricken West Africa. I identified patriarchy and conflict as twin pandemics that disproportionately affect women than men, giving poverty, disease, and human rights violations a feminine face.

Understanding the overlays between gender equality and sustainable social development requires, first and foremost, both a theoretical and practical understanding of the moral, ethical, and practical reasons why gender equality must be integral to sustainable development [1]. For this reason, I advance critical feminist theory, a tenet that interprets social development in terms of the social relations of power between women and men [2] as a suitable conceptual framework for addressing the intersections, ruptures, and trade-offs between gender equality and sustainable social development. I ask questions that are pertinent to the development of a gender-sensitive discourse on a possible inclusive and sustainable social development culture in Africa, and these are: How does patriarchy fuel gender inequality and poverty in Southern Africa? How does violent war fuel gender discrimination and poverty in West Africa? Is sustainable social development possible in the presence of patriarchy and war in Southern Africa and West Africa? How can policymakers redirect their focus for sustainable social development in Southern Africa and West Africa?

I identify patriarchy as a producer of negative masculinities, which impose passive femininities on women and further shape the characteristics and discourse of war, and war, on the other hand, as a reproducer of patriarchal violence, further holding both patriarchy and war accountable for gender inequalities, poverty, and related factors that delay achievement of the sustainable social development agenda. Feminist theories of patriarchy and war in relation to social development enrich the discourse by taking the analysis away from the patriarchal notions of men as aggressively strong and of women as passively peaceful and towards a more nuanced understanding of patriarchy and war as anchored on a dynamic that privileges the elite at the expense of the less powerful. Such a power analysis anchors gender analysis on historical realities of how colonialism aggravated gendered patriarchal relations in Africa by promoting a system that privileged men over women in terms of access to resources, information, and opportunities for empowerment. In the aftermath of colonialism, men remain more powerful than women based not only on patriarchal notions of weak femininities and strong masculinities but also on a legacy of a colonial system that systemically privileged men over women. Critical feminist theory further advances the possibility for social relations to change through education and awareness through ‘de-socialisation.’ [3–5]. This review study has the potential to inform high-level policy advancement on confronting patriarchy and war as pre-requisites for sustainable social development.

The Brundtland Report [6] defined sustainable social development as “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” The World Bank’s ethos of social

sustainability relates to “putting people first in development processes by empowering people, building cohesive and resilient societies and making institutions accessible and accountable to citizens” [7]. The two definitions concur that current needs of the populace can only be met when social policies, institutions, mechanisms, and operational regulations are made cohesive and resilient to disasters and can deliver social goods and services for all in a manner that empowers the poor and marginalised for sustainable production beyond the present consumption needs. Ridding the environment and institutions of all factors that lead to inequality and poverty enhances the achievement of sustainable social development. A better method of proffering policy-level recommendations on ending patriarchy and war starts with understanding how these twin scourges intersect to generate retrogressive and untenable development processes.

1.2. Theoretical concerns—Nexus between gender equality and sustainable social development

Concerns over the relationship between sustainable social development, patriarchy, and war stretch as far back as the World War I period. Postwar 20th-century feminist critique understood the impact of World War I on the lives of marginalised populations, especially women, as evidence of how globalising capitalism and patriarchal culture was detrimental to development [8–11]. To date, arguments of the relationship between gender equality and sustainable development have sustained, from the publication of the Brundtland Report (1987) through the adoption of the Millennium Development Goals agenda in 2000 to the Sustainable 2030 Agenda and its 17 sustainable development goals (SDGs) in 2015. Within the SDGs implementation strategy, Goal 5, ‘Achieve gender equality and empower all women and girls’, has been identified as a cross-cutting issue that advances concerns of gender-based discrimination such as unpaid work, sexual and reproductive rights, and gender-based violence, and these are all critical aspects to economic growth and sustainability [12]. Achieving SDG5 is a priority that contributes to the increase in global well-being. A thorough analysis of the 9 targets set by SDG Goal 5 on gender equality arguably reveals the centrality of this goal to sustainable development and that its concerns touch on aspects of many other SDGs, if not on all aspects of the 17. In view of all this, conjecturing the link between patriarchy and war in eroding the hopes for gender equality becomes unavoidable. Key to the 2030 Agenda is the recognition of how prospects for achievement of all SDGs relate to eradicating discrimination, all forms of inequalities, poverty, human and terrestrial prosperity, promoting freedom, and universal peace and security [13]. Likewise, Goals 5.1 to 5.6 address this aspect of eradication inequalities, while another set of goals, 5.a to 5.c, further seek to ensure gender equality by specifically addressing the following: 5.a: “Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance, and natural resources, in accordance with national laws”; 5.b: “Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women”; and 5.c: “Adopt and strengthen sound policies and enforceable legislation for the promotion of

gender equality and the empowerment of all women and girls at all levels.” [13].

Patriarchy, a power-based system that produces and reproduces gendered inequalities, manifests in subtle, dynamic, and flexible ways as a gimmick to normalise and perpetuate its presence. Patriarchal relations, principles, and ideals are systemically entrenched in the political, social, and economic crevices of society as the basis upon which inequality between men and women is defined in both the public and private realms [14]. Patriarchy, working in favour of men, determines who controls and who has access to what resources, as well as who makes what decisions and to what effect in the social, economic, environmental, and political spheres. As noted above, a class and power analysis of patriarchy extends patriarchal relations above anatomical differences towards class and power differences. Linkages to people and positions of power produce and reproduce patriarchal characteristics or masculine attributes in certain women, who in turn exert patriarchal power and control over less powerful women and men. As earlier noted, feminist critical theory historically conjectures how patriarchy has sustained its ugly presence in capitalism, colonialism, nationalism, globalisation, neoliberalism, post-colonialism, and imperialism [15–20]. Feminist scholarship thusly argues that patriarchy, like feminisms, cannot be a monolith belief system but various strands of patriarchal belief systems that reinforce each other to subordinate the less powerful in a pattern that reproduces geographies of insecurity and unsustainability. Global patriarchy, for example, has implications for economic and political global hegemonies that manifest in the manner in which global decisions and policies are made in a top-down manner with negative ramifications for the well-being of the less powerful regions, continents, and citizens. These dynamics have likewise negative ramifications for the social sustainable development of less powerful continents, regions, and nations. In short, patriarchy is an ideology for abuse of power and control of the less powerful. The paradoxical nature of patriarchy is its ability to create conditions of the normalisation of subservience not only by those who reap benefits from the system but by the victims of the system as well [15]. As an ideology of subordination, patriarchy creates and recreates violence in both the public and private spheres to instill and perpetuate fear and control, hence its linkages with war and violence.

Violence as an ideology of patriarchy is a systemic strategy for obtaining and maintaining patriarchal control. In Africa, traditional pre-colonial perceptions of women as substandard, aggravated by colonial policies that devalue women, have normalised perceptions of women as less powerful and men as the more rationale species. This belief plays out beyond mere social relations, influencing the patterns in which resources and opportunities are deployed and accessed in the economic, environmental, and political arenas. Control and fear are also characteristics of war. Patriarchy determines how wars are planned and carried out and how people of different classes and genders are affected by the consequences of war, such as conflict-related sexual violence, displacement, disease, and poverty. In the absence of direct war in most Southern African countries, women bear the consequences of stigma and discrimination emanating from patriarchal systems on both the private and public fronts. They have less access to resources and less access to positions of influence in politics and development issues, leading to less decision-making power as humans. The fundamentally gendered nature of direct war exacerbates pre-existing patriarchal

norms within society, further increasing risks for violence, discrimination, hunger, and displacement for marginalised groups, especially women. In conflict-ridden West Africa, women and girls are the most affected. They suffer the brunt of poverty and hunger and are subjected to sexual exploitation, harassment, rape, and abuse at the mercy of terrorist insurgencies. War therefore plays out as part of a broader set of cultural understandings and practices and a manifestation of patriarchal violence.

This research answers specific research gaps. While much has been documented on gender equality and on sustainable social development as separate topics, a research gap exists in studies that analyse sustainable social development jointly with gender equality in Africa. Assessing gender equality and sustainable development on a continuum enables a reflection on their mutual dependence in development theory and practice. There cannot be sustainable development without gender equality, and vice versa. Excluding a gender equality analysis in the sustainable social development discourse is similar to creating a sustainable development pathway that excludes 51 percent of the continent's population. A second research gap is that dominant existing literature on the sustainable social development agenda has a propensity to measure social development in terms of gross domestic product, available natural resources, infrastructure, and employment rate, overlooking the role of social determinants of growth and sustainability such as gender equality and equity across all pillars of sustainable development, which can be achieved when patriarchy and war are eradicated. Thusly, this review study takes gender equality as an important category of analysis in the sustainable social development discourse. Thirdly, little documented evidence pays attention to the gender dimensions of the human capital value that is destroyed by war. The lives, integrity, and worth of women and girls are lost when they are used as collateral damage in conflict, as victims of sexual and gender-based violence, displacement, poverty, and hunger. This review study confronts these identified problems by underlining firstly that the human factor is as equally important as the wealth factor in enabling sustainable development. Secondly, I argue that gender equality is a basic requirement for sustainable social development, yet both patriarchy and war erode its benefits. Finally, I emphasise that patriarchy and war produce and reproduce each other with serious negative ramifications for gender equality, hence the need for policy actions to focus on eliminating both pandemics to enable a sustainable social development practice. Patriarchy and war fragment the polity along gender and power lines, but the Social Sustainability agenda inclusively attends to the need to "put people first" in development processes. It promotes social inclusion of the poor and vulnerable by empowering people, building cohesive and resilient societies, and making institutions accessible and accountable to citizens [21].

1.3. Delimitation of the study

Southern Africa and West Africa were purposively chosen as typical representations of how prospects for gender equality are constantly eroded by patriarchy and war. Southern Africa, which has fewer direct wars, was chosen as an archetype of how patriarchy produces and reproduces inequalities, while West Africa, a modern prototype of coups and political strife in Africa, demonstrated the gendered effects of war and violence.

2. Methodology

Data gathering and data analysis methods

The review study achieved its goal through a rigorous desk review of available literature on gender equality and sustainable social development, as well as on the implications of patriarchy and war for the sustainable social development agenda in Southern Africa and West Africa. In total, 120 online articles, journals, books, research papers, reports, and reviews were identified online using a computer key word search. A thorough audit of the identified resources was undertaken by reading through the abstracts, introductions, and conclusions to ascertain their relevance to the topic under study. A total of 45 resources were discarded for irrelevance, while the retained 75 articles were thoroughly reviewed to gather secondary data for the study.

A thematic content analysis of the secondary data accumulated from reading the 75 resources was undertaken. The first stage entailed generating key themes for the study. NVivo was then used to break down and organise the rest of the data under the key themes that were generated from the study topic, intermingling it with formulated hunches to produce coherent arguments as findings for the revised study.

3. Results

3.1. The case studies: Introduction

Attaining gender equality is a crucial human rights concern embedded across all the SDG goals and targets [22]. Patriarchy accounts for gendered inequalities across all fronts of life, majorly manifesting as gender-based violence and feminised poverty, further causing untenable development. Gender inequalities traverse other inequalities—across all SDG thematic areas. Gender inequalities further intersect power imbalance and discriminatory practices, unequivocally serving as the means for combating challenges to sustainable social development [23]. Although gender equality/inequality issues extend beyond SDG5 and require to be addressed within all the 17 SDG sectors and 86 SDG targets, the limited scope of this study confined the discussion to a few selected SDGs and/or SDG targets [24,25]. The four selected targets include education, employment/unemployment rates, inequalities in quality of employment, and education. With the intention of raising the awareness of policymakers on the importance of prioritising SDG5, I assess how regional governments focus development priorities on SDG targets to enable women to access resources while affording them choices to effectively participate and make decisions at all development levels for the attainment of gender equality [26,27].

3.1.1. Gender inequality in employment levels

Patriarchy is one of the biggest challenges in Southern African countries, amongst other challenges like post-election violence, traces of civil wars, terrorist insurgencies [28–30] and pervasive state corruption [31]. Patriarchal standards in the region are visible, for example, through the female-to-male employment ratio. In the Seychelles, for example, the existing statistics of the female to male share of employment in middle management and senior management positions for 2009 to 2019 have a gender gradient that is tilted against women. This in turn translates to a

gendered gradient of feminised poverty, an economic form of violence.

Figure 1 shows an average female unemployment rate of 3.85 percent for women in the Seychelles from 2009 to 2019, meaning that 96.15 percent are formally employed. Out of the 96.15 percent of women who are employed, only 35.2 percent are in middle to senior management levels, and 64.8 percent are in lower-level employment status. The other side of the coin is that 64.8 men are in middle- to senior-management positions, while only 35.2 percent are in lower-level employment. These patterns show gross inequalities skewed against women. Seychelles is indeed a microcosm of the global patterns in employment. For instance, the global labour force participation rate for women is approximately 38 percent for women and 72 percent for men in middle to senior management positions [32,33]. This inequality gap applies both in the private and public spheres, including for women employed in formal politics and in key decision-making positions such as cabinet, parliament, and the judiciary. During the period from 1997–2005, the African Union’s (AU) set target for 30 percent women in politics and decision-making was missed, and only three countries—Mozambique, South Africa, and the United Republic of Tanzania—had reached the target in parliament, at 34.8 percent, 32.8 percent, and 30.4 percent, respectively [34]. In line with Agenda 2030, the AU revised the target to 50:50 by 2030, and to date, only South Africa, Namibia, and Mozambique are closest to realising the target, at 45.8 percent, 44.2 percent, and 42.4 percent, respectively [34].

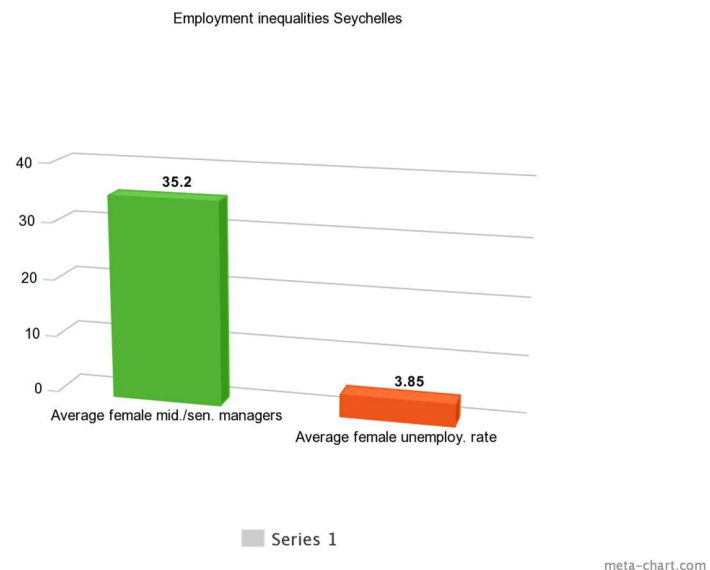


Figure 1. Employment inequalities Seychelles.

Clear arguments for both the economic and social benefits of achieving gender equality in the employment sector have been advanced for a long time. McKinsey & Company [35] argue that the most gender diverse companies are 25 percent more likely to experience above-average profitability, while the Grant Thornton report [36] establishes that having women on the board of a company boosts productivity. Yet to date, existing evidence in the area indicates a lack of progress, with the global gender gap report [37] showing that, at the current rate of progress, it will still take another 131 years to reach gender parity. Globally, only 26 percent of women in the private sector hold a C-suite position, and of those in four female C-suite executives, only one

in twenty is a woman of colour [35]. Another report shows that, globally, only 24 percent of CEOs/MDs are women, 37 percent of CFOs, and 24 percent are CMOs, and that companies with female chairs have 60 percent of women in leadership positions, compared to 27 percent in companies with male chairs [36–38]. Gender equality has been on the agenda for decades, and reports speculate that achieving it could add as much as \$12 trillion to the global economy, yet no country has yet achieved complete gender parity [39].

3.1.2. Poverty and its feminised face

The Southern African region is endowed with natural resources [32,33]. Many countries in the region have high gross domestic products (GDP), an indicator of domestic wealth, as indicated in **Figure 2**. In 2019, for example, South Africa and Angola retained the prime regional economies at US\$503.7 billion and US\$138.8 billion, respectively, while Tanzania, the DRC, Zambia, Mozambique, and Botswana followed with GDPs ranging between US\$60 billion and US\$23 billion [39]. Seychelles and Comoros, on the other hand, had the lowest GDP economies of 1.4 billion and 1.6 billion, respectively.

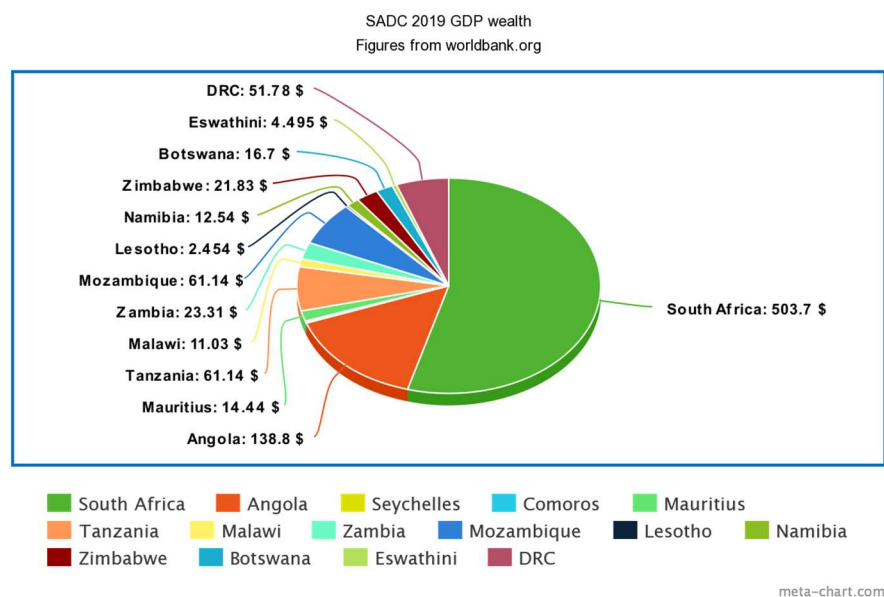


Figure 2. SADC 2019 GDP wealth.

The paradox for the region is that despite the evidence of material resource wealth and high GDP wealth, citizens experience obnoxious high levels of gendered inequalities on all fronts. **Figure 3** highlights GDP per capita wealth figures for the SADC region as at 2019. More than 60 percent of the population in Southern Africa lack access to an adequate supply of safe water, a third of the SADC population lives in abject poverty and about 40 percent of the labour force is either unemployed or underemployed [40,41]. Poverty thus, is not conceptualised through objective social indicators like income levels, consumption expenditures and infrastructural standards only, but also through subjective social indicators like a levelled playing field where citizens of all genders, classes and creeds are able to access the social determinants of well-being in an equal manner [42].

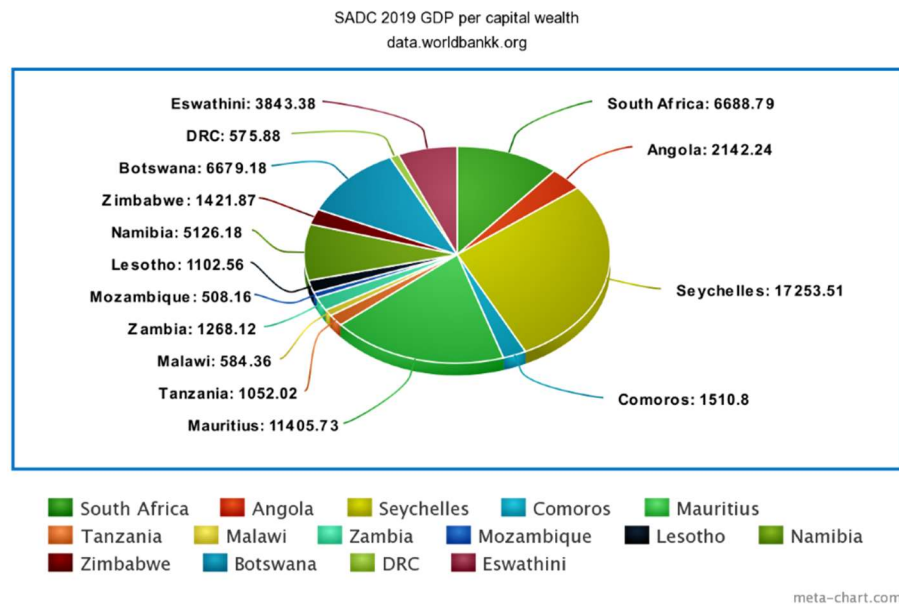


Figure 3. SADC 2019 GDP per capita wealth.

There is a need to transcend mere economic figures and statistics and focus on subjective social indicators and related social determinants of health as the measure for ascertaining a country's economic balance. For example, the Seychelles, a country with the second-lowest GDP of 1.6 billion, has the largest GDP per capita wealth, an indication that this country is striving towards sustainable social development than the rest of the countries, albeit at the most simplistic level. On the other hand, Seychelles' tallies with Mauritius as most developed nations, with a recorded human development index (HDI) ranking of 0.80. The GDP per capita and HDI of the Seychelles prove that the system therein ensures fundamental rights and adequate standards of living for its population. However, despite the projected wealth, women and children in this country are vulnerable to serious risks such as sexual exploitation, sexual abuse, child marriage, and child labour. Children who are exploited in labour have no access to better education, good health, or prospects for better employment. Likewise, victims of child marriages, rape, and sexual exploitation discontinue their education and lack access to better employment opportunities, further failing to contribute to their countries' GDPs. Rather, they depend more on government spending for social services, which is a huge barrier to sustainable development.

3.1.3. Gender-based violence and sustainable development

While projecting a high GDP and GDP per capita as noted above, Seychelles does not have available data on child marriages, which is an indication of huge gaps in the area of attainment of children's sexual rights. Seychelles ratified the African Charter on Human and People's Rights on the Rights of Women in Africa, including Article 6, which sets the minimum age for marriage as 18. Yet, the country's Civil Status Act (1980) has the minimum legal age of marriage at 15 years for girls and 18 years for boys, further allowing girls to marry even before the age of 15 in the event of consent from a minister [43]. The vague legislation presents huge risks for safety and protection of children's rights in matters of sex and marriage, further defeating the country's commitment to SDG target 5.3 of ending child marriages by 2030 [44,45].

Passing girls into adulthood at the age of 12 to 15 years has further implications for child labour, as these children are forced to assume adulthood and work to fend for families at that childhood level. The fact that Seychelles is ranked in the highest HDI when it has huge legal anomalies in the area of its legislative frameworks for child marriages is indicative of the fact that global methods and standards of ascertaining development metrics still do not encompass subjective indicators, especially those relating to gender equality and the rights of women and girls. Child marriage and child prostitution have huge consequences for both human and economic development. They lead to unwanted pregnancies, births, diseases, infant mortality, and maternal deaths; add on to negative population growth and place the care burden on the central governments.

The scourge of gender-based violence (GBV) is not unique to the Seychelles alone but a grim reality in the whole Southern African region. The extent of this scourge has compelled African Heads of State and Government to adopt the Kinshasa Declaration in 2021, a concern for the increase in violence against women and girls in Africa, as well as committed actions to address it [41,42]. The ferocity of GBV in Southern Africa has overtaken all efforts from governments, non-government organizations, development partners, and donors to combat it, and there remains no evidence or indicators to suggest that GBV statistics have dissipated. On the contrary, the advent of civil wars and political unrest, COVID-19, and ICT usage appallingly heightened cases of GBV. In South Africa, for example, more than 23 000 teenagers were impregnated during lockdown, including 934 girls aged between 10–14 years old [43]. The Zimbabwe Demographic and Health Survey [44] and other prevalence studies indicate that the most prevalent form of GBV is intimate partner violence among women aged between 15–49 years. About 35 percent of women in this age group have experienced physical violence since age 15; 14 percent have experienced sexual violence at least once in their lifetime; and 32 percent of ever-married women have experienced spousal emotional violence in their lifetime. GBV presents a major obstacle to gender equality and sustainability, with devastating consequences like HIV, unwanted pregnancies, stress, and depression, leading to suicides. GBV, especially child marriage, has dire human and economic costs on the girl child, families, communities, and the state.

The inequalities in employment levels, child marriage, and child labour challenges highlighted above and their impacts on sustainability indicate that achievement of substantive gender equality is still a long way off in Southern Africa.

3.2. War and sustainable social development in West Africa

West Africa is endowed with minerals, diamonds, and oil reserves, yet the region has huge poverty and inequality levels amongst its people. This is caused by the background of pandemics, violent conflicts, *coups d'état* and violent extremism, among other negative dynamics. Patriarchy and war dictate the pace at which women have access to decision-making processes that avail resources and opportunities to them. Countries in West Africa have suffered prolonged conflict dynamics, causing the region to be characterised by poverty and very low Human Development Index scores. As a result, people face a lack of basic services such as "... health care, portable

drinking water, education, and electricity, underpinned by governance deficits and the exclusion and marginalisation of certain segments of the population, especially women and youth” [46]. Women experience a double measure of these challenges owing to gender discrimination and prescribed gender roles. West Africa trails behind in fulfilling the requirements of SDG 4 on quality education for all, further revealing a lack of commitment to avail equal opportunities for education to all. For example, women from rich families in Mali are 15 times more likely to have received a secondary education than those from poor families [47]. Likewise, in Niger, approximately 70 percent of the poorest girls have never attended primary school. Among those who have attended, only one in two girls goes to primary school, one in 10 to secondary school, and one in 50 to high school. The average length of schooling is just 18 months, far way behind world standards [46].

There is a huge human development gap between women and men in West Africa United [48], with Cape Verde, Ghana, and Senegal falling into the lowest possible category on the UN’s gender-based HDI [48]. West Africa has been ascribed an inequalities high crisis level [47], and the 2017 UNDP Gender Inequality Index (GII) placed all West African countries at the bottom of the global GII rankings, between 131st and 158th out of the 158 classified countries [49,50]. Out of 162 countries classified in 2018, Senegal ranked 125th, Burkina Faso 147th, Niger 154th, and Mali 158 [49,50]. Disparities between men and women are most notable in the areas of health, education, and living standards. The Commitment to Reducing Inequality (2022) analysis revealed that West Africa is trailing behind five major economic blocs in Africa in the area of tackling inequality, further describing West African governments as half committed to reducing inequality when compared to their counterparts in Eastern and Southern Africa [51]. In the CRI, Nigeria, Sierra Leone, and Guinea-Bissau are ranked the lowest in efforts to reduce inequalities through social spending [51].

Nigeria, with an estimated GDP of \$477 billion in 2022, stands out as the most powerful economy in West Africa [52]. Declining economic rudiments and related variables like corruption, mismanagement, natural disasters, pandemics, and civil wars landed the country’s persistent inflation at a staggering 17-year high of 25.8 percent in August 2023, leaving Nigerians in poverty with a GDP per capita of USD 2513.00 [52]. Nigeria’s glaring gender and class inequality levels are an impediment to sustainability. Five million Nigerians face hunger, yet the combined wealth of five richest men, \$29.9 billion, could end extreme poverty at a national level, and the country’s richest man would have to spend \$1 million a day for 42 years to exhaust his fortune [52]. Women, who represent between 60 and 79 percent of Nigeria’s rural labour force, are five times less likely to own their own land than men, and also less likely to have a decent education. 94 percent of women are illiterate, while over three-quarters of the poorest women in Nigeria have never been to school [52]. One of the most crucial social determinants of well-being is health, yet the majority of poor people in Nigeria lack basic health amenities and competent medical practitioners [53]. Nigeria’s infant mortality rate is estimated at 99 per 1000 births, while the life expectancy of an average Nigerian at birth is lowly estimated at 47 years, a figure falling below that of Sub-Saharan Africa (51 years) [53].

There is a huge effect of disaggregated conflict on the poverty index and

indicators in Africa, showing conflict as having direct causal effects of poverty while worsening the standard of living along gender and class inequality lines [54]. Violent conflict destroys infrastructure and institutions, disturbs production, and leads to unemployment and inflation. Forced displacements destroy social cohesion, increasing violence against women, girls, and the marginalised and often causing unwanted pregnancies, sexually transmitted diseases, death, and injury [55-59]. Increasing political and military tensions have disturbed development pathways in Burkina Faso, Guinea-Bissau, Niger, and Mali, while civil wars and tribal resource wars have also ravaged wealth and lives in Niger and Nigeria [60]. In Mali, more than 7.5 million people faced food shortages in the last 19 years, making the country a humanitarian crisis zone [60]. Women and girls, owing to gender expectations, bear the brunt of violence and hunger in the homes as they take care of children and the elderly, while men and boys flee from scenes of violence.

Another obvious consequence of armed conflict is sexual violence, which in most cases is targeted at women and girls owing to their anatomical nature and supposed weak positions in society. Islamist fundamentalist movements and militias deliberately target women as collateral damage for their war and terror tactics [61]. In north-east Nigeria, the presence of Boko Haram makes women and girls the victims of deliberate, systematic attacks and kidnappings where they are subjected to inhuman acts of sex slavery, rape, forced concubinage, abortion, and sterilisation among other forms of sexual violence [61]. Such violations have serious ramifications for their health and well-being. Girls face increased sexual and reproductive health challenges in the absence of the required health care and services; gender equality is delayed, economic growth is reversed, and prospects for better human capital results are abridged [62,63]. Thusly, war and fragility hold back women's economic empowerment and better human capital outcomes for the current generations and for posterity [61]. Health and education are the building blocks of sustainable social development because they empower people to build better lives [63,64]. Gender-based human fragility, like all other forms of human fragility, does not only affect the well-being, lives, and livelihoods of individual people but of households, communities, and societies [64]. "Investing in women's and girls' human capital should be seen as investing in coping capacities on a societal level, which helps to achieve sustainable development" [65].

The political and war crisis has subjected Mali to a status of poverty among the countries in West Africa since 2012. The 2012 military coup d'état caused massive displacements of populations, creating a conducive environment for the rape of women and girls, including many other forms of gender-based violence [66,67]. GBV rose to 54 percent during COVID-19 compared to 43 percent before the pandemic, encouraged by school closures, food shortages, and financial difficulties that forced women and girls to cohabit with abusive men [68]. Post-Covid, GBV has become an everyday and near-normal occurrence for women and girls, firstly because the northern part of Mali has been under the control of armed groups, and secondly because the victims do not have an opportunity to seek help or report cases of violations [69,70]. While cases of rape, sexual assault and genital mutilation, physical violence, and forced marriage are still the most commonly reported in the northern and central regions, particularly in Menaka, Gourma, Timbuktu, Mopti, Socoura, and Kayes circles, the actual figures remain a mystery as very few cases are reported, and

little follow-up of reported cases is done [70]. UNFPA reports cases of deliberate denial of resources for livelihoods to women and girls, an aspect that compounds gender inequalities [68]. Traditional and religious beliefs are also major drivers of inequalities stemming from GBV in Mali. Close to 89 percent of Malian women aged 15–49 had undergone FGM (Female Genital Mutilation) nationwide and 91 percent in the capital city of Bamako. 76 percent of Female Genital Mutilation (FGM) victims were less than 5 years old [67]. The number of FGM survivors remains high due to the persistence of the traditional idea that girls should have their sexual desire reduced at an early age. Young girls are also married off in the belief that marriage is the only way they can prevent having children out of wedlock and also as collateral for food security for their poor parents. As such, GBV is normalised and tolerated by communities, and efforts to report it are often met with impunity.

4. Discussions

This review study successfully establishes that the challenges of patriarchy and war in Southern Africa and West Africa, respectively, are a major catalyst for the ever-growing inequalities in education, health, employment, well-being, consumption, and production. Both patriarchy and war produce and reproduce gendered inequalities across the whole development spectrum. Development can never be sustainable without deliberately integrating gender equality in all these pillars and across all the 17 SDGs and their 86 targets. The discussions also identified COVID-19 as a major impediment to gender equality, both in peace and war zones, but especially in war-torn countries like Mali and Niger, to mention a few. Covid-19 causes inequalities across all the pillars discussed in this review study, including health, education, human rights, well-being, employment, and production. The review study further efficaciously interrogated and defined the associations between and among the various SDGs that were discussed regarding gender inequality, based on the reviewed literature explored in this study. Case studies across selected Southern African and West African countries were documented, revealing how failure to prioritise gender equality in development processes compounds grave inequalities that prevent women and girls from actualising their potential in the present and for future generations. The reviewed literature and the documented case studies all showed minimal progress in the implementation of SGD targets. Glaring inequality gaps were revealed between women and men across all human development sectors. The plight of women in both Southern Africa and West Africa demonstrated huge push backs in the area of gender and development since independence of Africa from colonial rule, further demonstrating synergies between the colonial political economy and the post-colonial political economy in relation to patriarchy, war, and gendered inequalities in Africa. These push backs likewise equate the push backs in sustainable social development. The review study also established that in Africa, war aggravates existing patriarchal structures, prying on the societal positions of women to compound domestic violence, rape, abductions, prostitution, child marriage, spousal violence, displacement, and human trafficking, which all lead to feminised poverty. Feminised poverty in turn debilitates the state because central government budgets get spent on mitigating the manifestations of inequality and poverty instead of uprooting the causes of poverty

and inequality. Finally, the review study identified a worrying rupture in the design of targeted policies and programmes, data collection on indicators, and in the defining of development priorities. The human development index and related metrics are set outside the considerations of the gender specific social determinants of well-being, to the extent that a country supposed to be in the highest level of HDI in Africa has no documented statistics on child marriages and child abuse and still tolerates a local law that allows girls to marry at the age of 15, further making it possible for them to be married off with a minister's consent even below the age of 15. On this note, the review study makes the following recommendations, which are imperative in efforts to make gender equality a central tenet of sustainable social development:

- World governments, development partners, and policymakers must give preeminence to mainstreaming gender in all development initiatives to ensure that all planet investments equate sustainable development to gender equality.
- Gender issues should be encompassed in formulae for data collection on indicators, taking into consideration the social dimensions of sustainable development.
- More attention should be given to peacemaking and peacebuilding initiatives aimed at stopping wars across the regions, as well as to poverty alleviation.
- Increased capacity building and awareness among professionals involved in the design of policies, projects, and budgets for the implementation of the SDGs will better sensitise them on how gender is a central tenet without which development can ever be sustainable.
- Involving women in decision-making, design, and implementation of SGD goals has the potential to influence a gender sensitive culture across the whole spectrum because women have experiential knowledge and skills of surviving gendered processes.
- Gender-sensitive recruitment practice should be made a legal issue, and gender audits should be practised to ascertain adherence to gender-balanced recruitment policies.
- All forms of GBV in peacetime and wartime should be criminalised.
- Domesticating international protocols such as CEDAW may increase chances of prosecuting offenders.
- There is a need for a policy revamp in all areas of human development, as well as the need to set inclusive and realistic targets for development, including indicators that take gender equality and women's empowerment as key.
- There is also a need for Africa to speak with one voice in matters of GBV on all fronts of life.

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References

1. Leach M, Lyla M, Prabhakaran P. Gender Equality and Sustainable Development: A Pathways Approach. UN Women; 2016.
2. Parpart JL, Connelly P, Barriteau EV. Theoretical Perspectives on Gender and Development. International Development Research Centre; 2000.

3. Kitch SL. Does War have Gender? In: Hunter AE (editor). *On Peace, War, and Gender: A Challenge to Genetic Explanations*. The Feminist Press; 1991. pp. 92-103.
4. Odera JA, Mulusa J. SDGs, Gender Equality and Women's Empowerment: What Prospects for Delivery? In: Kaltenborn M, Krajewski M, Kuhn H (editors). *Sustainable Development Goals and Human Rights. Interdisciplinary Studies in Human Rights*; 2020.
5. Alonso H, Gustafson M. Bibliography on the History of U.S. Women in Movements for Peace. *Women's Studies Quarterly*. 1984; 12(2): 46-50.
6. World Commission on Environment and Development. Report of the World Commission on Environment and Development. Our common future. Available online: [https://www.google.com/search?q=The+Brundtland+Report+percent5B6percent5D+percent28World+Commission+on+Environment+and+Development+\(accessed+on+2+January+2024\).](https://www.google.com/search?q=The+Brundtland+Report+percent5B6percent5D+percent28World+Commission+on+Environment+and+Development+(accessed+on+2+January+2024).)
7. Barron P, Cord L, Cuesta J, et al. *Social Sustainability in Development: Meeting the Challenges of the 21st Century*. World Bank Group; 2023. doi: 10.1596/978-1-4648-1946-9
8. Beegle K, Christiaensen L. Accelerating Poverty Reduction in Africa. World Bank; 2019. doi: 10.1596/978-1-4648-1232-3
9. Kent SK. The Politics of Sexual Difference: World War I and the Demise of British Feminism. *Journal of British Studies*. 1988; 27(3): 232-253. doi: 10.1086/385912
10. Brewer, A. *Marxist Theories of Imperialism: A Critical Survey*. Routledge and Kegan Paul; 1980.
11. Kamester M, Vellacott J. *Militarism versus Feminism: Writings on Women and War*. Virago Press; 1987.
12. Hirsu L, Hashemi L, Quezada-Rayes Z. SDG 5: Achieve Gender Equality and Empower all Women and Girls. Jean Monnet Sustainable Development Goals. Policy Brief Series. RMIT University. Available online: <https://www.rmit.edu.au/content/dam/rmit/rmit-images/college-of-dsc-images/eu-centre/sdg-5-policy-brief.pdf> (accessed 2 January 2024).
13. United Nations. *Transforming Our World: The 2030 agenda for sustainable development*. United Nations, Department of Economic and Social Affairs; 2015.
14. Mshweshwe L. Understanding domestic violence: masculinity, culture, traditions. *Heliyon*. 2020; 6(10): e05334. doi: 10.1016/j.heliyon.2020.e05334
15. Sikweyiya Y, Addo-Lartey AA, Alangea DO, et al. Patriarchy and gender-inequitable attitudes as drivers of intimate partner violence against women in the central region of Ghana. *BMC Public Health*. 2020; 20(1). doi: 10.1186/s12889-020-08825-z
16. Bannerji, H. Patriarchy in the Era of Neoliberalism: The Case of India. *Social Scientist*. 2016; 4(3/4): 3-27.
17. Parekh S, Wilcox, S. Feminist perspectives on globalization. Available online: <https://plato.stanford.edu/archive/spr2020/entries/feminism-globalization/> (accessed on 2 January 2024).
18. Campbell B. *End of Equality (Manifestos for the 21st Century)*. Paper Back. Seagull Books; 2014.
19. Hundle AK. Postcolonial Patriarchal Nativism, Domestic Violence and Transnational Feminist Research in Contemporary Uganda. *Feminist Review*. 2019; 121(1): 37-52. doi: 10.1177/0141778918818835
20. Hearn J, Collinson DL. Men, Masculinities, Managements and Organisational Culture. *German Journal of Human Resource Management: Zeitschrift für Personalforschung*. 1998; 12(2): 210-222. doi: 10.1177/239700229801200205
21. DeKeseredy WS. Bringing Feminist Sociological Analyses of Patriarchy Back to the Forefront of the Study of Woman Abuse. *Violence Against Women*. 2020; 27(5): 621-638. doi: 10.1177/1077801220958485
22. Dhar S. Gender and Sustainable Development Goals (SDGs). *Indian Journal of Gender Studies*. 2018; 25(1): 47-78. doi: 10.1177/0971521517738451
23. Hepp P, Somerville C, Borisch B. Accelerating the United Nation's 2030 Global agenda: Why prioritization of the gender goal is essential. *Global Policy*. 2019; 10(4): 677-685. doi: 10.1111/1758-5899.12721
24. Agarwal B. Gender equality, food security and the sustainable development goals. *Current Opinion in Environmental Sustainability*. 2018; 34: 26-32. doi: 10.1016/j.cosust.2018.07.002
25. Asadikia A, Rajabifard A, Kalantari M. Systematic prioritisation of SDGs: Machine learning approach. *World Development*. 2021; 140: 105269. doi: 10.1016/j.worlddev.2020.105269
26. Obura DO. Getting to 2030 - Scaling effort to ambition through a narrative model of the SDGs. *Marine Policy*. 2020; 117: 103973. doi: 10.1016/j.marpol.2020.103973
27. Del Río Castro G, González Fernández MC, Uruburu Colsa Á. Unleashing the convergence amid digitalization and sustainability towards pursuing the Sustainable Development Goals (SDGs): A holistic review. *Journal of Cleaner Production*. 2021; 280: 122204. doi: 10.1016/j.jclepro.2020.122204

28. Political Economy in Southern Africa. Political conflict and development in SADC. Available online: <https://politicaleconomy.org.za/2019/01/political-conflict-and-development-in-sadc/> (accessed on 2 January 2024).
29. Aebly M. SADC—The Southern Arrested Development Community? Enduring Challenges to Peace and Security in Southern Africa. The Nordic Africa Institute; 2019.
30. Adebajo A, Nagar D, Paterson M, et al. Peacekeeping and peacebuilding: SADC's evolving security architecture. In: Governance and security challenges in post-apartheid Southern Africa. Centre for Conflict Resolution; 2013. pp. 35-45.
31. Ufere N, Gaskin J, Perelli S, et al. Why is bribery pervasive among firms in sub-Saharan African countries? Multi-industry empirical evidence of organizational isomorphism. *Journal of Business Research*. 2020; 108: 92-104. doi: 10.1016/j.jbusres.2019.09.060
32. Alence R, Mattes R. Mineral Governance Barometer: Southern Africa. OSISA/South African Resource Watch; 2016.
33. Mbonigaba J, Tipoy CK, Awolusi OD. Mineral resources endowment and economic growth in Southern African countries. *International Journal of Diplomacy and Economy*. 2018; 4(1): 59. doi: 10.1504/ijdi.2018.10012382
34. Meta. 2023 Sustainability Report. Available online: <https://sustainability.fb.com/wp-content/uploads/2023/07/Meta-2023-Sustainability-Report-1.pdf> (accessed on 2 January 2024).
35. Thornton, G. Women in Business 2023: The push for parity. Available online: (<https://www.grantthornton.global/en/insights/wib-2023/> (accessed on 2 January 2024).
36. 5050 Women on Board. Gender Diversity Index Fourth Quarter 2022 Key Findings. Available online: <https://www.5050WOB-2022-Q4-Infograohic-FINAL.pdf> (accessed on 2 January 2024).
37. World Economic Forum. Global Gender Gap Report 2023. Insight Report June 2023. Available online: https://www.WEF_GGGR_2023.pdf (weforum.org) (accessed on 2 January 2024).
38. Meta. 2023 Sustainability Report. Available online: <https://sustainability.fb.com/wp-content/uploads/2023/07/Meta-2023-Sustainability-Report-1.pdf> (accessed on 2 January 2024).
39. Alize le R. SADC. Available online: <https://futures.issafrica.org/geographic/recs/sadc> (accessed on 2 January 2024).
40. Jauch H. Time to Turn the Tide Tackling Poverty, Inequality and Unemployment in Southern Africa. Friedrich Ebert Stiftung. Available online: <https://library.fes.de/pdf-files/iez/08221.pdf> (accessed on 2 January 2024).
41. Development Finance International, Norwegian Church Aid and Oxfam. The Crisis of Extreme Inequality in SADC Fighting Austerity and the COVID-19 Pandemic. Oxfam International; 2022.
42. Dasgupta P, Weale M. On measuring the quality of life. *World Development*. 1992; 20(1).
43. United States Department of State. Seychelles 2019 Human Rights Report: Bureau of Democracy, Human Rights and Labor. Available online: <https://www.state.gov/wp-content/uploads/2020/02/SEYCHELLES-2019-HUMAN-RIGHTS-REPORT.pdf> (accessed on 2 January 2024).
44. Girls not brides. Available online: <https://www.girlsnotbrides.org/> (accessed on 2 January 2024).
45. African Union. 2nd Men's Conference on Positive Masculinity: Advancing actions and promoting positive masculinity to end violence against women and girls. Available online: <https://au.in/en/newsevents/20221110/secon-men's-conference-positive-masculinity> (accessed on 2 January 2024).
46. Oxfam. Briefing Report, July 2019. Available online: <https://oxfamlibrary.openrepository.com/bitstream/handle/10546/620837/bp-west-africa-inequality-crisis-090719-en.pdf> (accessed on 2 January 2024).
47. UNDP. Human Development Report 2019, Inequalities in human development in the 21st century Briefing note for countries on the 2019 Human Development Report. Available online: http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/fr/SEN.pdf (accessed on 2 January 2024).
48. UNDP. Africa Human Development Report 2016: Accelerating Gender Equality and Women's Empowerment in Africa. Available online: <https://hdr.undp.org/content/regional-human-development-report-2016-africa> (accessed on 2 January 2024).
49. UNDP. The 2020 Human Development Report. UNDP; 2020.
50. Oxfam, Development Finance International. The commitment to reducing inequality index 2022. Available online: <https://www.mn-cri-2022-mey-111022-en.pdf> (accessed on 2 January 2024).
51. World Bank. Nigeria Overview. Press Release, 19 December 2023. Available online: <https://www.worldbank.org/en/country/nigeria/overview#:~:text=From percent202015 per cent2D2022 percent2C percent20however percent2C, as percent20the percent20COVID per cent2D19 percent20pandemic> (accessed on 2 January 2024).

- 2024).
52. Ucha C. Poverty in Nigeria: Some Dimensions and Contributing Factors. *U. Global Majority E-Journal*. 2010; 1(1): 46-56.
53. Okunlola OC, Okafor IG. Conflict–Poverty Relationship in Africa: A Disaggregated Approach. *Journal of Interdisciplinary Economics*. 2020; 34(1): 104-129. doi: 10.1177/0260107920935726
54. Justino P, Verwimp P. Poverty Dynamics, Violent Conflict, and Convergence in Rwanda. *Review of Income and Wealth*. 2012; 59(1): 66-90. doi: 10.1111/j.1475-4991.2012.00528.x
55. USAID. Fact sheet, Sexual and Gender-Based Violence (GBV) in Mali. Available online <http://www.usaid.gov/mali> (accessed on 2 January 2024).
56. Addison T, Bach K, Shepard A, et al. Fragile states, conflict and chronic poverty Policy Brief, 24. Chronic Poverty Research Centre; 2010. Available online: http://www.chronicpoverty.org/uploads/publication_files/PB_percent2024.Pdf (accessed on 2 January 2024).
57. Baddeley M. Civil War and Human Development: Impacts of Finance and Financial Infrastructure. Available online: <https://api.repository.cam.ac.uk/server/api/core/bitstreams/deb83d77-e4a6-461a-bd47-d6c8eed977fe/content> (accessed on 1 April 2024).
58. Bannerji, H. Patriarchy in the Era of Neoliberalism: The Case of India. *Social Scientist*. 2016; 4(3/4): 3-27.
59. McGillivray M, Noorbakhsh F. Aid, Conflict and Human Development. World Institute for Development Economics Research, United Nations University; 2004.
60. International Rescue Committee. New sanctions risk plunging the people of Mali further into humanitarian crisis, warn 13 NGOs. Available online: <https://www.rescue.org/press-release/new-sanctions-risk-plunging-people-mali-further-humanitarian-crisis-warn-13-ngos> (accessed on 2 January 2024).
61. Organisation of Economic Cooperation and Development. How Fragile Contexts Affect the Well-Being and Potential of Women and Girls, OECD Development Co-operation Directorate. OECD Publishing; 2022.
62. Forichon K. Considering Human Capital in a Multidimensional Analysis of Fragility. OECD Development Co-operation Working Papers 80. OECD Publishing; 2020.
63. Loudon S, Goemans C, Koester D. Gender Equality and Fragility. OECD Development Co-operation Working Papers, No. 98. Paris: OECD Publishing; 2021.
64. Lwamba E, Shisler S, Riddlehoover W, et al. Strengthening women’s empowerment and gender equality in fragile contexts towards peaceful and inclusive societies: A systematic review and meta-analysis. *Campbell Systematic Reviews*. 2022; 18(1): e1214. doi: 10.1002/cl2.1214
65. Final evaluation report of the Global Programme: Women, Peace and Security, assistance to women/girls affected by conflict and women’s participation in the peace-building process in Mali (French). Available online: <https://docplayer.fr/207168019-Violences-basees-sur-le-genre-en-afrique-de-l-ouest-cas-du-senegal-du-mali-du-burkina-faso-et-du-niger.html> (accessed on 2 January 2024).
66. USAID. Ending extreme poverty in fragile contexts—Getting to Zero: A USAID discussion series, January 28. Available online: http://pdf.usaid.gov/pdf_docs/pnaec864.pdf (accessed on 2 January 2024).
67. Annual statistical report of cases of gender-based violence reported in 2018, February 2019, Sous cluster VBG au Mali, UNFPA. Available online: <https://reliefweb.int/report/central-african-republic/rapport-annuel-des-statistiques-de-vbg-janvier-d-cembre-2018-gbvims> (accessed on 2 January 2024).
68. Trust Africa. Exploratory study on the prevention and elimination of gender-based violence in Mali: Bamako, Mopti and Koulikoro. Available online: https://media.africaportal.org/documents/etude_exploratoire_sur_la_prevention_et_elimination_zone_de_bamako_mopti_et_koulikoro.pdf (accessed on 2 January 2024).
69. Africa.unwomen. Le-mali-dit-stop-aux-violence-basees-sur-legenre-vbg. Africa.unwomen, 12 April 2018. Available online: <https://africa.unwomen.org/en/news-and-events/stories/2018/04/le-mali-dit-stop-aux-violence-basees-sur-legenre-vbg> (accessed on 2 January 2024).
70. Institut National de la Statistique (INSTAT) and ICF. 2018 Mali Demographic and Health Survey Key Findings. Rockville, Maryland, USA. INSTAT and ICF; 2019

Article

Optimizing tourist flows through operative carrying capacity assessment: The case of Bakkhali coastal tourism, W.B., India

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Abstract: Carrying capacity assessment of nature-based tourist destinations is important for keeping the consumption of natural resources and anthropogenic pollution levels within environmentally safe and sustainable limits. With the mostly rural character of such destinations, the local community's well-being also needs to be prioritized. Exposure to natural hazards and climate crises have further exacerbated concerns about the long-term sustainability of these locations. The interrelationship between tourism intensity and its impacts clearly reflects Butler's Tourism Area Life Cycle model of 1980. The 'elements of capacity' and their 'critical range' mark a significant threshold in the model that leads us to the concept of carrying capacity. The capacity may be physical, spatial, ecological, environmental, social, economic, management, and governance, among others. This is also linked with the quality of the touristic experience and satisfaction. In this context, aiming to understand the optimum level of tourist traffic flow in Bakkhali, one of the popular beach destinations of the deltaic island system of the Indian Sundarbans, this study assesses its visitor carrying capacity at three levels—physical, real, and effective. It also briefly introduces the idea of 'operative' carrying capacity at the fourth level. The study is based on tourist data until 2019 and adopts the well-established methodological framework of carrying capacity assessment applied widely in several settings. The result suggests that tourism operations at Bakkhali may optimally handle 2040 visitors per day, which may be stretched to a maximum of 2267 visitors per day. This may be used as baseline information for sustainable coastal tourism policy framing in the long term while planning for tourism management and infrastructure development in the Sundarban region in immediate terms.

Keywords: beach tourism; carrying capacity; limiting factors; operative carrying capacity; sustainability

1. Introduction

The World Tourism Organization (UNWTO), a United Nations specialized agency, defines tourism as *'a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes. These people are called visitors (which may be either tourists or excursionists; residents or non-residents) and tourism has to do with their activities, some of which involve tourism expenditure'*. Tourism involves travelling and staying of people *'outside their usual environment for not more than one consecutive year for leisure, business and other purposes'* and is a sub-set of travel, while visitors are a particular type of traveler moving from one geographic location to another. UNWTO further differentiates between stay-trips and day-trips, classifying visitors as a 'tourist' (or overnight visitor) who opts for an overnight stay or as a 'same-day visitor' (or excursionist).

The tourism sector is known for its significant contribution to a country's economic development and hence plays a vital role in supporting living and livelihood in the places of visit. Tourism activities impact the natural and built environment, as well as the local community, and in turn, also get impacted. The dynamics and complexities between these dimensions influence the various stages of tourism growth and are well-depicted by Butler's theory of 'tourism area life cycle' or TALC [1].

It is interesting to note how these stages correlate with the number of visitations, particularly the development and the stagnation stages where the rates of visitation are reversed. A large number of tourists within a short span marks the development stage, whereas reduced visitations for a prolonged period indicate stagnation. **Figure 1** reinterprets the TALC model to highlight this correlation [2]. The most significant segment of Butler's hypothetical evolution of a tourist area is the post-stagnation stage, when the area can either get rejuvenated by positive strategies and action or can slip into absolute decline through five likelihoods. While E is attributed to catastrophes, B and C are hopeful possibilities where the 'capacity levels' are respected with due consideration, as minor modifications to capacity levels lead to modest growth in tourism (B) and tourism is stabilised by cutting the capacity levels (C). Once the capacity levels are reached or surpassed with passage of time and simultaneous increase of visitors, the attractiveness of a tourist area and consequent visitor experience get negatively affected. Appropriate destination planning and management can effectively reverse this trend and arrest the decline by adjusting the capacity levels even before the stage of stagnation (**Figure 1**).

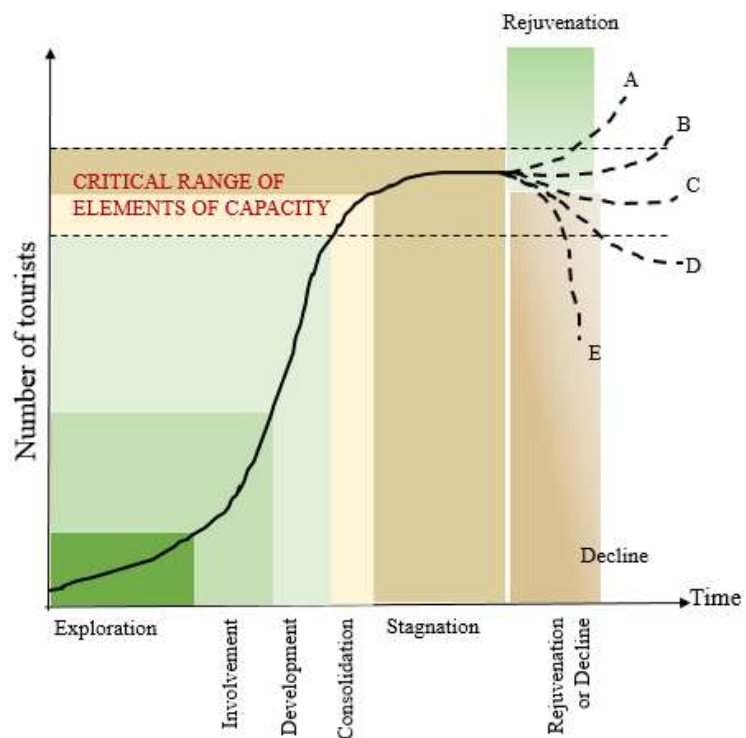


Figure 1. Carrying capacity related to tourism area life cycle [1].

TALC is the seminal model and a forebear of the sustainability concept in tourism. This is where the tourism carrying capacity figures prominently as a tool to assess and understand the threshold of tourism growth for a specific tourist area.

1.1. Need of the study

Coastal zones are densely populated regions of the world supporting about 60% of the world's population and also vulnerable to multiple natural hazards like storm surges and floods. The land-ocean interface in these zones has a complex ecosystem and experiences intense economic activities such as tourism owing to their rich resource base and aesthetic appeal. The rising anthropogenic pressure threatens the sustainability of these fragile environments [3]. The Indian Sundarbans is one such ecologically rich coastal region in south Bengal (**Figure 2**)—a World Heritage Site inscribed in 1987. It has the world's largest mangrove forests, comprising 55% forest land and 45% wetlands in the form of tidal rivers, creeks, canals, and vast estuarine mouths of the river [4]. Sandy beach is present in a few areas, while large stretches of muddy beach are common in the Sundarbans [3].



Figure 2. Location of the Indian Sundarbans [4].

The sandy beach of Bakkhali is a popular seaside location in one of the inhabited islands of the Indian Sundarbans. The State Government introduced tourism here in 1972, and in the last five decades, it has grown considerably, mainly with private initiatives. Uncontrolled tourism, inadequate planning, and a lack of ecosystem-based management have caused widespread degradation, resulting in a loss of biodiversity and ecosystem services in the Sundarbans [5]. Studies on tourism carrying capacity in the context of the Indian Sundarbans are lacking, and therefore, such an assessment for Bakkhali was felt necessary.

1.2. Aim of the study

Sustainability implies human economy to remain within earth's carrying capacity [6]. Aiming for controlled tourism growth for long-term sustainability of both environment and socio-economic conditions, this paper aims to understand the spatio-physical threshold of tourist population that may be supported by the Bakkhali tourist area within the sustainable limits. This leads to the assessment of its carrying capacity to guide/develop a plan of action for optimizing tourist traffic flow to the site.

1.3. Methodology

The methodology involves a literature review, field visits, and primary and secondary data collection. Literature review consists of two tracks: one, tourism theory covering the tourism life cycle, sustainability, and carrying capacity (CC), and second, studies on the tourism site, its development history, abiotic, built, and tourism profiles, and related challenges. These are discussed in sections 2 and 3, respectively. Tourism data and field surveys constitute the primary study. The methodology flow diagram is given in **Figure 3**.

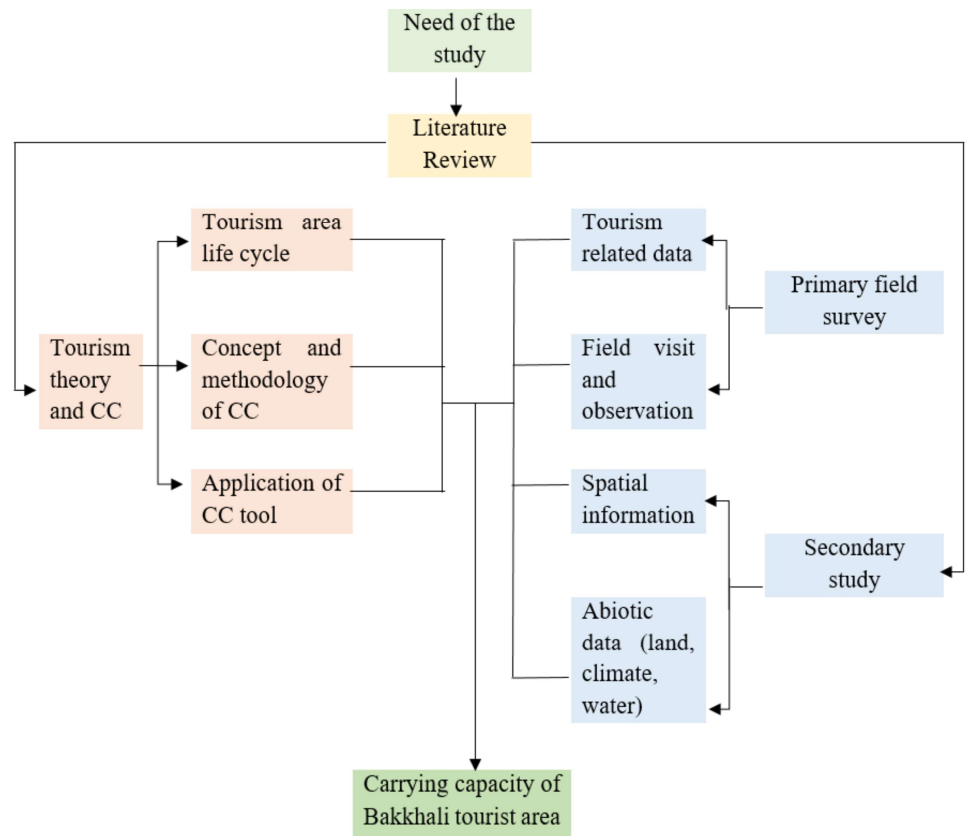


Figure 3. Research methodology.

2. Carrying capacity

2.1. Carrying capacity—Definition and dimensions

A year after the concept of ‘tourism area life cycle’ emerged, we find the United Nations World Tourism Organization defining the carrying capacity of a tourist resort as ‘*The maximum number of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic, socio-cultural environment and an unacceptable decrease in the quality of visitors’ satisfaction*’ [7,8]. This definition is echoed by McNeely and Thorsell [9] when they described carrying capacity as ‘*the maximum level of visitors use an area can accommodate with high levels of satisfaction for visitors and few negative impacts on resources*’. UNEP puts an emphasis on environment and defines carrying capacity as ‘*The maximum number of users which can be sustained by a natural or manmade resource without*

endangering the character and quality of that resource at a sustained resource productivity over time' [10]. The concept of capacity emerges from the concerns of the sustenance of fragile ecosystems in the face of accelerated anthropocentric activities and anthropogenic load. This is particularly critical to coastal environments, as these have finite resources and capacity and therefore should be central to coastal management initiatives [10]. Exceeded limits of capacity in peripheral destinations negatively affect visitor expectations, community wellbeing, and the natural environmental system [11]. Hunter [12] identified four different types of carrying capacity: physical, psychological (or perceptual), social, and economic carrying capacity. MacLeod and Cooper [13] have classified the capacity types in a slightly different manner: physical, ecological, social, and economic, with corresponding focal themes. Tourism carrying capacity is instrumental in the planning and management of tourism growth and to limit tourist flows [14]. Quicoy and Briones [15] view carrying capacity as an ecotourism tool having interdependent stakeholders from the tourism industry, community/local authorities, and environmental supporters. Tourism carrying capacity should not be viewed as a fixed framework but as a supportive tool for tourism management, with its assessment and implementation being a part of the tourism development planning process [16]. The concept is also an integral aspect of addressing the long-term sustainability of tourism sites [17].

The carrying capacity concept is most applicable in the context of natural protected areas where the visitor numbers can be regulated by the park management to a well-defined physical extent. It is quite challenging to ascertain the threshold of visitors for open-access visitation areas. Also, since no destination or person is identical, the diverse characteristics of the visitors, the hosts (local population), and the visited (destination) impede the process of objective assessment. Perception of visitors plays a significant role in determining the carrying capacity, as qualitative dimensions of attractiveness and satisfaction are subjective. Thus, carrying capacity appraisal involves both qualitative and quantitative approaches.

Carrying capacity in tourism involves three overlapping terms: tourist carrying capacity, tourism carrying capacity, and visitor carrying capacity. From the UNWTO glossary of tourism terms [18], these may be understood as below:

- 1) Tourist carrying capacity: Tourists undertake over-night stays in the tourist area. Hence, such carrying capacity studies would consider only the overnight visitors.
- 2) Visitor carrying capacity: Visitors include both tourists and excursionists, i.e., day-trippers. Hence, this study has a larger scope and considers all visitors.
- 3) Tourism carrying capacity: Tourism involves activities of visitors. Thus, the capacity of the tourist area to support all such activities comes under its purview, expressed in the number of people as per the UNWTO definition.

Cifuentes and Ceballos-Lascurain developed the methodology [19,20] based on which carrying capacity studies have been conducted by several scholars world-wide, as follows:

$$\text{Physical Carrying Capacity} = \frac{\text{Area used by tourists (say, swimming area)}}{\text{Average Individual Standard}}$$

$$\text{Rotation Coefficient} = \frac{\text{No. of daily hours area open to tourists}}{\text{Average time of visit}}$$

The total number of allowable daily visits is then determined by:

Total daily visits (maximum) = Carrying Capacity $\times$ Rotation Coefficient

The physical carrying capacity is further calibrated in a top-down process through real carrying capacity and effective carrying capacity (**Figure 4**) by accounting for the local constraints and management capacity [19–21]. Additionally, a concept of ‘operative carrying capacity’ has been introduced in this paper.

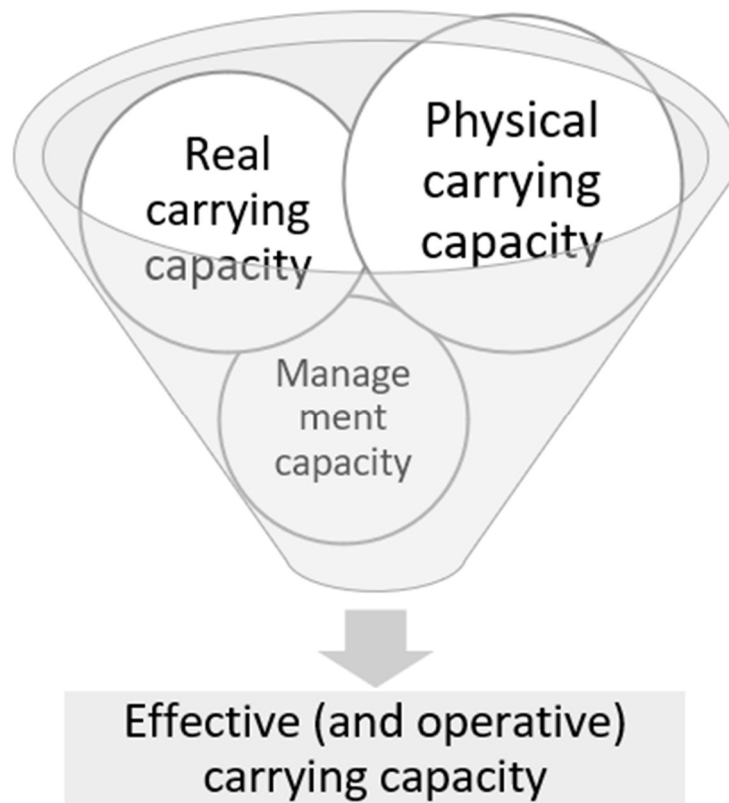


Figure 4. Interconnected top-down process of carrying capacity assessment.

The current paper has applied the physical carrying capacity (CC) assessment tool for finding the optimum number of visitors in the context of Bakkhali, the study area.

2.2. Carrying capacity assessment: Precedent studies

The deterioration in the tourist areas' environmental quality with increased footfall and intensity is seldom addressed in tourism potential studies and propositions. It is prudent to plan for controlled tourism growth from the very inception of tourism development, especially in nature-based destinations, to ensure overall sustainability. The World Tourism Organization defines sustainable tourism as “tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, and the environment and host communities”. In the 2030 Agenda for Sustainable Development, the importance of sustainable tourism is highlighted in SDG target 12.b [22].

Sustainable tourism for coastal areas is closely related to coastal zone management, which in turn uses Carrying Capacity Assessment (CCA) as a necessary

tool for formulating tourism development and management plans [7]. A tourism carrying capacity study as a part of the planning process has been presented in the report on European tourism destinations [23]. Zacarias et al. [21] focused on Praia de Faro of Portugal and assessed its physico-ecological carrying capacity for coastal management. It suggests applying the physico-ecological carrying capacity concept for ecosystem management and the socio-cultural carrying capacity for tourists and beach users.

Some applied research on carrying capacity estimation for controlled tourism in specific geographical locations include Fuka-Matrouh-Egypt [24], the Natural Reserve Mombacho Volcano-Granada and the Natural Reserve Datanl-El Diablo, Jinotega, Nicaragua [25], the Greek islands of Kalymnos, Kos, and Rhodes [26], Phong Nha-Ke Bang and Dong Hoi, Quang Binh Province, Vietnam [27], the Purbeck section of the Dorset and East Devon Coast [28], Calatagan, Batangas, Philippines [15], South Andaman Island beaches, India [29], and the Town of Mali Lošinj under both normal and recent pandemic conditions [30].

The metrics and parameters that we use in this study based on the precedent literature are:

Physical carrying capacity of beach area is one tourist per 200 m² (50 users per ha of coastal zone), and for swimming in the sea, it is one tourist per 8 m² [24].

The beach capacity of 200 m²/tourist has been adopted considering (a) ecological fragility of the coast—a habitat of the shore crabs *Ocypode macrocera* [31], their population decreasing due to increased tourism activities [32], (b) the beach use is concentrated along the shoreline in a linear manner, as much of the beach width is occupied by vending stalls, and (c) generous space for kids to run around as most tourists visit as families.

For assessing the real and effective carrying capacities, correction factors include local impediments affecting the physical carrying capacity, including climatic, abiotic, and spatial factors like monsoon months, strong winds, excessive sun-shine, cyclonic events, beach quality, sea water, beach area availability, and other related site-specific information [27,29].

3. The study area

Bakkhali Beach (21°33'32"N, 88°15'59"E) is located in the village Amrabati, Namkhana Block, Kakdwip sub-division, district South 24 Parganas in the Indian State of West Bengal (**Figure 5**). Tourism was initiated here when a government tourist lodge was set up on the eastern bank of a creek named Bakkhali (**Figure 6a**) in 1972. The convex-shaped sea-facing beach acquired its name from this creek [33]. It is 122 km south of the administrative centre of Kolkata, the capital city of West Bengal. The Namkhana Island is bordered by the Saptamukhi River on the east, Muri Ganga River on the west, Hatania-Doania River on the north, and overlooks the Bay of Bengal on the south. Its three smaller islands, namely Frazerganj, Fredrick Island, and Henry Island, are in the vicinity of Bakkhali (**Figure 6b**). The number of residents in the village is 6675 [34].

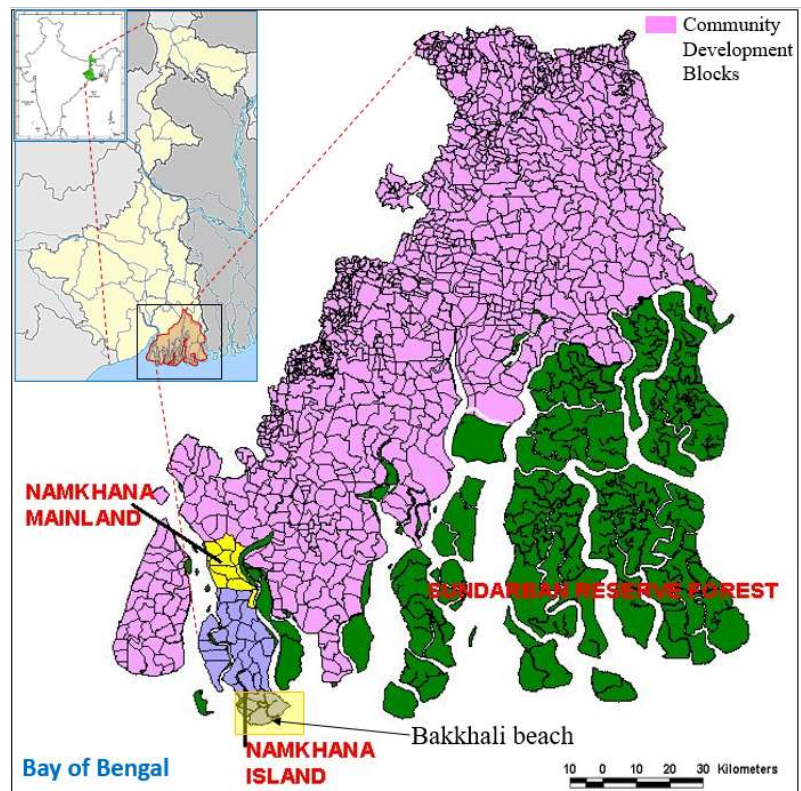


Figure 5. Location of Bakkhali in the Indian Sundarban region.



Figure 6. (a) Bakkhali creek and adjacent forests (part) in 1906–1907, 1920–1921 [35]; (b) Bakkhali beach (central part) of the Namkhana Island's convex sea front [36].

3.1. Abiotic characteristics of Bakkhali coastal region

The coastal areas of Sundarban are susceptible and vulnerable to flooding, erosion, overwash dynamics, shoreline retreat, and habitat loss at the sea face and the mouths of tidal rivers and estuaries [37]. High-intensity storms, changing directions of approach to the low-lying beaches, increased evaporation rate in dry periods, and shortage of fresh water supply further aggravate the damage to the beaches, sand dunes,

and mangroves [37]. Bakkhali beach face is nearly flat with a gentle seaward slope with MSL 1.50 m to 3.30 m and width varying between 150 m and 500 m [38]. Bakkhali experiences two predominant wind systems—the southwesterly in the summer and northeasterly in the winter, with wind velocity of 15–50 km/h and average minimum velocity of 10 km/h, respectively [39]. Cyclonic events are common in the Sundarbans due to frequent low pressure zone formation on the Bay of Bengal [40], and Bakkhali is no exception. Cyclones accompanied with heavy rainfall and wind velocities reaching up to 120 km/hour are recurrent. These also cause significant damage to the beaches within a very short period by eroding and redepositing the sands [39].

The Bakkhali coast is affected by erosion and accretion [39,41]. The erosion in Bakkhali has been so severe that the sand cover of Bakkhali sea beach has been removed, exposing the older alluvium with the formation of clay balls [42].

The coastal areas are also exposed to surface solar UV radiation [43]. Further, the coastal water quality gets affected due to anthropogenic inputs from land-based sources like domestic and agricultural wastes [44]. With close to 1000 tourists per day visiting the beach, it is obvious that tourism activities add to this load.

3.2. Built characteristics of Bakkhali tourism

The tourist accommodations are built on both sides of the major thoroughfare leading to the beach in a typical ‘ribbon development’ pattern common to the Asian countries. The majority of the hotels have very little foreground in the front and therefore create a picture of chaos and confusion. The lodgings are two to three stories high and boast highly urbanized facades (**Figure 7**). The West Bengal Tourism Development Corporation Ltd. (WBTDC) has also refurbished and expanded its tourist accommodation—the Bakkhali tourist lodge, a single-storey cottage cluster—into multi-storey blocks, renaming it Balutot Tourism Property, Bakkhali [45]. Our field survey carried out in 2019–2020 revealed about 27 tourist accommodation establishments with a total built-up area of 16,574 m² and 1705 bed capacity.



Figure 7. Some of the tourist lodges in Bakkhali (Bakkhali-Frezerganj Hoteliers Welfare Association).

The Gangasagar Bakkhali Development Authority (GBDA), constituted in June 2013 [46], is also planning to expand the tourism activities through a guided day-tourism journey from Frazerganj Fishing Harbour to Jambu Island and Benuban in collaboration with the Forest, Tourism, Fisheries, and Transport Departments. This substantiates the importance of conducting a carrying capacity assessment to inform where to draw the line.

3.3. Tourism scenario at Bakkhali

The tourist volume was 259,696 in 2018 (source: Tourism Department), and the month-wise break up of its tourist overnights is given in **Figure 8**. Tourist footfall in the Bakkhali-Fraserganj region has been reported to be 62,288 in 2001 to 190,030 in 2015 [47]. This indicates an annual growth of 14.65% in tourist volume till 2015 and 12.22% till 2018.

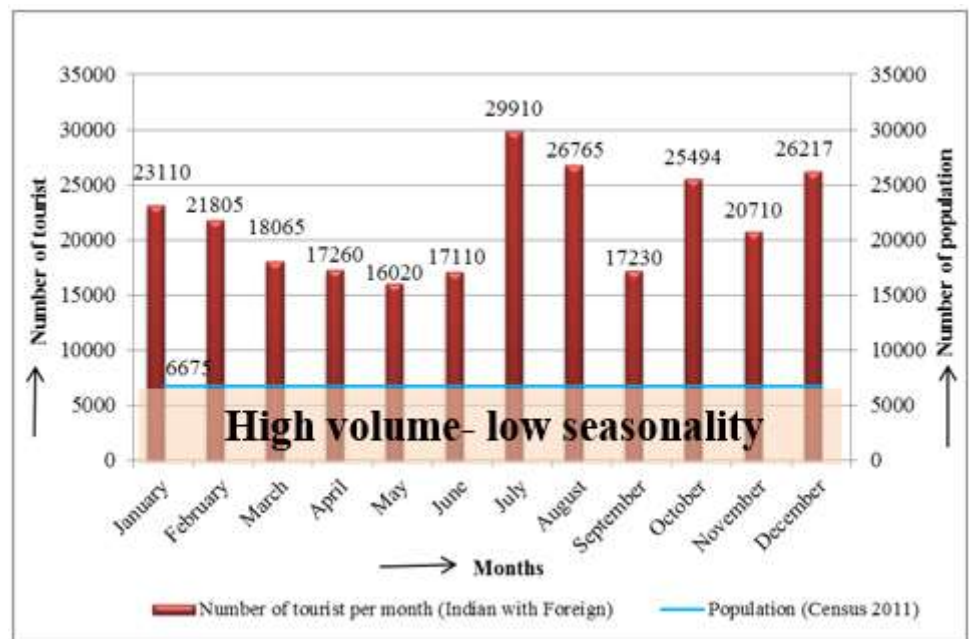


Figure 8. Month-wise break-up of tourist overnights in 2018 at Bakkhali (source: Tourism Department).

Our primary survey of 368 tourist respondents regarding their purpose of visit is indicated in **Figure 9**, and the sea beach stands out as the main reason for visiting Bakkhali.

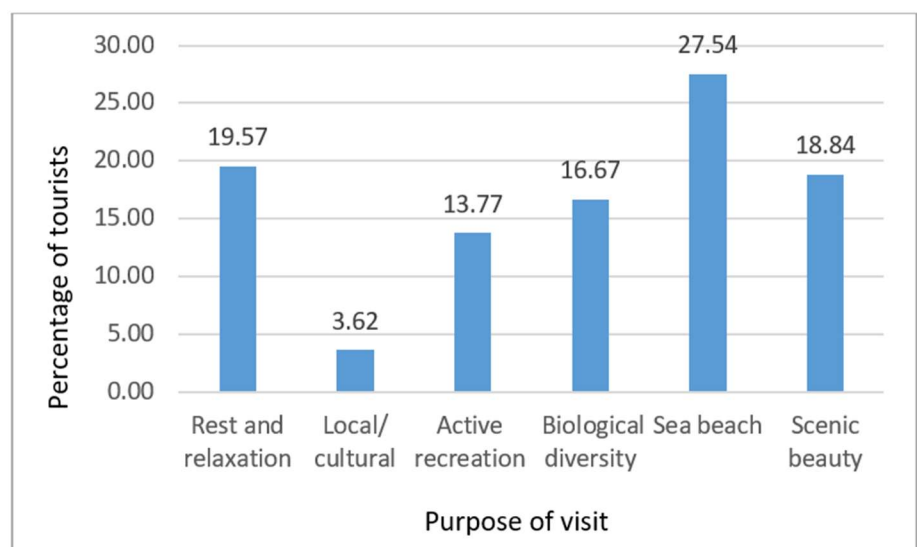


Figure 9. Tourist preferences and purpose of visiting Bakkhali (source: Authors' survey).

The above charts and our field survey reveal the following:

- a) The monthly tourist arrival is 2–4 times higher than the local population.
- b) The destination is characterized by high volume, low seasonality tourism.
- c) Annual average tourist flow is 711 tourists per day, and peak tourist flow is 965 tourists per day in the month of July 2018.
- d) A clear majority of tourists arrive at the weekend and stay over night.
- e) About 50% of tourists spend one night, 42% two nights, and the rest more than two nights.
- f) Half of the tourists surveyed are repeat visitors and have visited Bakkhali at least thrice.
- g) The main draw for visitors is the sea beach, followed by people visiting for leisure, natural qualities, and opportunities to observe biological diversity.
- h) The local people go to the beach in connection to their livelihoods, such as fishing, vending, attending their shops, and the like, varying in their spatial and temporal distribution.

4. Carrying Capacity Assessment (CCA) for Bakkhali

CCA begins with enumeration of spatio-physical data, as given in **Table 1**.

Table 1. Spatial information used for assessment of carrying capacity.

Tourist areas	Value	Remarks
Bakkhali beach area	614,089 m ²	Calculated from Google Earth
Picnic spot	53,371 m ²	
Beach length	4.164 km	Calculated from Google Earth
Sea-bathing/swimming area: 5 m into the sea for the entire length of the beach = (4164 × 5)	20,820 m ²	Computed

While assessing the Physical Carrying Capacity (PCC) for Bakkhali, the beach area and the picnic spot areas have only been considered as the ‘effective area’, especially as PCC is not merely the tourists’ spatial density but a measure of acceptable crowding in a specific location of tourist interest.

Physical Carrying Capacity or PCC is expressed as:

$$PCC = A \times D \times R_f$$

where,

A = effective area (in m²) available for use by a tourist, i.e., the Bakkhali beach area and the picnic spot area. This has been calculated directly from Google Earth (**Table 1**) and is:

Beach area: 614,089 m²

Sea-bathing/swimming area = 20,820 m²

Picnic area: 53,371 m²

D = tourist density in this case would be of two types:

Beach area: one tourist per 200 m² [24]

Swimming in the sea: one tourist per 8 m² [24]

Picnic area: Considering ten picnickers per group, each group would need a 200 m² area for comfortable sitting and play activities. Hence, tourist density would be 20

m² per tourist.

Rf = rotation factor, i.e., the number of times these visits are possible to be undertaken within a specific duration, i.e., the daily permissible visiting hours, and is given by:

Rf = visiting hours/average trip time.

Similar to D, Rf will also be of three types corresponding to D:

Beach area:

Since Bakkhali Beach is the main attraction, tourists spend substantial time on the beach, considered to be 3 hours on average. The total time available for beachgoers is from sun-rise to sun-set, which is an annual average of 12 hours. Hence, $Rf = (12/3) = 4$.

Swimming in the sea:

On average, tourists spend about 1.5 hours actively engaging with the sea from morning to noon till lunch time, i.e., about 6 hours. Hence, $Rf = (6/1.5) = 4$.

Picnic spot:

Picnicking normally starts at 11 a.m. and continues till 4 p.m., covering the lunch hours. The same group continues for the said five hours. Thus, $Rf = 5/5 = 1$.

The physical carrying capacity of Bakkhali has been assessed based on these three different types of tourist areas and is given below in the successive **Tables 2–4**:

Table 2. Calculation of Physical Carrying Capacity (PCC) for beach.

Beach area in m ²	Tourist density = One tourist per 200 m ² (in person/ m ²)	Rotation factor	PCC = A × D × Rf (no. of tourists per day)
A	D	Rf	D
614089	0.005 (1/200 m ²)	4	12282

Table 3. Calculation of Physical Carrying Capacity (PCC) for sea.

Beach area in m ²	Tourist density = One tourist per 8 m ² (in person/ m ²)	Rotation factor	PCC = A × D × Rf (no. of tourists per day)
A	D	Rf	D
20820	0.125 (1/8 m ²)	4	10410

Table 4. Calculation of Physical Carrying Capacity (PCC) for picnic spot.

Picnic spot area in m ²	Tourist density = One tourist per 10 m ² (in person/ m ²)	Rotation factor	PCC = A × D × Rf (no. of tourists per day)
A	D	Rf	D
53371	0.05 (1/20 m ²)	1	2668

4.1. Real carrying capacity

RCC is the maximum number of tourists, derived from PCC but moderated according to the destination's limitations (local, physical, or environmental conditions and management's capability). It is given by:

$$RCC = PCC \times (Cf_1 \times Cf_2 \times Cf_3 \times \dots Cf_n)$$

where: “ Cf_i (corrective factors or limiting factors) are factors having negative impact on tourism activities and assessed by limiting threshold which is used for identifying

the impact level of a factor”

The corrective factor can be determined by: $Cf_1 = (1 - M_1/M_t)$.
where M_1 : limiting magnitude of variable 1; M_t : total magnitude of variable.

These factors depend on the tourism activities and local conditions of the site, especially unfavourable climatic factors such as heavy downpours, gusty winds, unbearable solar exposure, coastal storms, etc.

High rainfall, strong winds, excessive sunshine, cyclones, and beach quality are the limiting factors for the Bakkhali coast.

Rainfall (Cf_1):

Bakkhali experiences heavy rainfall in the months of July and August to the tune of nearly 500 mm. August also has the highest number of rainy days at 27.6 days [48]. Thus, the limiting magnitude for this climatic factor will be $(30 + 31 + 31 + 30) = 122$ days out of 365 days in a year.

$$Cf_1 = 1 - (122/365) = 1 - 0.33 = 0.67$$

Strong winds (Cf_2):

The windiest month in Bakkhali is July, with an average wind speed of 16.9 mph (27.2 km/h), closely followed by June [49]. The calmest month is November, with an average wind speed of 8.2 mph (13.3 km/h). Hence, both June and July with high speed winds have been considered.

$$Cf_2 = 1 - (61/365) = 1 - 0.17 = 0.83$$

Excessive sunshine (Cf_3):

Day temperature at Bakkhali is highest in May, although March has the maximum sun hours. A combination of high day temperature and sun-shine hours can be observed from March to June. Additionally, with the south-facing beach, the Ultra Violet load is also very high during the noon when the solar zenith angle is maximum [43]. Hence, the noon hours (12 noon to 3 pm) during March to June may be considered a limiting factor for the tourists. Thus, the magnitude of the variable is $(31 + 30 + 31 + 30)$ days $\times$ 3 h = 366 h. The total magnitude is 365 days $\times$ 12 h = 4380 h.

$$Cf_3 = 1 - 366/4380 = 1 - 0.08 = 0.92$$

Cyclone (Cf_4):

Bakkhali takes the brunt of the cyclone occurrences originating from the Bay of Bengal. Severe cyclonic events take place mostly during April (Fani), and May (Aila, Amphan, Yaas), affecting normal life in this region [40]. Thus, limiting magnitude is taken as 61 days out of 365 days.

$$Cf_4 = 1 - 61/365 = 1 - 0.17 = 0.83$$

Beach quality (Cf_5):

The quality of the beach and the sea environment contributes to the tourist experience in a major way. Here eight parameters have been considered: (a) on-beach vending activities, (b) beach materials, (c) beach slope, (d) tide action, (e) beach length, (f) beach color, (g) litter, and (h) seawater quality. Except for the first, all the other seven parameters have been adopted from Sridhar et al. [29]. On-beach vending is common on many beaches, with both positive and negative sides to it. While local people get an opportunity to earn, ill-management results in litter and solid waste accumulation. **Table 5** shows the tourists' perception of the beach quality and their level of satisfaction.

Table 5. Limitation assessment of quality and ambience of Bakkhali beach.

on-beach vending activities	beach materials	beach slope	tide action	beach length	beach color	litter	seawater quality	Limiting magnitude
(-)	(+)	(+)	(+)	(+)	(+)	(-)	(+)	(2/8) = 0.25

In case of Bakkhali, on-beach vending and litter contribute negatively, thus

$$Cf_5 = 1 - 2/8 = 1 - 0.25 = 0.75$$

For the picnic spot, the following seven parameters have been considered based on the authors' perceptions: (a) ground cover, (b) sea view, (c) view of surrounding land, (d) tree canopy and overall aesthetics, (e) spaciousness, (f) litter, and (g) tourist amenities/conveniences. Out of these seven, only sea view and spaciousness appear positive. **Table 6** shows the tourists' perception of the picnic spot and their level of satisfaction.

Table 6. Limitation assessment of quality and ambience of picnic spot.

ground cover	sea view	view of surrounding land	tree canopy and overall aesthetics	spaciousness	litter	tourist amenities	Limiting magnitude
(-)	(+)	(-)	(-)	(+)	(-)	(-)	(5/7) = 0.71

$$Cf_5 (\text{picnic spot}) = 1 - 5/7 = 1 - 0.71 = 0.29$$

The Real Carrying Capacity (**Table 7**) presents a more realistic number of tourists who may engage in touristic activities at a given point in time in Bakkhali. These figures have to be further rationalized based on the current state of tourism management or management capacity (Mc), a crucial and defining factor for sustainability. Goal 14 of the United Nation's Sustainable Development Goal SDG 17 aims to "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" and identifies five ocean emergencies: coastal eutrophication, ocean acidification, ocean warming, including sea-level rise, plastic pollution, and overfishing [22]. The UN Ocean Conference 2022 recognises tourism as one of the major economic activities that depend on a healthy ocean [50]. Ill-managed tourism also contributes to some of the ocean emergencies, particularly pollution. Hence, implementing better coastal waste collection is vital to address marine pollution since 60 to 90 percent of ocean litter is made up of different plastic polymers [50]. The study on beach pollution at Bakkhali [47] found that the micro-litter load was significantly higher than that observed in most other sea beaches of India. Mostly generated through tourism activities, these put the beach infauna at severe risk. Other than this, an overarching sustainability management plan aligned with the Coastal Zone Management Plans (CZMP) and its environmental regulations; capacity building of stakeholders; visitor sensitization; 'green' design, construction, and operation of buildings and infrastructure; and disaster preparedness and emergency response plans need to be urgently prepared by the local and state bodies in charge of tourism. The management capacity has been assessed based on these parameters adapted from the Green Globe International Standard for Sustainable Tourism [51].

Table 7. Calculation of Real Carrying Capacity (RCC).

Tourist area	Physical Carrying Capacity (PCC)	Correction factors					Product of the Cf.s	Real Carrying Capacity (RCC)
		Cf ₁	Cf ₂	Cf ₃	Cf ₄	Cf ₅		
							CF	(PCC × Cf)
Beach	12282	0.67	0.83	0.92	0.83	0.75	0.3185	3912
Sea	10410	0.67	0.83	0.92	0.83	0.75	0.3185	3315
Picnic spot	2668	0.67	0.83	0.92	0.83	0.29	0.1231	328

Five broad capacity parameters have been shortlisted: (a) sewage treatment facilities; (b) solid waste management; (c) ‘green’ lodging regulations; (d) capacity building; and (e) tourist sensitization. These are appraised in qualitative terms to arrive at the final score of the current capacity of tourism management at Bakkhali, as observed in our field survey (**Table 8**).

Table 8. Management capacity assessment.

Sewage treatment facilities	Solid waste management	Green lodging regulations	Capacity building	Tourist sensitization	Mc current score
(–)	(–/+)	(–)	(–/+)	(–/+)	(1.5/5) = 0.3

The real carrying capacity further reduces when Mc is applied to obtain the Effective Carrying Capacity, as computed as given in **Table 9**.

Table 9. Calculation of Effective Carrying Capacity (ECC).

Tourist area	Real Carrying Capacity (RCC)	Management Capacity (Mc)	Effective Carrying Capacity (ECC)
	(PCC × Cf)		(RCC × Mc)
Beach	3912	0.3	1174
Sea	3315	0.3	995
Picnic spot	328	0.3	98
		Total	2267

Operative Carrying Capacity: However, tourist carrying capacity in terms of only ‘tourists’ is not enough. The simultaneous and proportional increase of supporting aids for operational tourism, i.e., transportation-related manpower, shopkeepers/vendors, facility providers, and other service staff also need to be factored here, since these additional heads will have a substantial share in consumption of land, energy, water, and bio-resources while contributing to the pollution load. This is the unaccounted ‘shadow’ of the mainstream tourists. A fourth step, proposed here as ‘Operative Carrying Capacity’ that considers this support population who may not be part of the host community, needs to be apportioned in the estimated volume.

Going with a reasonable ratio of support heads to tourists as 1:10, the carrying capacity may be further moderated to 90% of the ECC, such that the balance 10% is attributed to the operational aids that would support the tourist volume. The final carrying capacity works out to be 2040 tourists per day with 227 support heads (**Table 10**).

Table 10. Calculation of Operational Carrying Capacity (OCC).

Tourist area	Effective Carrying Capacity (ECC) (RCC × Mc)	Operational Carrying Capacity (OCC) (ECC × 0.9)
Beach	1174	1057
Sea	995	895
Picnic spot	98	88
	2267	2040

However, this hypothesis of 10% ‘shadow of tourism’, i.e., one support head to 10 tourists, is an assumption that requires to be tested through multiple case studies in diverse contexts and hence opens up a fresh avenue for research investigation.

5. Discussions

The bed capacity as surveyed in 2019-‘20 was 1705, and considering 100% occupancy, the optimized ‘operative’ tourist flow per day as found in OCC is 2040. This leaves only a little window for tourism growth under the current tourism management scenario. Tourism development at Bakkhali, therefore, has to be strictly controlled and regulated.

Tourism planners and proponents may disapprove of the idea of ‘too many tourists’ [52], but events of overtourism underline the need to limit tourist influx [53,54]. Making a distinction between tourist ‘flows’ and tourist ‘flood’ underscores sustainable and resilient tourism, particularly for coastal areas in the context of climate change. A robust tourism management plan that is aligned with the coastal zone management plans and capable of critical boundary delineation of tourism growth is the current necessity. Meso-scale steps involving land use planning, formulating specific guidelines and design control rules for the public places and the private hotels, ensuring their construction and operation are environmentally appropriate, and having a strict monitoring system in place are some of the critical management interventions essential for the long-term sustainability of this coastal destination. The role, responsibility, and relationship of different stakeholder groups for sustainable tourism management have been proposed in **Figure 10**.

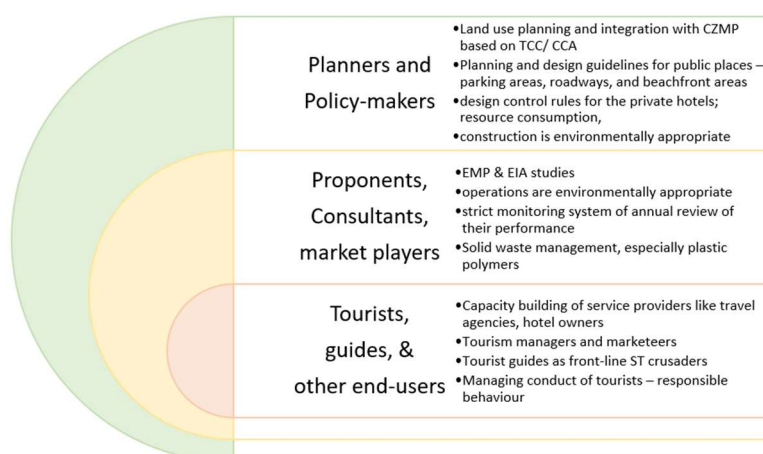


Figure 10. Role, responsibility, and relationship of stakeholder hierarchical groups in Sustainable tourism (ST).

Tourism managers often see growth through a skewed lens and miss the sense of its proportion to the destination capacity. This results in excessive tourist flows causing undesirable conditions such as congestion, environmental pollution, and visual quality deterioration. The cascading effect reduces the natural attractiveness and interferes with the touristic experience. Hence, tourism growth should be in consonance with the destination's carrying capacity to remain within sustainable limits [14]. Focusing only on economic development may be counterproductive in the not-so-long run, and hence, optimizing tourist flows based on carrying capacity assessment is essential.

6. Conclusion

This paper conducted the carrying capacity assessment of the Bakkhali beach of the West Bengal coastal zone in one of the deltaic islands of the Indian Sundarbans. Enduring fifty years of tourism in this remote rural setting, Bakkhali has seen a recent spurt in tourism with investments in infrastructure creation, bringing in private players of varying capacity in the local tourism market. However, the environment is taking the hit in all these economic upsurges. Although the peak tourist traffic per day in 2018 was 965 per day, the level of management is falling short, and it shows in the environmental degradation in the beach and the surrounding area. The tourism administration of Bakkhali should plan and extend appropriate, proactive, and prompt solid waste management services covering sewage treatment plants, gainful reuse of organic waste, and recycling of non-biodegradable waste as an absolute priority. The proliferation of shops, small commercial enterprises, and support infrastructures adds to the load. This may be considered the tourists' *'shadow'*, which undergoes simultaneous growth alongside the tourist population. The current study found that Bakkhali needs to optimize tourist flow to a preferable 2040 tourists per day based on the spatio-physical capacity, climatic constraints, management capacity, and operative factors. The *'operative'* carrying capacity concept is introduced in this study to account for the *'shadow'* factor of tourism. Carrying out empirical research on the relationship between tourism and its shadow will lead us to establish a database on the exact nature of this relationship—both qualitative and quantitative. Evaluating the ecological and environmental impacts are the other dimensions that may be carried out in the future for a holistic assessment.

The result obtained through this study intends to inform actors in the tourism sector—policymakers, tourism developers, tourism planners, managers and marketers, local administrative bodies, tourism promotion proponents, tourism potential identifiers, and the local community—on the optimized limit of tourist traffic in Bakkhali to maintain its natural pristine qualities and ecosystem services for long-term sustainability [54]. Any increase in the number of visitors without an appropriate environmental management plan will add pressure on tourism products, such as lodging facilities, food and beverages, passenger transport, recreation- and -leisure activities, and other services, triggering overconsumption and crossing the sustainable limit.

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data collection and field study, SS. All authors have read and agreed to the published version of the manuscript.

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References

1. Butler RW. The concept of a tourist area cycle of evolution: implications for management of resources. *Canadian Geographies / Géographies canadiennes*. 1980; 24(1): 5-12. doi: 10.1111/j.1541-0064.1980.tb00970.x
2. Numpty Nerd. The Butler Model of Tourism Development. Available online: <https://www.numptynerd.net/tourism-the-butler-model.html> (accessed on 10 January 2024).
3. Ajai, Nayak S, Bhattacharyya S. Coastal Zones of India. Space Applications Centre, ISRO, Government of India; 2012.
4. World Heritage Convention, United Nations Educational, Scientific and Cultural Organization. Sundarbans National Park. Available online: <https://whc.unesco.org/en/list/452/>. (accessed on 16 January 2024).
5. Newton A, Icely J, Cristina S, et al. Anthropogenic, Direct Pressures on Coastal Wetlands. *Frontiers in Ecology and Evolution*. 2020; 8. doi: 10.3389/fevo.2020.00144
6. Wackernagel M, Schulz NB, Deumling D, et al. Tracking the ecological overshoot of the human economy. *Proceedings of the National Academy of Sciences*. 2002; 99(14): 9266-9271. doi: 10.1073/pnas.142033699
7. PAP/RAC. Guidelines for Carrying Capacity Assessment for Tourism in Mediterranean Coastal Areas. Available online: https://www.ucm.es/data/cont/media/www/pag-52315/1997_GuidelinesCarryng-COSTAS.pdf (accessed on 2 April 2024).
8. World Tourism Organization. Saturation of Tourist Destinations: Report of the Secretary General, Madrid. World Tourism Organization; 1981.
9. Mcneely JA, Thorsell JW. Guidelines for the development of terrestrial and marine national parks for tourism and travel. International Union for Conservation of Nature and Natural Resources; 1987.
10. UNEP. Guidelines for Integrated Planning and Management of Coastal and Marine Areas in the Wider Caribbean Region. UNEP Caribbean Environment Programme, Kingston, Jamaica; 1996.
11. Buhalis D. Limits of tourism development in peripheral destinations: problems and challenges. *Tourism Management*. 1999; 20(2): 183-185.
12. Hunter C. Key concepts for tourism and the environment. In: Hunter C, Green H (editors). *Tourism and the Environment. A Sustainable Relationship?* Routledge; 1995. pp. 52-92.
13. MacLeod M, Cooper JAG. Carrying capacity in coastal areas. In: Schwartz ML (editor). *Encyclopedia of Coastal Science*. Springer Netherlands; 2005. p. 226. doi: 10.1007/1-4020-3880-1
14. Coccossis H, Mexa A. Tourism carrying capacity: a theoretical overview. In: Coccossis H, Mexa A (editors). *The Challenge of Tourism Carrying Capacity Assessment: Theory and Practice*. Ashgate Publishing; 2004. pp. 37-54.
15. Quicoy AR, Briones ND. Beach Carrying Capacity Assessment of Coastal Ecotourism in Calatagan, Batangas, Philippines. *Journal of Environmental Science and Management*. 2009; 12(2): 11-27.
16. Tomczyk M. Capacity of the tourism and the role of creative industries - perception of visitors, barriers and motivation. *European Journal of Service Management*. 2018; 27: 489-498. doi: 10.18276/ejsm.2018.27/2-60
17. Sarkar S, Bardhan S, Sanyal P. Ecotourism Studies: Lessons from Literature Review, *International Journal of Innovative Knowledge Concepts*. 2019; 7(7): 61-73.
18. UNWTO. Glossary of tourism terms. Available online: <https://www.unwto.org/glossary-tourism-terms> (accessed on 10 January 2024).
19. Cifuentes Arias M. Determination of Tourism Carrying Capacity in Protected Areas (Spanish). CATIE; 1992.
20. Ceballos-Lascurain H. Tourism, Ecotourism and Protected Areas: The State of Nature-Based Tourism around the World and Guidelines for its Development. IUCN; 1996.
21. Zacarias DA, Williams AT, Newton A. Recreation carrying capacity estimations to support beach management at Praia de

- Faro, Portugal. *Applied Geography*. 2011; 31(3): 1075-1081. doi: 10.1016/j.apgeog.2011.01.020
22. United Nations Sustainable Development Goals. Sustainable Tourism. Available online: <https://sdgs.un.org/topics/sustainable-tourism> (accessed on 15 January 2024).
23. Coccossis H, Mexa A, Collovini A, et al. Defining, Measuring and Evaluating Carrying Capacity in European Tourism Destinations. Available online: https://www.ucm.es/data/cont/media/www/pag-49173/2001_CAPACIDAD%20DE%20CARGA_Uni%C3%B3n%20Europea_Informe%20COCCOSIS%20%28informe%209.pdf (accessed on 1 April 2024).
24. Klaric Z, Komilis P, Dragicevic M, et al. Carrying Capacity Assessment for Tourism Development. Available online: <https://iczmplatform.org/storage/documents/xxnSWbLStRM7QQQdnjsHx3jPfSNMb2U8zm6Gza4z.pdf> (accessed on 2 April 2024).
25. Somarriba-Chang M, Garnier M, Laguna V. Estimation of the tourist carrying capacity of the Natural Reserve Mombacho Volcano, Granada, and the Natural Reserve Datanlí-El Diablo, Jinotega, Nicaragua. In: *WIT Transactions on Ecology and the Environment*. WIT Press; 2006. Volume 97. pp. 341-351. doi: 10.2495/st060321
26. Tselentis BS, Prokopiou DG, Toanoglou M. Carrying capacity assessment for the Greek islands of Kalymnos, Kos and Rhodes. In: *WIT Transactions on Ecology and the Environment*. WIT Press; 2006. Volume 97. pp. 353-363. doi: 10.2495/st060331
27. Nghi T, Lan NT, Thai ND, et al. Tourism carrying capacity assessment for Phong Nha-Ke Bang and Dong Hoi, Quang Binh Province. *VNU Journal of Science, Earth Sciences*. 2007; 23: 80-87.
28. The Market Research Group. The Purbeck Section of the Dorset & East Devon World Heritage Site Carrying Capacity Evaluation Report. Bournemouth University; 2007.
29. Sridhar R, Yuvaraj E, Sachithanandam V, et al. Tourism Carrying Capacity for Beaches of South Andaman Island, India. In: Butowski L (editor). *Tourism—From Empirical Research Towards Practical Application*. IntechOpen; 2016. pp. 61-81. doi: 10.5772/62724
30. Grofelnik H. Assessment of acceptable tourism beach carrying capacity in both normal and COVID-19 pandemic conditions - case study of the Town of Mali Lošinj. *Hrvatski geografski glasnik/Croatian Geographical Bulletin*. 2020; 82(2): 131-152. doi: 10.21861/hgg.2020.82.02.05
31. India Biodiversity Portal. Available online: <https://indiabiodiversity.org/observation/show/1822689> (accessed on 4 April 2024).
32. Naskar R. Abundance and Distribution Pattern of Intertidal Shore Crabs on Exposed Sandy Beaches of Bakhali, Sundarbans. *International Journal of Engineering, Science and Mathematics*. 2018; 7 (4/2): 153-159.
33. Bakkhali-Frezeranj Hoteliers Welfare Association. Available online: <https://www.bakkhalihoteliers.in/> (accessed on 1 April 2024).
34. Indian Village Directory. Available online: <https://villageinfo.in/west-bengal/south-twenty-four-parganas/namkhana/amrabati.html> (accessed on 10 January 2024).
35. Brown J. Block 79-63k Scale—Survey of India Maps. Zenodo; 2022. doi: 10.5281/ZENODO.6525633
36. Google Earth Pro 2024. Bakkhali 21°34'39"N 88°16'08"E, elevation 16 m. 3D Buildings data layer. Available online: <https://earth.google.com/web/@21.58017193,88.26136715,24.93461694a,10776.16115395d,35y,0h,0t,0r> (accessed on 30 March 2024).
37. Paul AK, Paul A. Adjustment of the Coastal Communities in Response to Climate Variability and Sea Level Rise in the Sundarban, West Bengal, India. In: Siddiqui AR, Sahay A (editors). *Climate Change, Disaster and Adaptations*. Sustainable Development Goals Series. Springer, Cham. 2022; pp. 201-217. doi: 10.1007/978-3-030-91010-5_16
38. Bandyopadhyay J, Mondal I, Roy B. Change Detection of Land Use & Land Cover and Identification of Interrelationship between Geomorphology and Land Use Land Cover in and around Bakkhali-Fraseranj and Henry Island, South 24 Parganas, West Bengal, India. *International Journal of Remote Sensing & Geoscience*. 2014, 3(2): 44-51.
39. Sinha S, Mondal SK, Mondal S, et al. Sediment characterization and dispersal analysis along a part of the meso- to microtidal coast: a case study from the east coast of India. *Arabian Journal of Geosciences*. 2021; 14: 18. doi: 10.1007/s12517-020-06249-y
40. Dutta S, Maiti S, Garai S, et al. Analyzing adaptation strategies to climate change followed by the farming community of the Indian Sunderbans using Analytical Hierarchy Process. *Journal of Coastal Conservation*. 2020; 24(5). doi: 10.1007/s11852-020-00779-z

41. Thakur S, Dey D, Das P, et al. Shoreline change detection using Remote Sensing in the Bakkhali Coastal Region, West Bengal, India. *Indian Journal of Geosciences*. 2017; 71(4): 611-626.
42. Sengupta D, Ghosh T, Roychaudhuri S, et al. Field Trip Guide: ER001 Pre-Congress Field Trip Sundarban Delta System. Available online: https://www.researchgate.net/publication/360016429_Sundarban_Delta_System (accessed on 2 April 2024).
43. Bhattacharya R, Bhounick A. Measurement of surface solar UV-B radiation at tropical coastal station Bakkhali in West Bengal, India. *International Journal of Engineering Science and Technology*. 2012; 4(8): 3824-3832.
44. Singh S, Bhaduri B, Banerjee PK, et al. Assessment of Coastal Water Quality at Bakkhali, West Bengal (India). *Journal of Environmental Science & Engineering*. 2012; 54(2): 217-226.
45. West Bengal Tourism Development Corporation Ltd. Available online: https://www.wbtdcl.com/home/Lodge_tariff?Lodge_id=MTk&Lodge_destinationName=MTc (accessed on 10 January 2024).
46. Gangasagar Bakkhali Development Authority. Available online: <http://www.gbdaonline.in/> (accessed on 10 January 2024).
47. Bhattacharya A, Chanda A. Characterizing micro-litter pollution in Bakkhali and Fraserganj Beaches of West Bengal, India. *Regional Studies in Marine Science*. 2023; 65: 103102. doi: 10.1016/j.rsma.2023.103102
48. Climate-Data. Bakkhali climate (India). Available online: <https://en.climate-data.org/asia/india/west-bengal/bakkhali-798630/> (accessed on 10 January 2024).
49. Wanderlog. Bakkhali, India weather in May. Available online: [https://wanderlog.com/weather/5662/5/bakkhali-weather-in-may#:~:text=Historically%2C%20the%20wind%20in%20Bakkhali,8.2%20mph%20\(13.3%20kph\)](https://wanderlog.com/weather/5662/5/bakkhali-weather-in-may#:~:text=Historically%2C%20the%20wind%20in%20Bakkhali,8.2%20mph%20(13.3%20kph)) (accessed on 10 January 2024).
50. United Nations Ocean Conference. Available online: <https://www.un.org/en/conferences/ocean2022/about>, <https://www.un.org/en/conferences/ocean2022/faqs> (accessed on 16 January 2024).
51. Green Globe. International Standard for Sustainable Tourism. Available online: <https://www.greenglobe.com/criteria-indicators> (accessed on 4 April 2024).
52. Butler RW. Tourism carrying capacity research: a perspective article. *Tourism Review*. 2019; 75(1): 207-211. doi: 10.1108/tr-05-2019-0194
53. Wall G. From carrying capacity to overtourism: A perspective article. *Tourism Review*. 2020; 75(1): 212-215. doi: 10.1108/tr-08-2019-0356
54. Efthymiou L, Markatos G. Carrying Capacity and Sustainable Development. In: Buhalis D (editor). *Encyclopedia of Tourism Management and Marketing*. Edward Elgar Publishing; 2022. pp. 433-435. doi: 10.4337/9781800377486.carrying.capacity

Article

FIKR (Facet, Insight, Knowledge, and Resilience) personality profile for employee development: Literature emphasizes personality characteristic evaluation

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Abstract: This short note aims to review all the available literature using the keywords ‘Employee Development’ in the Scopus database and identify the personality traits that are supported by the FIKR (Facet, Insight, Knowledge, and Resilience) personality profiling assessment. Our research on 21 May 2024 involved a comprehensive search using the Scopus database and the keywords ‘Employee Development’ in the article title. We meticulously analyzed the bibliometric data using VOSviewer, a tool that generates clear graphical representations of bibliometric maps, to ensure the comprehensiveness and accuracy of our findings. This rigorous approach enhances the credibility of our research. A total of 1366 papers were reached using the Scopus database search, which had high relevancy. Based on the visualization of the paper network confirming the main research themes, from 1932 to 2024, there were 115 items, separating into six clusters. In the first cluster, ‘Knowledge Management’ was found. Interestingly, the only personality trait highlighted was ‘self-concept’ in the second cluster. Therefore, the present study highlights knowledge as an important FIKR personality profiling assessment. At the same time, ‘self-conceptual,’ one of the 20 PTs in the Humanology FIKR personality profiling inventory, is well-supported in the literature on employee development in an organization. The literature review provides a rationale for supporting and highlighting the use of knowledge and self-conceptual traits, among other things, under the FIKR personality profiling assessment in an organization’s employee development.

Keywords: assessment; personal trait; employee development

1. Introduction

A personality profiling assessment provides insights into an individual’s knowledge and skills, highlighting areas for improvement and development [1–3]. This assessment helps employees gain self-awareness, which is essential for personal and professional growth.

The FIKR (Facet, Insight, Resilience, and Knowledge) personality profiling assessment is valuable. It helps individuals understand their personality traits and how they can leverage them to thrive in their roles and contribute effectively to the organization. By assessing different facets of an individual’s personality, such as their strengths, weaknesses, motivations, and communication style, the FIKR personality profiling assessment provides valuable insights into their unique personality profile [4].

Understanding resilience can help employees navigate challenges and bounce back from setbacks. Overall, the FIKR personality profiling assessment is a

comprehensive tool that enables employee development by providing valuable insights into an individual's personality traits, strengths, areas for growth, and resilience. Using the FIKR personality profiling assessment for employee development is a strategic approach to understanding and enhancing individual and team performance [5–9].

This short note aims to review all the available literature using the keywords 'Employee Development' in the Scopus database and to identify the personality traits used and supported in the literature.

2. Methodology

On 21 May 2024, the keywords 'Employee Development' were used for the relevant publications in the article title. Later, bibliometric analyses using VOSviewer software (VOS stands for visualization of similarities; see www.vosviewer.com) were used to generate a clear graphical representation of bibliometric maps, especially for extensive datasets [10,11]. Scopus, which comprises many significant research papers and offers integrated analysis tools for creating informative visual representations [12]. VOSviewer was employed to analyze each keyword, calculate links, calculate total link strengths, and compare co-occurrences with other keywords.

The duplication of papers was checked with 'Remove Duplicate' in Excel before the VOS analysis was performed. There have been no duplicate papers found. Therefore, all papers were included in the VOS analysis.

3. Results

The Scopus database was highly relevant, and 1366 papers were reached. Based on these 1366 papers, we performed a bibliometric analysis using the VOSviewer software to highlight the trends of studies conducted on 'Employee Development' from 1932 to 2024 (**Figure 1**).

Figure 1 gives a holistic overview of the past research based on keywords' co-occurrences with 'Employee Development'. The analysis reveals discernible prominence, reflecting seven significant clusters that can be identified based on visualization in **Figure 1a**.

Out of 115 items, a total of six clusters were mapped. In the first cluster, 'Knowledge Management' was found (**Figure 1b**). Interestingly, the only personality trait highlighted was 'self-concept' in the second cluster (**Figure 1c**).

When 'knowledge management' is scrutinized in detail (**Figure 1b**), it is found that it is linked mostly directly (in terms of similarity) to employee development, personnel, surveys, information management, and employee performance. When the 'self-concept' is scrutinized (**Figure 1c**), it is linked mostly directly (in terms of similarity) to organization, human, occupational health, male, middle-aged, adult, female, questionnaires, employee, and leadership.

Out of the 115 items in **Figure 1**, personality traits include self-concept, reliability, motivation, leadership, and attitude. Therefore, the present study highlights knowledge as an important FIKR personality profiling assessment, while 'self-conceptual', one of the 20 PTs in the Humanology FIKR personality profiling

inventory, is well-supported in the literature on employee development in an organization.

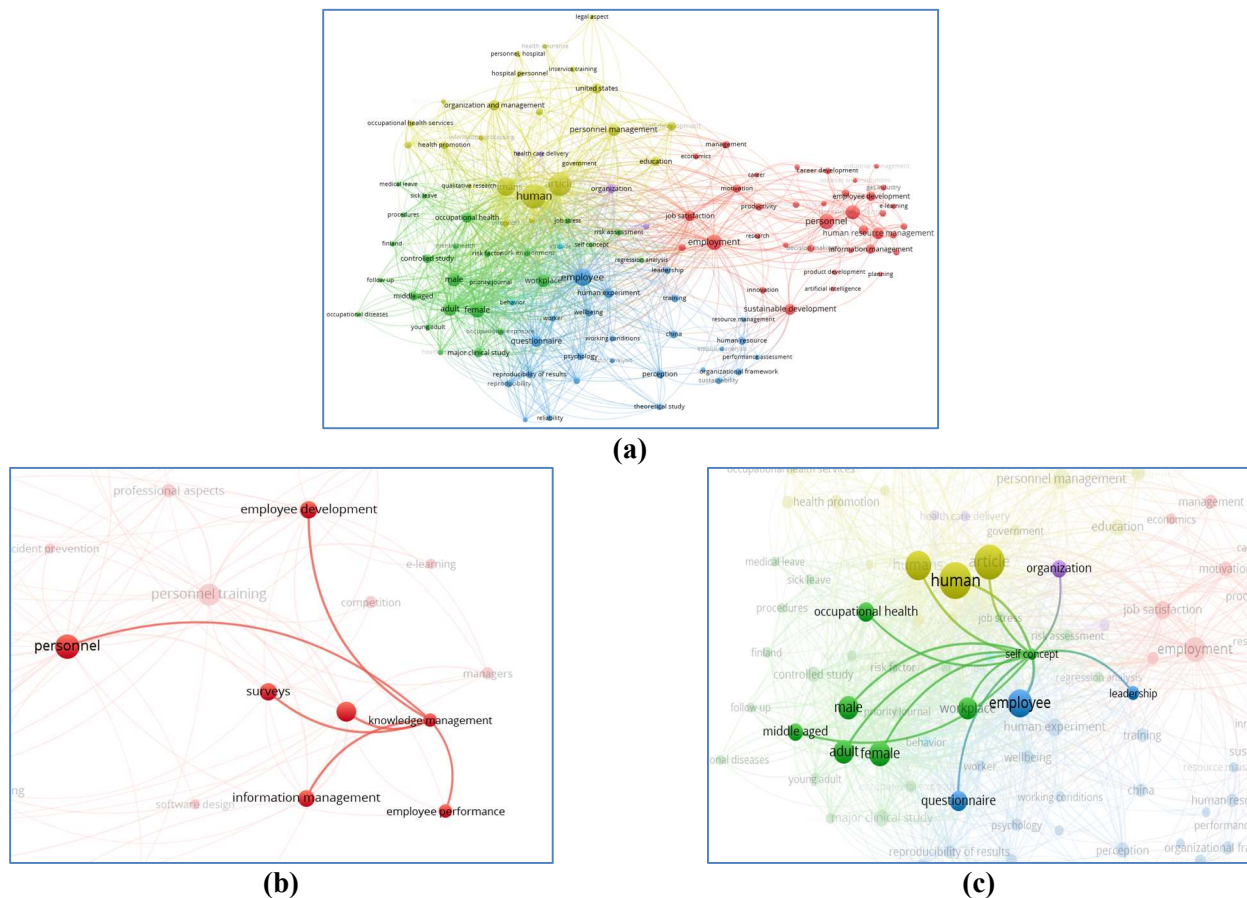


Figure 1. A bibliometric analysis of research themes on ‘Employee Development’ based on visualization of similarity (VOS). **(a)** Overall visualization; **(b)** visualization focuses on Knowledge Management; **(c)** visualization focuses on Self-concept. Visualization of the paper network confirming the main themes of research, from 1932 and 2024 based on the Scopus database. The colours in the top panel indicate the themes of research that the papers are discussing.

4. Discussion

4.1. High knowledge level as an important criterion for employee development

A high knowledge level is considered an important criterion for the development of employees within an organization. Employees with a high level of knowledge are valuable assets to the company, as they possess the necessary expertise and skills to perform their job effectively. Furthermore, highly knowledgeable employees are more likely to be innovative and adaptable, as they possess a deep understanding of their field and can quickly learn and adapt to new information and technologies. Additionally, employees with a high level of knowledge contribute to the overall growth and success of the organization [13–15].

They can provide valuable insights and ideas, solve complex problems, and contribute to developing new strategies and processes. Furthermore, employees with a high knowledge level are more likely to be sought after by other companies, which

leads to better employment opportunities and potentially higher salaries [16]. For instance, highly knowledgeable employees are often selected for leadership positions, as their expertise and ability to make informed decisions are highly valued. Overall, a high knowledge level is crucial for employee development as it enhances productivity, innovation, and adaptability and contributes to the overall success of the organization.

‘Knowledge management’ could be linked directly to employee development, personnel, surveys, information management, and employee performance, as explained by the following points: In today’s fast-paced and competitive business environment, organizations recognize the importance of employee development and performance improvement. They understand that investing in their employees’ knowledge and skills can lead to increased productivity, innovation, and overall organizational success. Organizations have increasingly turned to knowledge management strategies to support employee development and performance improvement. By leveraging knowledge management systems and processes, companies can effectively capture, store, and distribute valuable knowledge and expertise within the organization. This not only ensures that employees have access to the information they need to excel in their roles but also facilitates collaboration and knowledge sharing across teams and departments.

Furthermore, an effective knowledge management strategy can involve mentoring and coaching programs that provide employees with guidance and support to enhance their skills and knowledge. These programs can pair less experienced employees with seasoned professionals, allowing for valuable knowledge transfer and skill development. Additionally, learning management systems and online training platforms can provide employees with convenient access to educational resources and courses to further their professional development. In addition, organizations can cultivate a culture that values continuous learning and knowledge sharing, encouraging employees to actively seek out new information and insights. This can be achieved through initiatives such as regular knowledge-sharing sessions, cross-functional projects, and communities of practice where employees can share knowledge.

4.2. Self-conceptual as an important personality trait for employee development

A self-conceptual personality trait (PT) is one of the 20 PTs under the FIKR personality profiling assessment under Humanology [4].

The self-concept personality trait (PT) is one of the 20 PTs under the FIRK (Facet, Insight, Resilience, and Knowledge) PT testing. Self-conceptual personality incorporates an individual’s perception and comprehension of themselves, including their thoughts, emotions, beliefs, and behaviours. It consists of the conscious and subliminal aspects of a person’s identity and plays a crucial role in determining how they interact with the world around them. Individuals with a strong self-concept typically have a crystal-clear understanding of who they are and what is significant to them. They can reflect on their thoughts and actions and have a strong awareness of themselves. They may be more likely to engage in introspection and self-reflection,

and they may have a greater understanding of their positive and negative aspects [17–21].

The concept of self-concept personality traits in leadership has garnered significant attention in organizational psychology and management. Understanding how individuals perceive themselves and how it influences their leadership style and effectiveness is crucial for fostering a deeper understanding of good leadership. In this paper, we will explore the importance of self-concept personality traits in leadership and delve into how they shape leaders' abilities to communicate, make decisions, and effectively lead their teams. Additionally, we will examine the impact of self-awareness on the overall success of leaders in various organizational contexts [22–28].

Self-concept personality traits profoundly impact an individual's abilities [29]. Employees who possess a strong self-concept personality trait are more likely to be effective and influential because they have a clear understanding of their own strengths, weaknesses, values, and beliefs.

Self-concept personality traits play a significant role in shaping an employee's communication style. Leaders with a strong self-concept are better equipped to articulate their vision, values, and goals to their team members with clarity and conviction. This ability to effectively communicate fosters trust and cohesion within the team, ultimately leading to higher levels of productivity and collaboration.

The following is a list of personality traits frequently observed in leaders with a high self-concept level, as indicated in **Figure 2**.



Figure 2. Personality traits of highly self-concept leaders.

- **Confidence, authenticity, and resilience**

The employees (and leaders) show a strong sense of self-concept and exhibit confidence, authenticity, and resilience in their roles. They are known to make decisions based on their values and beliefs, inspiring others to follow their lead.

The employee has self-confidence, the ability to accept criticism and not become defensive, the ability to set attainable goals, and the willingness to take risks and try new experiences. The employee is always considered egoistic, autonomous, egocentric, self-reliant, and self-contained. The employee is good at self-expression, realizes and actualizes his inner self, and strives for his goals. Self-awareness, self-confidence, and self-esteem are the defining characteristics of an employee. The employee has a positive opinion of themselves and their skills. The employee exhibits extraordinary self-assurance and assertiveness in their behaviour.

- Strong relationships

The employees (and leaders) prioritize building strong relationships with stakeholders, employees, and the community. They communicate openly, listen actively, and show empathy towards others.

The employee tends to have a positive opinion of himself and his worth. The employee may have a high sense of self-worth and be less affected by criticism or negative feedback from others. As a result, the employee may become more resilient in the face of obstacles and defeats. Employees may be willing to take risks, advocate for their needs and preferences, and speak up for themselves. As a result, the employees may be better equipped to serve as leaders, communicators, and problem-solvers.

- Empowering others

The employees (and leaders) empower their teams by fostering a culture of trust, collaboration, and innovation. They provide guidance and support while allowing individuals to grow and develop professionally.

Possessing a strong self-concept can be advantageous in numerous aspects of one's existence. Note, however, that those with this personality trait may also be prone to narcissism or excessive self-centeredness. This is an essential factor to remember. It is crucial to establish a healthy balance between a strong sense of self-awareness and self-confidence, on the one hand, and empathy and concern for others, on the other, in order to build strong relationships and maintain a healthy perspective.

- Personal growth

The employees (and leaders) are committed to their personal growth and development. They seek feedback, embrace challenges, and continuously strive for self-improvement. This mindset allows them to adapt to changing environments and lead with agility.

Self-assurance is another essential characteristic of an employee. Employees who possess this trait tend to believe in their own abilities and skills and may be highly confident in their ability to accomplish their goals. This self-assurance can be extremely advantageous in many facets of one's life, including personal relationships, the advancement of one's career, and the pursuit of creative endeavours.

In sum, while self-concept and personality traits undoubtedly contribute to effective leadership, it is essential to strike a balance and recognize that they are just one piece of the leadership puzzle. Employees (and leaders) should strive to cultivate a holistic set of skills and qualities to excel in their roles. This includes developing emotional intelligence, fostering adaptability, and creating a supportive and inclusive environment for their teams. By integrating these elements with a strong self-concept,

employees can maximize their impact and create lasting positive change within their organizations.

4.3. The importance of knowledge and self-concept for employee development

In today's competitive job market, employee development is crucial for individuals and organizations. It is widely recognized that employees who continuously enhance their knowledge and skills are more likely to succeed and contribute to the organisation's overall success. By investing in employee development, organizations not only increase the capabilities and productivity of their workforce but also enhance their competitive advantage. They can adapt to changing technologies, market trends, and customer needs [30]. This is particularly important in a globalized economy where organizations operate in diverse cultural contexts and face unique challenges. Moreover, employee development goes beyond just acquiring technical skills. It also encompasses the development of a strong self-concept, or an individual's perception and beliefs about themselves. This includes their abilities, values, and overall identity [31,32].

A positive self-concept is essential for employee development as it influences motivation, confidence, and resilience. Employees with a strong self-concept are more likely to take initiative and seek opportunities for growth and development. They are also more likely to be adaptable and open to learning, as they have a belief in their capabilities. Furthermore, a positive self-concept also affects employees' attitudes and behaviour towards their work and colleagues. Employees with a positive self-concept are more likely to exhibit professionalism, teamwork, and a willingness to collaborate, which leads to a positive work environment and fosters employee engagement and satisfaction. Overall, knowledge and self-concept play a critical role in employee development. These factors contribute to job satisfaction and are essential for individuals' and organisations' success and growth [33–35].

Hence, as organizations continue to prioritize employee engagement and effective teamwork, the FIKR personality profiling assessment emerges as a strategic tool for achieving these objectives. The assessment results provide managers and teams with actionable insights into individual personality styles, facilitating improved communication, collaboration, and cohesion within the workforce [36]. By increasing employees' alignment with their roles and promoting a better understanding of their colleagues' unique qualities and preferences, the FIKR personality profiling assessment becomes instrumental in creating a cohesive and productive work environment.

5. Conclusions

The present study highlights knowledge as an important FIKR personality profiling assessment. At the same time, 'self-conceptual', one of the 20 PTs in the Humanology FIKR personality profiling inventory, is well-supported in the literature on employee development in an organization. The literature review provides a rationale for supporting and highlighting the use of knowledge and self-conceptual traits, among other things, under the FIKR personality profiling assessment in an

organisation's employee development. The FIKR personality profiling assessment helps human resource practitioners identify any bias or imbalance in their training and learning methods, allowing them to design and develop learning events that accommodate and acknowledge individual learning styles.

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References

1. Damman S. Where Is Your 'F'? Psychological Testing, Communication and Identity Formation in a Multinational Corporation. *Anthropology in Action*. 2012; 19(1). doi: 10.3167/aia.2012.190106
2. Jaeger A. Achieving business excellence through self-assessment for personal and professional excellence. *Total Quality Management & Business Excellence*. 2017; 29(13-14): 1612-1632. doi: 10.1080/14783363.2017.1288564
3. Romaniuk K, Snart F. Enhancing employability: the role of prior learning assessment and portfolios. *Journal of Workplace Learning*. 2000; 12(1): 29-34. doi: 10.1108/13665620010309774
4. Humanology. Humanology Sdn Bhd. Available online: <https://hba.com.my/> (accessed on 25 May 2024).
5. Caldwell C, Beverage MS, Converse PD. Selecting for Flair Factors: Improving the Selection Process. *Business and Management Research*. 2018; 7(1): 1. doi: 10.5430/bmr.v7n1p1
6. Cattell HEP, Mead AD. The Sixteen Personality Factor Questionnaire (16PF). Available online: <https://doi.org/10.4135/9781849200479.n7> (accessed on 25 May 2024).
7. Furnham A. Personality Assessment: Overview. In: Wright JD (editor). *International Encyclopedia of the Social & Behavioral Sciences*, 2nd ed. Elsevier; 2015. pp. 849-856. doi: 10.1016/b978-0-08-097086-8.25027-7
8. Helens-Hart R. The Employability Self-Assessment: Identifying and Appraising Career Identity, Personal Adaptability, and Social and Human Capital. *Management Teaching Review*. 2018; 4(1): 6-13. doi: 10.1177/2379298118775937
9. Kessler R. Collaborate with employees to make your competency-based systems stronger. *Employment Relations Today*. 2004; 31(3): 27-32. doi: 10.1002/ert.20027
10. Ellegaard O, Wallin JA. The bibliometric analysis of scholarly production: How great is the impact? *Scientometrics*. 2015; 105(3): 1809-1831. doi: 10.1007/s11192-015-1645-z
11. van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*. 2009; 84(2): 523-538. doi: 10.1007/s11192-009-0146-3
12. Guz AN, Rushchitsky JJ. Scopus: A system for the evaluation of scientific journals. *International Applied Mechanics*. 2009; 45(4): 351-362. doi: 10.1007/s10778-009-0189-4
13. Nazari K, Emami M. Knowledge Management: From Theory to Practice. *Australian Journal of Business and Management Research*. 2012; 01(11): 22-30. doi: 10.52283/nswrca.ajbmr.20120111a03
14. Amar AD, Juneja JA. A descriptive model of innovation and creativity in organizations: a synthesis of research and practice. *Knowledge Management Research & Practice*. 2008; 6(4): 298-311. doi: 10.1057/kmrp.2008.18
15. Shaher ATQ, Ali KAM. The effect of entrepreneurial orientation and knowledge management on innovation performance: The mediation role of market orientation. *Management Science Letters*. 2020; 10(15): 3723–3734. doi: 10.5267/j.msl.2020.6.020
16. Syech S, Anisah A, Sari AP. Employee Performance Model based on Knowledge Management and Employee Retention. *J-MAS (Jurnal Manajemen dan Sains)*. 2023; 7(2): 1391. doi: 10.33087/jmas.v7i2.983
17. Shek DTL, Zhu X, Dou D, et al. Self-leadership as an attribute of service leadership: Its relationship to well-being among university students in Hong Kong. *Frontiers in Psychology*. 2023; 14. doi: 10.3389/fpsyg.2023.1088154

18. Andersen JA. Leadership, personality and effectiveness. *The Journal of Socio-Economics*. 2006; 35(6): 1078-1091. doi: 10.1016/j.socec.2005.11.066
19. Kirkpatrick SA, Locke EA. Leadership: do traits matter? *Academy of Management Perspectives*. 1991; 5(2): 48-60. doi: 10.5465/ame.1991.4274679
20. Suhartono S. Leadership Communication Style in Improving Public Service Performance (A Case Study of the village office of Camba Berua). *International Journal of Advanced Engineering, Management and Science*. 2020; 6(6): 267-274. doi: 10.22161/ijaems.66.7
21. Day DV, Dragoni L. Leadership Development: An Outcome-Oriented Review Based on Time and Levels of Analyses. *Annual Review of Organizational Psychology and Organizational Behavior*. 2015; 2(1): 133-156. doi: 10.1146/annurev-orgpsych-032414-111328
22. Rubens A, Schoenfeld GA, Schaffer BS, et al. Self-awareness and leadership: Developing an individual strategic professional development plan in an MBA leadership course. *The International Journal of Management Education*. 2018; 16(1): 1-13. doi: 10.1016/j.ijme.2017.11.001
23. Judge TA, Bono JE, Ilies R, et al. Personality and leadership: A qualitative and quantitative review. *Journal of Applied Psychology*. 2002; 87(4): 765-780. doi: 10.1037/0021-9010.87.4.765
24. Hogan R, Kaiser RB. What we know about Leadership. *Review of General Psychology*. 2005; 9(2): 169-180. doi: 10.1037/1089-2680.9.2.169
25. Epitropaki O, Kark R, Mainemelis C, et al. Leadership and followership identity processes: A multilevel review. *The Leadership Quarterly*. 2017; 28(1): 104-129. doi: 10.1016/j.leaqua.2016.10.003
26. Ullah I, Wisetsri W, Wu H, et al. Leadership Styles and Organizational Citizenship Behavior for the Environment: The Mediating Role of Self-Efficacy and Psychological Ownership. *Frontiers in Psychology*. 2021; 12. doi: 10.3389/fpsyg.2021.683101
27. Williams S. Personality and self-leadership. *Human Resource Management Review*. 1997; 7(2): 139-155.
28. Sosik JJ. Self-concept based aspects of the charismatic leader: More than meets the eye. *The Leadership Quarterly*. 1998; 9(4): 503-526.
29. Lord RG, Brown DJ, Freiberg SJ. Understanding the Dynamics of Leadership: The Role of Follower Self-Concepts in the Leader/Follower Relationship. *Organizational Behavior and Human Decision Processes*. 1999; 78(3): 167-203. doi: 10.1006/obhd.1999.2832
30. Shamroukh MG, Kamel MK. Mechanisms for Knowledge Management and Achieving Organizational Development of Higher Education Institutions from a Community Organization Perspective. *College of Social Work Social Studies and Research Journal*. 2021; 22(1): 15-52. doi: 10.21608/jfss.2021.135273
31. Aydogmus C, Metin Camgoz S, Ergeneli A, et al. Perceptions of transformational leadership and job satisfaction: The roles of personality traits and psychological empowerment. *Journal of Management & Organization*. 2016; 24(1): 81-107. doi: 10.1017/jmo.2016.59
32. Hill NC, Ritchie JB. The Effect of Self-Esteem on Leadership and Achievement: A Paradigm and a Review. *Group & Organization Studies*. 1977; 2(4): 491-503. doi: 10.1177/105960117700200410
33. Marsh HW, Seaton M, Dicke T, et al. The centrality of academic self-concept to motivation and learning. In: *The Cambridge Handbook of Motivation and Learning*. Cambridge University Press; 2019.
34. Shi P, Lu X, Zhou Y, et al. Online Star vs. Celebrity Endorsements: The Role of Self-Concept and Advertising Appeal in Influencing Purchase Intention. *Frontiers in Psychology*. 2021; 12. doi: 10.3389/fpsyg.2021.736883
35. Hott L, Sonstegard M. Relating Self-Conception to Curriculum Development. *The Journal of Educational Research*. 1965; 58(8): 348-351. doi: 10.1080/00220671.1965.10883241
36. Haraldsdottir RK, Gunnlaugsdottir J. The missing link in information and records management: personal knowledge registration. *Records Management Journal*. 2018; 28(1): 79-98. doi: 10.1108/rmj-05-2017-0013

Article

Developing a model for digital adoption in family business: A proposed research framework

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Abstract: Digital technology is becoming more and more popular very quickly. This is changing every part of the business and having a big effect on how it works. Unfortunately, no business can avoid the effects, problems, and chances that come with digital change. Companies are also forced to change how they do things. Given this context, numerous organizations are unprepared to transform. There are no exceptions made for the family business. The family business is anticipated to embrace digitalization as a widely popular business technique in many locations globally. Its participation in the digital economy is still very important. Unfortunately, there are not many studies on how digital technology is used in family business. When compared to other types of businesses in general, the family business is distinguished by several distinctive qualities that set it apart from other types of enterprises. Consequently, there exists a tension between the perceived gradual nature of change in family businesses and the swift pace of digitalization. This discrepancy highlights the urgent need for further exploration into the integration of digital technology within the context of family businesses, as well as the development of strategies to support their successful digital transformation amidst these distinctive organizational dynamics. This research aims to identify the crucial aspects that contribute to the successful implementation of digitalization in the family business. The adopted research method for this study involves conducting a comprehensive literature review. This approach entails systematically reviewing and analyzing existing academic and industry literature on the utilization of digital technology in family businesses. This study proposes a research design to investigate the use of digital technologies in family businesses. The study also presents a suggested mixed-method approach, combining qualitative and quantitative methods and propositions.

Keywords: digital adoption; family business; mixed methodology; key success factors; case study

1. Introduction

The family business is a mode of conducting business that is quite common all over the world. It dominates 80%–98% of global companies [1–3], thus playing a crucial part in a nation's economic development [4,5]. About 70%–75% of national income in many countries is contributed by the family business. A further 50%–75% of the world's entire population of working age is employed by it [6]. As a result, it is a reliable economic power source for businesses of all sizes, from small to multinational [7]. Hence, significant corporate actors are considering the necessity of digital adoption due to the crucial importance of continuity for them [8–12].

Indonesian family businesses share some commonalities with family businesses globally, but there might also be aspects that differentiate them. Family businesses

around the world often prioritize long-term growth and stability over short-term profits. This can be due to a desire to preserve the business for future generations. Family values like loyalty, trust, and shared goals can influence decision-making within the business. Ensuring a smooth transition of leadership to the next generation can be a common challenge for family businesses globally. However, there are also potential factors that differentiate Indonesian family businesses from those in other countries. Indonesian culture emphasizes collectivism, respect for hierarchy, and maintaining harmonious relationships. This might influence management style and decision-making. The role of family networks in Indonesian business can be significant. Government regulations and access to financing might also differ from other countries. Indonesia is a developing economy. Family businesses in this context might be more risk-taking and entrepreneurial compared to those in more developed economies.

Digital technology is becoming more and more popular very quickly. This is changing every part of the business and having a big effect on how it works. It is generally inseparable from the presence of digitalization [13] and radically alters the idea of management and leadership. This study explored how the family business will approach digital adoption. Cahyadi and Magda [13] mentioned that adaptability to digitalization is a key indicator of a business's success. The Internet is used for company development as part of digital infrastructure. A limited firm can avoid the consequences, difficulties, and possibilities that arose from the digital revolution. It compels enterprises to overhaul their infrastructure. Given this context, numerous organizations are unprepared to transform. The family business is also required to embrace digitalization, which is a widely practiced business approach in many nations throughout the world. The majority of research on digitization was conducted at non-family companies and academic institutions. Researching digital adoption in the family business is crucial for gaining a comprehensive grasp of the field. Comprehending the digital integration inside the family business is crucial, as it needs to be prepared to embrace this trend. Scholars highlighted the significance of business change for the family business [14].

Furthermore, experts have disclosed that the present moment is the ideal time to digitize the business. Shortening the bureaucratic process and preserving an entrepreneurial spirit in the family business is essential [15]. This research explores the current trends in digital adoption literature. It aims to analyze whether family business leaders or successors own unique characteristics in adopting digitalization through the evidence. Furthermore, this study will try to create contributions toward future practice in the family business discipline in the form of a model that can be utilized by the family business to prepare for the process of digital adoption. It is vital to support the main priorities of Indonesian family businesses over the next two years, namely changing or adapting business models and increasing the use of new technologies.

2. Materials and methods

The research philosophy of this study is pragmatic, focusing on solving practical problems and contributing to the future practice of the family business. Pragmatic

employs a variety of methodologies, from qualitative to quantitative methods. The family business is a complex setup. According to Tagiuri and Davis [16], a family business consists of seven interest groups with the perspective, goal, and dynamic. Moreover, it is dense with learning-by-doing and immense tacit knowledge. So, practical meaning is suitable to this context. In addition, it becomes more challenging to investigate digital adoption since it shifts the social paradigm.

Consequently, this research will utilize primary and secondary source data from the best practice of digital adoption in the family business to explore the key success factors within the family business digital adoption. The second part is an approach to theory development. It sets the foundation for the research design, deciding the type of reasoning [17], and also several reasons as suggested by Easterby-Smith et al. [18]. First, it allows scholars to make a more informed decision. Second, it will distinguish between what strategies and methodologies work and what does not work. Last, it allows the research design to be adaptable, particularly in facing constraints. There are three types of reasoning [19]: deductive, inductive, and abductive. The family business is unique and will have a lot of unexpected variables. Therefore, abductive reasoning, generalizing from the interactions between the detail and the broad, will be suitable to be utilized.

This research selects a mixed-method (qualitative-quantitative) study as the research choice [20]. To carry out the mixed-method study, the study researched the technological entrepreneurship factors in nanotechnology businesses [21], which employed the mixed-method study, specifically interviews and questionnaires. This research will also employ a combination of open and closed data and qualitative and quantitative variables. It is considered that the mixed method is the most suitable method to be applied in the context of this research. The qualitative and quantitative study is conducted sequentially in this research, and lastly, the results are conveyed in combination. The sequential exploratory design uses the qualitative method to explore the phenomenon and subsequently uses the quantitative method to generalize the findings [20]. In other words, it validates exploratory dimensions from a small number of participants to generalize from a more significant number of respondents. In the data collection sequence, this research begins with qualitative data collection to explore the issue, and then quantitative data are collected. Qualitative data is given more importance to achieve real insight regarding the topic's issues and nature [20]. Moreover, this method allows individuals to become familiar with such issues as the core objective [21]. This study attempted to gather quantitative evidence to achieve generalizability based on the qualitative findings. The literature was reviewed initially in this investigation. Next, the characteristics influencing digital adoption in the family business were determined. Furthermore, the quantitative data was gathered using online surveys.

The questions were generally developed with the following six wh-question marks: how, what, why, when, where, and who [22]. Based on the research questions, there were five key questions, as follows:

- 1) How is the digital adoption process in your company in detail (involving actors, developing routines, using technology, needed time, key competencies, and capabilities)?
- 2) What does digitalization look like in your company?

- 3) Which data are available in digitalized form?
- 4) What motivates digitalization in your company?
- 5) How dynamic have the changes been within the digital adoption process?

Each interview will take time for 25–50 min on average. Open and axial coding approaches were employed accordingly. The output of this phase is an interview transcript. The participants are family owner-employees and family owners who work in the company. Moving on to the analysis phase. The interview transcript will be analyzed by following the thematic analytical procedures to identify the family business's constructs and dimensions of digital adoption factors. Moreover, it will be summarized on the proposed framework model and the relationship.

In the second phase, this study tries to generalize the findings using a quantitative method. After the initial exploration, the author uses the qualitative findings to create a quantitative phase. This phase involves the design of instruments to measure research variables, developing activities in experimental interventions, or making typological designs using existing instruments. Quantitative instruments, interventions, or variables are used in quantitative data collection and analysis procedures [20]. First of all, a survey will be conducted, questioning the constructs and dimensions that have been found in the qualitative phase previously. The questionnaire will be prepared by employing the interview findings and coding after the validity test. The study utilized a questionnaire, specifically an online questionnaire, that will be answered by many respondents from selected family businesses. The questionnaire answers will be analyzed quantitatively. This research will employ the PLS3 software because the number of respondents was less than two hundred [23]. Moreover, to examine the reliability of the questionnaire, this study will utilize the partial square method, and then *T*-statistics will be used to investigate the expected relationship between the variables. The respondents of this mixed-methods study will be selected conveniently from family-owner employees of the family business.

3. Results and discussion

This research constructs the state-of-the-art data by reviewing relevant works of literature. In an attempt at parsimoniously heightening understanding of the family business literature, this study has fused the family business topic into a digital adoption theme. At this stage, the identification phase consists of searching for articles from a variety of database sources. This study searched three different databases: Scopus, ProQuest, and Emerald, to ensure the quality of the found articles. Additionally, the brackets “AND” were utilized in the search process to merge the two extensive search queries that were produced. The further selection process and results are provided in **Table 1** below.

Table 1. Selecting process and result.

Steps	Scopus	ProQuest	Emerald	Additional
1) Keyword searching in the database	9	5	120	-
2) Screened relevant titles, abstracts, and keywords	8	1	28	-
3) Articles sought for retrieval	7	1	28	-
4) Eligible to criteria	6	0	2	4

The first one identifies all of the appropriate keywords for digital adoption, and the second one determines the appropriate keywords for the family business. In total, the author found twelve articles included in the review.

There have only been a few numbers of academics who have investigated this subject, even though digital adoption is extremely important to family businesses. Eleven of the twelve publications are research papers, and the remaining one is a review paper. There has been research conducted on this subject in a variety of countries, including France [24], Germany [25–30], India [31], Japan [32], Pakistan [33], and various European nations. Research predominantly occurs in Europe and examines wineries from many angles. No research has been conducted in Indonesia so far. The purpose differs across the twelve works of literature. Ano and Bent [24] investigated the human elements involved in implementing digital strategies. Rashid and Ratten [33], and Soluk and Kammerlander [30] utilized dynamic capabilities to analyze the family enterprise and more. This research will incorporate and modify the central concepts of Basly and Hammouda [34] and Soluk and Kammerlander [30]. The author considered the information to be contemporary and reliable and found their analysis beneficial for constructing the proposed model.

Digitalization encompasses a broad range of technological advancements and their integration into business operations. In the context of family businesses, this can manifest in several key areas, such as operational digitalization, marketing and sales digitalization, and product and service digitalization. Family businesses can leverage digital tools and technologies to streamline internal processes and enhance efficiency. This could involve implementing customer relationship management (CRM) systems to centralize customer data and interactions or adopting enterprise resource planning (ERP) software to integrate various business functions (e.g., accounting and inventory management). The rise of digital marketing channels presents opportunities for family businesses to expand their reach and connect with new customer segments. Social media platforms, online advertising tools, and e-commerce platforms offer valuable tools for marketing and selling products or services directly to consumers. The digital realm opens doors for family businesses to innovate and offer new digital products or services. This could involve developing mobile apps or online platforms that enhance customer experiences or integrating digital components into existing product offerings (e.g., smart home appliances with internet connectivity).

Certain characteristics of Indonesian family businesses can act as facilitators for digital adoption. For example, strong family values that prioritize long-term sustainability can create a supportive environment for investments in digital transformation, recognizing the long-term benefits for the future of the business. However, some characteristics might also present challenges for digital adoption. For instance, a lack of familiarity with technology among older family members or a risk-averse culture within the family might require strategies to bridge the digital skills gap and promote a culture of innovation.

Furthermore, the importance of protecting socio-emotional wealth becomes fundamental for the family business. The family business is willing to use non-economic logic when this attribute is threatened. Moreover, they will risk the company solely to maintain the socio-emotional wealth. The value of socio-emotional wealth is deeply anchored to family members and non-family members in the family business.

Basly and Hammouda [34] revealed influencing factors toward digital entrepreneurship adoption based on the socio-emotional wealth perspective. Based on socio-emotional wealth, family business characteristics are formed by several factors. Those factors are idiosyncratic, human resources, family ownership, and willingness to change. Finally, the propositions are:

Proposition 1: Socio-emotional wealth conceived by the family business influences the digital adoption decision and process.

Proposition 2: Idiosyncratic attitudes owned by the family business influence the digital adoption decision and process.

Proposition 3: Human resources managed by the family business influence the digital adoption decision and process.

Proposition 4: Family ownership in the family business influences the digital adoption decision and process.

Proposition 5: Willingness to change the family business influences the digital adoption decision and process.

The stages of digital adoption also include process, product/service, and business model, depending on the dynamic capability. The transfer of information and business processes from analog to digital is called process digitization. Digital technology integration into a company's goods and services, as well as the digitization of the interactions between the company and its suppliers and customers, are the hallmarks of product and service digitalization. Transforming business models and developing comprehensive digital solutions are considered to be business model digitalization. Companies start the internal and external stages of the digitization process. Internally, the firm is aware of a discrepancy between its technically outdated internal conditions and relevant IT standards; however, external triggers arise from requests from business partners for the alignment of IT standards and the provision of digital information. The deployment of digital technology is intended to increase efficiency and cut expenses [35]. Basic digital technology is still being used today, including enterprise resource planning, the usage of RFID tags, and electronic invoices. At this point, the result is a digital process. Dynamic capability is known as the company's ability to respond to changing environments [36]. The high-volume rise of digital technology is restructuring the business and vividly changing the concept of management and business. In this topic, digital adoption is vital because it drives the boosting of digital technology's benefit to develop the company's capabilities [37–39]. The relationship between dynamic capability and strategic management has been studied pretty much, and it has been found that there is a significant influence between them. Therefore, the propositions are:

Proposition 6: Digital adoption stages influence the digital leadership decision and process in the family business.

Proposition 7: Dynamic capability represented in the digital adoption stage and possessed by the family business influences the digital adoption decision and process in the family business. The proposed research framework is provided in **Figure 1** below.

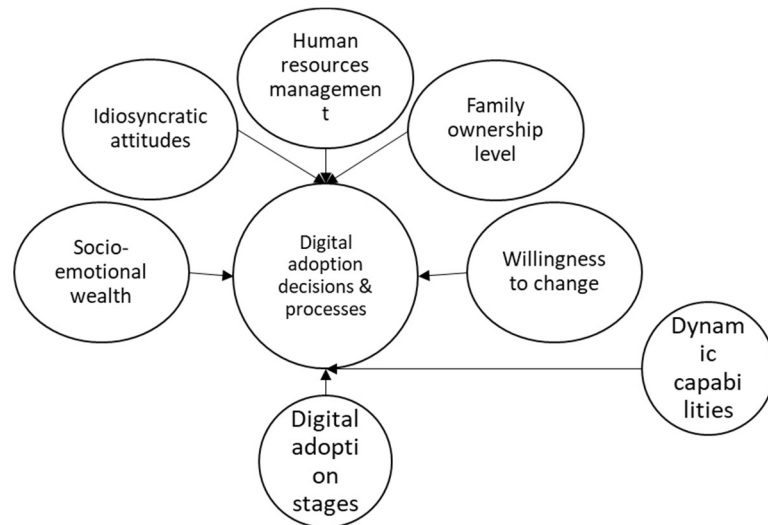


Figure 1. Proposed research framework.

4. Conclusion

In conclusion, the rapid increase in digital technology is reshaping all aspects of the company and significantly influencing its operations. Given this context, numerous firms are unprepared to transform, even the family business. This study tries to recognize and visualize models and relationships between the family business and digital adoption. This manner attempts to offer a state-of-the-art perspective on the opportunities coming up from digital adoption for the family business. This study investigated the relationships between family business characteristics, digital adoption stages, dynamic capabilities, and digital adoption decisions and processes. By exploring these factors, we aimed to contribute to the understanding of how Indonesian family businesses can navigate the digital transformation landscape. The findings suggest specific family business characteristics facilitate digital adoption, while others might pose challenges. The characteristics are socio-emotional wealth, idiosyncratic attitudes, human resources management, family ownership level, and willingness to change. These insights provide valuable guidance for Indonesian family businesses as they embark on their digital journeys. Furthermore, this research contributes to the family business discipline by proposing a research framework and highlighting the unique context of Indonesian family businesses. By delving deeper into this area, future research can explore potential areas within family business and digital adoption employing the mixed method to grasp comprehensive results.

Author contributions: Conceptualization, NLT, WD, and NNA; methodology, NLT and WD; data curation, NLT; writing—original draft preparation, NLT; writing—review and editing, NLT; supervision, WD and NNA; project administration, NLT. All authors have read and agreed to the published version of the manuscript.

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References

1. Chua JH, Chrisman JJ, Chang EPC. Are family firms born or made? An exploratory investigation. *Family Business Review*. 2004; 17(1): 37-54. doi: 10.1111/J.1741-6248.2004.00002.X
2. Eddleston KA, Kellermanns, FW, Sarathy R. Resource configuration in family firms: Linking resources, strategic planning and technological opportunities to performance. *Journal of Management Studies*. 2008; 45(1): 26-50. doi: 10.1111/J.1467-6486.2007.00717.X
3. Kets de Vries MFR. The dynamics of family controlled firms: The good and the bad news. *Organizational Dynamics*. 1993; 21(3): 59-71. doi: 10.1016/0090-2616(93)90071-8
4. Fan CW, Tan J, Guller E, et al. *Asian Family Businesses Report 2011*. Credit Suisse; 2011.
5. Koentjoro S, Gunawan S. Managing knowledge, dynamic capabilities, innovative performance, and creating sustainable competitive advantage in family companies: A case study of a family company in Indonesia. *Journal of Open Innovation: Technology, Market, and Complexity*. 2020; 6(3): 90. doi: 10.3390/JOITMC6030090
6. Poza EJ, Daugherty MS. *Family Business*, 5th ed. Cengage; 2018.
7. Waldron J. The Digital Transformation of Traditional Family Businesses. Available online: <https://metasfresh.com/en/2021/09/15/the-digital-transformation-of-traditional-family-businesses/> (accessed on 8 January 2024).
8. Sigliano K. *The Digital Transformation of Family Business: Legacy, Speed and Customers*. Ie University; 2017.
9. Tirdasari NL, Indrawan D, Fahmi I. Family business in agriculture: Challenge and strategy to face global business. *Advances in Economics, Business and Management Research*. 2019; 98: 155-158. doi: 10.2991/icot-19.2019.33
10. Tirdasari NL, Dhewanto W. Family business succession in Indonesia: A study of hospitality industry. *Procedia: Social and Behavioral Sciences*. 2012; 57: 69-74. doi: 10.1016/j.sbspro.2012.09.1159
11. Tirdasari NL, Dhewanto W. Family business succession of hospitality industry in Indonesia. *Journal of Asia Pacific Business Innovation & Technology Management*. 2014; 4: 21-29.
12. Tirdasari NL, Dhewanto W. When is the right time for succession? Multiple cases of family businesses in Indonesia. *Journal of Family Business Management*. 2020; 10(4): 349-359. doi: 10.1108/JFBM-10-2019-0064
13. Cahyadi A, Magda R. Digital leadership in the economies of the G20 countries: A secondary research. *Economies*. 2021; 9(1): 32. doi: 10.3390/economies9010032
14. Calabro A, McGinness T. Mastering a comeback How family businesses are triumphing over COVID-19. Available online: <https://assets.kpmg/content/dam/kpmg/xx/pdf/2021/03/family-business-survey-report.pdf#page=9> (accessed on 8 January 2024).
15. Burt B, Choi S, Dixon J. Why digital transformation should be a family (business) affair. Available online: <https://www.pwc.com.au/digitalpulse/family-business-survey-digital-transformation.html> (accessed on 8 January 2024).
16. Tagiuri R, Davis J. Bivalent attributes of the family firm. *Family Business Review*. 1996; 9(2): 199-208.
17. Alici EN, Cengizoglu E. *The Effect of Knowledge Management in Start-Ups: Exploring the Transition Process of a Start-Up from Temporary to a Permanent Organization*. Umeå University; 2017.
18. Easterby-Smith M, Thorpe T, Jackson P. *Management Research*, 4th ed. Sage Publications Ltd; 2012.
19. Saunders MNK, Lewis P, Thornhill A. *Research Methods for Business Students*. In: Synthese. Pearson; 2019.
20. Creswell JW, Clark VLP. *Designing and Conducting Mixed Methods Research*. Sage Publications; 2017.
21. Nikraftar T, Hosseini E, Mohammadi E. The factors influencing technological entrepreneurship in nanotechnology businesses. *Revista de Gestão*. 2021; 29(1): 76-99.
22. Hosseini SH, Hajipour E, Kaffashpoor A, Darikandeh A. The mediating effect of organizational culture in the relationship of leadership style with organizational learning. *Journal of Human Behavior in the Social Environment*. 2020; 30(3): 279-288.
23. Tajpour M, Hosseini E, Alizadeh R. Entrepreneurship opportunities: The effect of social entrepreneurship on the presence of Afghan immigrant youth in Iranian universities. *Migration Social Entrepreneurship and Social Inclusion*. 2021; 1(15): 261-284.
24. Ano B, Bent R. Human determinants influencing the digital transformation strategy of multigenerational family businesses: A multiple-case study of five French growth-oriented family firms. *Journal of Family Business Management*. 2021; 12(4):

- 876-891. doi: 10.1108/JFBM-12-2020-0117
25. Brenk S, Lüttgens D, Diener K, Piller F. Learning from failures in business model innovation: Solving decision-making logic conflicts through intrapreneurial effectuation. *Journal of Business Economics*. 2019; 89(8-9): 1097-1147. doi: 10.1007/s11573-019-00954-1
26. Dressler M, Paunovic I. Sensing technologies, roles and technology adoption strategies for digital transformation of grape harvesting in SME wineries. *Journal of Open Innovation: Technology, Market, and Complexity*. 2021; 7(2): 123. doi: 10.3390/joitmc7020123
27. Pollák F, Markovič P. Size of business unit as a factor influencing adoption of digital marketing: Empirical analysis of SMEs operating in the central European market. *Administrative Sciences*. 2021; 11(3): 71. doi: 10.3390/admsci11030071
28. Pöschl A, Freiling J. The impact of family-external business succession on digitalization: Exploring management buy-ins. *International Journal of Information Systems and Project Management*. 2020; 8(2): 24-46. doi: 10.12821/ijispm080202
29. Rondi E, Massis AD, Kraus S. Servitization through open service innovation in family firms: Exploring the ability-willingness paradox. *Journal of Business Research*. 2021; 135: 436-444. doi: 10.1016/j.jbusres.2021.06.040
30. Soluk J, Kammerlander N. Digital transformation in family-owned Mittelstand firms: A dynamic capabilities perspective. *European Journal of Information Systems*. 2021; 30(6): 676-711. doi: 10.1080/0960085X.2020.1857666
31. Chatterjee S, Chaudhuri R, Vrontis D. Entrepreneurial behavior of family firms in the Indian community: adoption of a technology platform as a moderator. *Journal of Enterprising Communities*. 2021; 17(2): 433-453. doi: 10.1108/JEC-08-2021-0122
32. Chung YCY, Chang HH, Kitamura Y. Digital and traditional media advertising and business performance of agribusiness firms-Empirical evidence in Japan. *Agricultural Economics*. 2021; 67(2): 51-59.
33. Rashid S, Ratten V. A dynamic capabilities approach for the survival of Pakistani family-owned business in the digital world. *Journal of Family Business Management*. 2020; 10(4): 373-387. doi: 10.1108/JFBM-12-2019-0082
34. Basly S, Hammouda A. Family businesses and digital entrepreneurship adoption: A conceptual model. *The Journal of Entrepreneurship*. 2020; 29(2): 326-364. doi: 10.1177/0971355720930573
35. Cimini C, Boffelli A, Lagorio A, et al. How do industry 4.0 technologies influence organisational change? An empirical analysis of Italian SMEs. *Journal of Manufacturing Technology Management*. 2021; 32(3): 695-721. doi: 10.1108/JMTM-04-2019-0135
36. Abi J, Arief M. Examining the relationship between transformational leadership and dynamic capability to the adoption of digital marketing in consumer shopping good firms. *International Journal of Economics and Management*. 2017; 11(2): 487-504.
37. Elidjen L, Mihardjo WW, Rukmana RAN. Intervening Role of Innovation Management on Relationship between Digital Leadership and Dynamic Capability Accelerated by Collaboration. Primrose Hall Publishing Group; 2019.
38. Kane GC, Phillips AN, Copulsky J, Andrus G. How Digital Leadership is(n't) Different. Massachusetts Institute of Technology; 2019.
39. Mihardjo LWWW, Sasmoko S, Alamsjah F, Elidjen E. Digital leadership role in developing business model innovation and customer experience orientation in industry 4.0. *Management Science Letters*. 2019; 9(11): 1749-1762. doi: 10.5267/j.msl.2019.6.015

Commentary

Sustainable progress: Art-tech and inclusive education transforming virtual learning for equity and long-term impact

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Abstract: Sustainable inclusive education and art technology allow for better development for both the students and the educational community. This new approach integrates art education with technology education. There are five preliminary approaches to deepen Sustainable Social Development and Information and Communications Technologies. It represents a novel theory of sustainable development within inclusive education, leveraging art technology and art education to address significant challenges and drive transformation.

Keywords: art technology; inclusive education; technology education; sustainability theory

1. Introduction

Is it possible to develop a sustainable inclusive education model that integrates art and technology within virtual environments, ensuring the quality of students and their educational communities? The future of society hinges on nurturing responsible citizens who prioritize the well-being of children and youth, thereby contributing significantly to the state's development [1]. There are new educational forms to create and support complementary activities, both for technology education and art education, to transform social virtuality [2].

Integration of Sustainable Social Development (SSD) [3,4] and Information and Communications Technologies (ICT) [5], coupled with the incorporation of educational and art technology, aims to foster innovative approaches benefiting both social development and educational/artistic endeavors.

2. New focus

The SSD approach to inclusive education and art technology is important for several reasons, including social, cultural, and economic aspects. In some basic points, they are:

- 1) **Social equity:** inclusive education and the arts provide opportunities to address social and economic inequalities [6,7]. Inclusive education guarantees that everyone, regardless of their circumstances, has access to quality educational opportunities [8,9]. Media art, for its part, can be a powerful tool to give voice to marginalized communities [10–12].
- 2) **Diversity and Tolerance:** Inclusive education promotes understanding and acceptance of diversity [13,14]. Through a curriculum that reflects diverse perspectives and experiences, tolerance and mutual respect are fostered [15–17]. Art technology can also play a crucial role in representing and celebrating cultural diversity [18–21].
- 3) **Comprehensive Human Development:** Education and media art contribute to

integral human development. Education is not limited to the acquisition of knowledge but also encompasses the development of social and emotional skills [22–24]. Art, when combined with ICT and SSD, can inspire creativity and personal expression [25]. This contributes to the emotional and mental well-being of students and, of course, the entire educational community [26].

- 4) Long-Term Sustainability: Inclusive education and art technology contribute to building more sustainable societies in the long term [27]. By creating in education and artistic expression, it strengthens the basis for SSD and ICT. This empowers people to address future challenges in an informed and creative manner [28].
- 5) Social cohesion: Both inclusive education and art technology can play a vital role in building cohesive communities. Education promotes active participation in society through SSD [29,30]. Art technology serves to bring together students, teachers, and educational communities through creative expression and cultural participation.

This concept implies the interconnection of economic, social, and environmental dimensions to achieve equitable and long-term progress.

This scheme is centered around ICT and SSD and linked to “Social Equity”, “Diversity and Tolerance”, “Comprehensive Human Development”, “Social Cohesion”, and “Long-Term Sustainability” (see **Figure 1**). Additionally, a specific branch focuses on sustainability in inclusive education within virtual environments, integrating art and technology. This branch further extends to considerations of both student quality and the quality of educational communities. The emphasis lies in adopting a holistic approach to uphold high standards both for the individuals and for the community within the virtual educational setting.

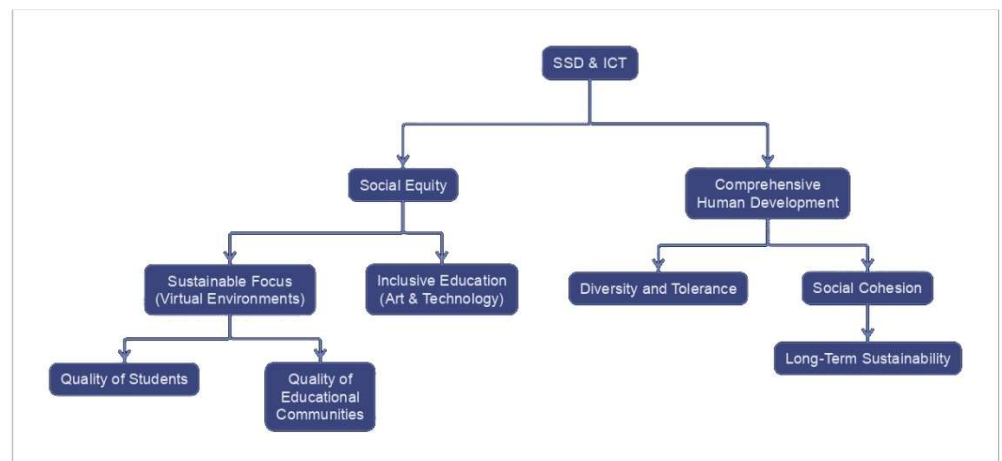


Figure 1. SSD & ICT Scheme (Source: original).

In the realm of ICT and SSD, our focus extends across key dimensions. Central to our approach is the promotion of “Social Equity”, fostering “Diversity and Tolerance”, and nurturing “Comprehensive Human Development”. This interconnected framework also addresses the crucial elements of “Social Cohesion” and “Long-Term Sustainability.” Additionally, we are dedicated to pioneering a sustainable focus on inclusive education within virtual environments, seamlessly integrating art and technology. This commitment aims not only to ensure the quality

of students but also to enhance the overall quality of educational communities, fostering a holistic and enduring impact.

3. Conclusion

There is no new theory of sustainable development in inclusive education on the incorporation of art technology and art education to transform the big challenges. Quite complex to develop sustainability to guarantee the equality of the school and the use of fundamental rights for students with different situations of daily life.

Under certain fundamental conditions, the issue of virtuality and long-term sustainability within the educational, technological, artistic, and creative systems ceases to exist through novel decision-making approaches at the societal level.

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References

1. Akbarovna AS. Inclusive education and its essence. *International Journal of Social Science & Interdisciplinary Research*. 2022; 11(1): 248-254.
2. Bernaschina D. Social pedagogy and media arts: innovative proposal for inclusive schooling (Spanish). *Alteridad*. 2023; 18(2): 164-176. doi: 10.17163/alt.v18n2.2023.01
3. Fedulova I, Ivanova V, Atyukova O, Nosov V. Inclusive education as a basis for sustainable development of society. *Journal of Social Studies Education Research*. 2019; 10(3): 118-135.
4. Lo LNK. The sustainable development of inclusive education. *Chinese Education & Society*. 2007; 40(4): 44-62. doi: 10.2753/ced1061-1932400404
5. Pegalajar Palomino M del C. Information and communication technologies and inclusive teaching: perceptions and attitudes of future early childhood and primary education teachers. *Problems of Education in the 21st Century*. 2018; 76(3): 380-392. doi: 10.33225/pec/18.76.380
6. Mezzanotte C. The social and Economic Rationale of Inclusive Education: An Overview of the Outcomes in Education for Diverse Groups of Students. *Organisation for Economic Co-operation and Development*; 2022. doi: 10.1787/bff7a85d-en
7. Rambla X, Langthaler M. The SDGs and inclusive education for all: From special education to addressing social inequalities. Available online: <https://www.econstor.eu/bitstream/10419/142739/1/861882016.pdf> (accessed on 2 May 2024).
8. Walton E, Carrington S, Saggars B, et al. What matters in learning communities for inclusive education: a cross-case analysis. *Professional Development in Education*. 2019; 48(1): 134-148. doi: 10.1080/19415257.2019.1689525
9. Jokinen M. Inclusive education—a sustainable approach? *American annals of the deaf*. 2018; 163(1): 70-77. doi: 10.1353/aad.2018.0012
10. Bernaschina D. Screen video art: A new experimental proposal for creative study. *Art Vision*. 2023; 29(51): 170-177. doi: 10.5152/artvis.2023.23202
11. Hidalgo L. Augmented Fotonovelas: Creating new media as pedagogical and social justice tools. *Qualitative Inquiry: QI*. 2015; 21(3): 300-314. doi: 10.1177/1077800414557831
12. Shank M, Schirch L. Strategic arts-based peacebuilding. *Peace & Change*. 2008; 33(2): 217-242. doi: 10.1111/j.1468-0130.2008.00490.x
13. Vavik T, Keitsch MM. Exploring relationships between universal design and social sustainable development: some methodological aspects to the debate on the sciences of sustainability. *Sustainable Development*. 2010; 18(5): 295-305. doi: 10.1002/sd.480
14. Gherardi SA. Unfinished Bridges over the Digital Divide: A Case Study in Technology and Inclusive Education [PhD thesis]. University of Illinois at Chicago; 2016.
15. Kapadekar M. Social Skills in an Inclusive Classroom [Master's thesis]. California State University; 2013.
16. Scamardella F, Saraiello E, Tafuri F. Gamification as a means to improve teaching/learning process. *Sustainable Social Development*. 2023; 1(2). doi: 10.54517/ssd.v1i2.2254

17. Sims PA, Huang X, Niles J. Curriculum Design for Transformative Enterprise Education within the Context of Strategic Sustainable Development [Master's thesis]. Blekinge Institute of Technology; 2017.
18. Hill LA, Brandeau G, Truelove E, Lineback K. *Collective Genius: The Art and Practice of Leading Innovation*. Harvard Business Review Press; 2014.
19. Llamazares de Prado JE, Arias Gago AR. Technology and education as elements in museum cultural inclusion. *Education and Urban Society*. 2021; 55(2): 238-258. doi: 10.1177/00131245211004576
20. Fürsich E. Media and the representation of Others. *International Social Science Journal*. 2010; 61(199): 113-130. doi:10.1111/j.1468-2451.2010.01751.x
21. Azmat F, Fujimoto Y, Rentschler R. Exploring cultural inclusion: Perspectives from a community arts organisation. *Australian Journal of Management*. 2015; 40(2): 375-396. doi: 10.1177/0312896214525180
22. Elias MJ, Zins J, Weissberg RP. *Promoting Social and Emotional Learning: Guidelines for educators*. Ascd; 1997.
23. Gu CC, Gomes T, Brizuela VS. Technical and Vocational Education and Training in Support of Strategic Sustainable Development [Master's thesis]. Blekinge Institute of Technology; 2011.
24. Ioannidi V, Malafantis KD. Inclusive Education and inclusive school development: a key-area for sustainability and teacher skills. *European Journal of Social Sciences Studies*. 2022; 8(1). doi: 10.46827/ejsss.v8i1.1335
25. d'Orville H. The relationship between sustainability and creativity. *Cadmus*. 2019; 4(1): 65-73.
26. Zins JE, Elias MJ. Social and Emotional Learning: Promoting the Development of All Students. *Journal of Educational and Psychological Consultation*. 2007; 17(2-3): 233-255. doi: 10.1080/10474410701413152
27. Sclater M. Beneath our eyes: an exploration of the relationship between technology enhanced learning and socio-ecological sustainability in art and design higher education. *International Journal of Art & Design Education*. 2016; 35(3): 296-306. doi: 10.1111/jade.12125
28. Vavik T, Keitsch MM. Exploring relationships between universal design and social sustainable development: some methodological aspects to the debate on the sciences of sustainability. *Sustainable Development*. 2010; 18(5): 295-305. doi: 10.1002/sd.480
29. Tafuri F, Saraiello E, Maietta MC. Technology to support sustainable education in physical education. *Sustainable Social Development*. 2023; 1(1). doi: 10.54517/ssd.v1i1.2194
30. Llamazares de Prado JE, Arias Gago AR. technology and education as elements in museum cultural inclusion. *Education and Urban Society*. 2021; 55(2): 238-258. doi: 10.1177/00131245211004576

Commentary

New reflections and strategies for social sustainability through the climate change crisis within inclusive participation and school

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Abstract: The goal of this paper corresponds to a small theory on the discovery of the incorporation of climate action to go deeper regarding educational treatment. There is no search to raise awareness in the social community for educational inclusion on current environmental problems such as pollution, loss of biodiversity, and climate change, among others. Social inclusion in ecology and the new treatment of sustainability through practice that allows us to assume and strengthen the greatest responsibility for the environment is notable and conscious, of course, the transversal programs within the environmental matter together with the inclusive school. This educational operation seeks to strengthen the practice of values that allow us to assume the greatest responsibility of caring for the environment in a notable and conscious way, of course, the transversal programs within the environmental field along with the participation of students with cultural-functional diversity. It is possible to debate the use of a modernized model for inclusive ecology to improve the structuring of the educational strategy, depending on the teaching and learning process of the inclusive school.

Keywords: climate change; inclusive; education; school; society; sustainability theory

1. Introduction

The sixth assessment report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) [1–4] that analyzed the new findings of the incorporation of climate action on the threat to human well-being and the health of the planet (but does not correspond to) the greatest benefits to taking the necessary and urgent measures. There is no guarantee for a sustainable and livable future for all. There is no treatment to incorporate the project on the climate change crisis, as well as the lack of promise to care for the environment and the participation of social actors through ecology [5,6].

The only question to deepen regarding educational treatment: should the recyclable and reusable materials incorporate the complementary subjects of social ecology and inclusive school? There is no search to raise awareness in the social community for educational inclusion on current environmental problems such as pollution, loss of biodiversity, and climate change, among others.

2. Social life problem through ecological inclusion in education

Social inclusion in ecology and the new treatment of sustainability through practice that allows us to assume and strengthen the greatest responsibility for the environment is notable and conscious, of course, the transversal programs within the environmental matter together with the inclusive school. For example, it is possible to know in students that both cultural diversity and functional diversity (disability) help to create educational ecologies, of course, inclusive education communities, as well as the (new) inclusive strategies to face environmental crisis and climate change with

resilience, depending on different approaches to environmental education and sustainability for making with eco-anxiety [7,8] and eco-friendly [9,10].

It is very difficult to deepen the bond with the ecology associated with climate change within the inclusive school. By differentiating the traditional disciplinary focus on research and problem-solving that remains in school education and, of course, in higher education to generate a pedagogically interdisciplinary and holistic approach, it is possible to exchange the accesses of social sustainability to discuss the problem-based challenges to pedagogical strategies within the inclusive school and the educational community that engage from the new perspectives of students and teachers, engaging creative and participatory opportunities within the climate change crisis [11–13].

The incorporation of the inclusive school, depending on the spaces of social vulnerability on human behavior, such as a student without having the ecological learning experience, adaptation to climate change for the curricular subject and the didactic tool through the study on the ecology, and the impacts of the absence on the use of recyclable and reusable materials theory. The educational project of ecological instruments aims to raise awareness in environmental education, of course, for all schools facing the climate change crisis towards the new search for educational strategies in the inclusive world.

Not all educational approaches implement the ecological field to respond to the necessary demands of climate change, but depending on different adaptations of educational processes for environmental education, such as social and cultural, of course, addressing curricular contents and teaching-learning methodologies to meet the changing needs of students. This makes it quite difficult to maintain the current and future challenges of sustainable ecological works, that is, the double concept of environmental education and inclusive school incorporates creative and educational works that use the resources of images and technological materials to address the different episodes and challenges of climate emergency, the ecological manifestation, and the lack of environmental education within the curricular subject.

2.1. Ecological-sustainability theory for inclusive education

There is a theory of sustainability to link the educational strategy within the social matter and inclusive ecology [14–17]. It is important to highlight educational participation in social ecology, according to Assadourian's study [18–20] on the original model that corresponds to set theory (Venn diagram) in which one set contains the education for sustainability group, the other set contains to the education for resilience group, and from both sets the overlapping area of education for the Earth is obtained, equivalent to eco-social education; On the other hand, the modernized model that corresponds to the double group: one set contains the environmental education group, and the other set contains the inclusive education group, and both sets transform the intersection of environmental education for inclusive sustainability (**Figure 1**).

Both models facilitate the use of environmentally related topics that are integrated into eco-social education. There is no proposal for a modernized model to include the development of curricular content associated with the ecological subject to improve the motivation of students with cultural-functional diversity (and the educational

community), depending on the skills on the climate change crisis. For several authors, it is possible to highlight some components of the roles in educational practice to underline the particular characteristics, that is, each teacher is capable of assuming responsibility for creating educational projects related to eco-anxiety and eco-friendly, depending on strategic planning and didactic material in order to contribute to the knowledge-based development of creative and experimental skills within teaching and the participation of the climate change crisis in ICT [21–26].

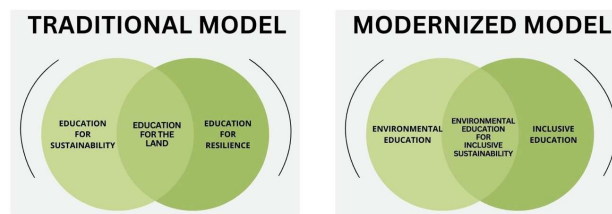


Figure 1. Two models for education and social sustainability (Source: Self-made).

2.2. Question of the role of teachers in inclusive educational practice

It is important to highlight the role of teachers in educational practice through their various functions and responsibilities to perform in the training and development of teaching at all levels of the educational system. Not all schools support the ecological curriculum, and they also do not encourage the participation of mandatory curricular content in environmental education for inclusive sustainability about incorporating the impact (or threat) of spreading environmental damage inside or outside the school. The greatest failure of sustainable development lies in the inability to generate eco-friendly and appropriate educational activities for school visibility.

Despite efforts to promote ecological practices and sustainable products, the implementation of environmental education and inclusive sustainability in the school environment has been insufficient. In many cases, products are not designed for environmentally sustainable manufacturing. There is the result of a negative impact on the environment and people's health in general. For example, school supplies can be made from flexible, resident, renewable, and non-toxic materials.

This educational operation seeks to strengthen the practice of values that allow us to assume the greatest responsibility of caring for the environment in a notable and conscious way, of course, the transversal programs within the environmental field along with the participation of students with cultural-functional diversity.

3. Final considerations

It is possible to debate the use of a modernized model for inclusive ecology to improve the structuring of the educational strategy, depending on the teaching and learning process of the inclusive school. On the other hand, there is no evidence that the modernized model creates the participation of students with cultural-functional diversity within the educational environmental field.

Important that needs to improve ecology through inclusive education about organizing (and planning) programs (or new activities) in the environmental education for inclusive sustainability. However, the new proposals for eco-anxiety and eco-friendly treatments in the face of the climate change crisis and the reaction of the

environment for all students with cultural-functional diversity, regardless of the level of study in the educational system.

Despite these challenges, the educational exchange for sustainability in the future project offers creativity, critical thinking, and problem-solving by integrating science, economics, ecology, arts, technologies, and others from the perspective of transdisciplinary methodology. Finally, there is guidance to improve a new search on the incorporation of a modernized model, addressing the use of recycled material through respect for the environment and also the use of the digital literacy program, such as environmental educational technology, to obtain the greatest influence of sustainable development. Likewise, it seeks to guarantee greater concern about climate change or the environmental crisis through the relationship between socio-environmental development and the quality of vital signs such as biodiversity.

Conflict of interest: The author declares no conflict of interest.

References

1. IPCC. Climate Change 2022: Impacts, Adaptation and Vulnerability 2022. Available online: <https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/> (accessed on 16 December 2023).
2. IPCC. AR6 Synthesis Report: Climate Change 2023. Available online: <https://www.ipcc.ch/report/sixth-assessment-report-cycle/> (accessed on 16 December 2023).
3. Planelles M. The great scientific review on the climate crisis: “The window to secure a livable future is closing” (Spanish). Available online: <https://elpais.com/clima-y-medio-ambiente/2023-03-20/la-gran-revision-cientifica-sobre-la-crisis-climatica-la-ventana-para-asegurar-un-futuro-habitable-se-cierra.html> (accessed on 16 December 2023).
4. Neslen A. We need power to prescribe climate policy, IPCC scientists say. Available online: <https://www.theguardian.com/environment/2023/dec/07/we-need-power-to-prescribe-climate-policy-ipcc-scientists-say> (accessed on 16 December 2023).
5. UNICEF. Adolescent development and participation. Available online: <https://www.unicef.org/adolescence> (accessed on 16 December 2023).
6. Sims L, Rocque R, Desmarais MÉ. Enabling students to face the environmental crisis and climate change with resilience: inclusive environmental and sustainability education approaches and strategies for coping with eco-anxiety. *International Journal of Higher Education and Sustainability*. 2020; 3(2): 112. doi: 10.1504/ijhes.2020.113059
7. Kurth C, Pihkala P. Eco-anxiety: What it is and why it matters. *Frontiers in Psychology*. 2022; 13. doi: 10.3389/fpsyg.2022.981814
8. Innocenti M, Perilli A, Santarelli G, et al. How Does Climate Change Worry Influence the Relationship between Climate Change Anxiety and Eco-Paralysis? A Moderation Study. *Climate*. 2023; 11(9): 190. doi: 10.3390/cli11090190
9. Orange E. From eco-friendly to eco-intelligent. *The Futurist*. 2010; 44(5): 28-32.
10. Mallett RK. Eco-Guilt Motivates Eco-Friendly Behavior. *Ecopsychology*. 2012; 4(3): 223-231. doi: 10.1089/eco.2012.0031
11. Lake D, Fernando H, Eardley D. The social lab classroom: wrestling with—and learning from—sustainability challenges. *Sustainability: Science, Practice and Policy*. 2016; 12(1): 76-87. doi: 10.1080/15487733.2016.11908155
12. Matschoss K, Fahy F, Rau H, et al. Challenging practices: experiences from community and individual living lab approaches. *Sustainability: Science, Practice and Policy*. 2021; 17(1): 135-151. doi: 10.1080/15487733.2021.1902062
13. McCrory G, Holmén J, Holmberg J, et al. Learning to Frame Complex Sustainability Challenges in Place: Explorations into a Transdisciplinary “Challenge Lab” Curriculum. *Frontiers in Sustainability*. 2021; 2. doi: 10.3389/frsus.2021.714193
14. Evans TL. *Living and Learning Sustainability: Pedagogy and Praxis in Sustainability Education* [PhD thesis]. Prescott College; 2011.
15. Schmitz CL, Stinson CH, James CD. Community and Environmental Sustainability. *Critical Social Work*. 2019; 11(3). doi: 10.22329/csw.v11i3.5834

16. Burns HL, Kelley SS, Spalding HE. Teaching sustainability: Recommendations for best pedagogical practices. *Journal of Sustainability Education*. 2019; 19.
17. Anderson V, Datta R, Dyck S, et al. Meanings and implications of culture in sustainability education research. *The Journal of Environmental Education*. 2015; 47(1): 1-18. doi: 10.1080/00958964.2015.1056077
18. Assadourian E. Ecosocial education: How to educate in the face of the ecological crisis (Spanish). Available online: <https://www.fuhem.es/wp-content/uploads/2018/04/SitMundo-2017-EducacionEcosocial-E.Assadourian.pdf> (accessed on 2 February 2024).
19. Assadourian E. Transforming Cultures: From Consumerism to Sustainability. *Journal of Macromarketing*. 2010; 30(2): 186-191. doi: 10.1177/0276146710361932
20. Assadourian E. The Path to Degrowth in Overdeveloped Countries. In: Starke L (editor). *State of the World 2012*. Island Press/Center for Resource Economics; 2012. pp. 22-37.
21. Lehtonen A, Salonen AO, Cantell H. Climate change education: A new approach for a world of wicked problems. In: Cook JW (editor). *Sustainability, Human Well-Being, and the Future of Education*. Palgrave Macmillan; 2019. pp. 339-374.
22. Bacon CM, Mulvaney D, Ball TB, et al. The creation of an integrated sustainability curriculum and student praxis projects. *International Journal of Sustainability in Higher Education*. 2011; 12(2): 193-208. doi: 10.1108/14676371111118237
23. Rieckmann M. Learning to transform the world: Key competencies in Education for Sustainable Development. In: De Licht A, Heiss J, Byun JW (editors). *Issues and Trends in Education for Sustainable Development*. UNESCO; 2018. pp. 39-59.
24. Sanson A, Dubicka B. Editorial: The climate and ecological mental health emergency – evidence and action. *Child and Adolescent Mental Health*. 2022; 27(1): 1-3. doi: 10.1111/camh.12540
25. Kranz J, Schwichow M, Breitenmoser P, et al. The (Un)political Perspective on Climate Change in Education—A Systematic Review. *Sustainability*. 2022; 14(7): 4194. doi: 10.3390/su14074194
26. Eilam E. Climate change education: the problem with walking away from disciplines. *Studies in Science Education*. 2022; 58(2): 231-264. doi: 10.1080/03057267.2021.2011589

Review

Towards concentric spatial systems for sustainable social development: Beyond western ethnocentric diametric spatial opposition and empty space

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Abstract: This article outlines key features of an emerging spatial turn in education, the social sciences, and the humanities and its relevance to developing sustainable social systems, with a particular focus on inclusive systems. This is cognisant of UN Sustainable Goal 4 on Equitable Inclusive Education and Goal 1 on No Poverty. Offering a necessarily illustrative selection of key conceptual traditions and recent applications of spatial understandings pertinent to education and inclusion, with wider applicability, this proposed spatial turn is examined as offering critical alternatives to Western ethnocentric frames of space. This leads to contrasts between concentric spatial systems of inclusion, assumed connection, and relative openness and diametric spatial systems of exclusion, splitting, and mirror image oppositions in education and community spaces of relation.

Keywords: concentric space; diametric space; inclusion; systems; education; nature

1. Introduction: A spatial turn to challenge the neutralising of space in social systems

Sustainable social development requires not only a systemic understanding but in doing so, it needs to address a frequently overlooked dimension, namely, that space is itself a system, a malleable system of relations impacting on causal trajectories and social meanings. Across education, the social sciences and the humanities, there is increasing interdisciplinary recognition of a so-called spatial turn, to accelerate a focus on spatial system dimensions. This spatial turn is now recognised in geography as being wider than simply treating space as place [1]. Place is one aspect of space and is long recognised in anthropology as bridging the material and symbolic. However, relational space is a wider conception than simply place, with alternative relational spaces relevant to sustainable social systems and their development [2]. This includes recognition that relational space is a systemic concept pertinent also to understandings of marginalisation [1] and inclusive systems [2].

Japanese conceptions of *ma* offer a spatial-relational dimension to space, space is a framing condition for social relationships. The Japanese concept of *ma* can signify the space between one thing and another and can also be used for understanding of human relationships [3]. A 2018 European Journal of Education, Special Issue Editorial on transitions asks the question, can Eurocentric modes of space be identified and challenged? [4].

A spatial turn is also being recognised for hermeneutics [5]. In seeking to understand spatial divisions and connections, Ferrare and Apple's critical education studies approach seeks understandings of 'spatial processes in education ... we not only need these "new" theories, but we also need to employ methodological tools that "think" spatially' [6].

This concern applies beyond simply education systems and more widely to sustainable social systems, including at local community level for engagement and inclusion of marginalised groups. Building on the UN Sustainable Development Goal (SDG) 4 on equitable and inclusive education, and SDG 1 on No Poverty, sustainable social systems must be inclusive systems and thereby incorporate a spatial focus on inclusion and challenge to exclusionary processes, structures, practices and discourses.

Interrogating a spatial turn for systems relevant to promotion of sustainable social development involves a cross-cultural focus on different kinds of space that challenge Western spatial ethnocentrism. A Western Cartesian tradition tends to operate through treating space in two ways, as ‘empty space, which almost everyone is convinced is mere nonentity’ [7] or as a diametric oppositional space bringing splits between for example, reason and emotion, mind and body. These Western traditions of spatial divisions as dualism precedes Descartes and includes nature versus culture diametric oppositions that can be traced to Ancient Rome [8].

Reconfiguration of the relational space of schools concerning nature requires challenge to traditional Western diametric oppositional contrasts between nature and culture. Descola’s cross-cultural anthropological review highlights the constructedness of this diametric opposition:

‘This Roman landscape, together with all of the values associated with it that colonization had introduced around cities as far away as the banks of the Rhine and in Britain, was the landscape that introduced the notion of a polarity between the wild and the domesticated that we still recognize today. This opposition is neither an objective representation of the properties of things nor an expression of a timeless human nature’ [8].

The ramifications of this for opening spaces in schools and wider sustainable social development of systems requires amplification.

Descola further challenges the Western bias of this split between nature and culture, ‘In China, India and Japan, it is hard to discover any dichotomy of ‘wild’ and ‘domesticated’ comparable to that which the Western world has forged’ [8]. While Teo [9] seeks to challenge a Western ethnocentric intuition in psychology, it is this Western ethnocentric intuition of diametric oppositional space that needs reconfiguration to promote sustainable social systems to overcome endemic exclusions and rigid boundaries. The diametric spatial opposition between us and them [2], any ingroup or outgroup in a given society, is not the hallmark of sustainable social systems. Similarly, the hierarchy of above versus below in diametric oppositional space has underpinned a conception of humans as being above nature, for their control and domination of nature, as part of a Western modernist tradition of subjugating and conquering the spaces of nature to human beings’ acquisitive needs. A different concentric relational space is needed for sustainable social systems.

Spatial understandings require reconstruction beyond a Western tradition of treating space as empty and homogenous, as a mere abstraction or metaphor. Space is a framing condition sustaining system trajectories and requires uncovering as such; it needs a conceptualisation beyond related diametric oppositional Western categories of ideal versus real to more directly examine the materiality of spatial impacts on systems.

2. Key contrasting cross-cultural spaces of relation: Diametric and concentric spatial systems

Key contrasting concentric and diametric structures of relation have been observed cross-culturally by a range of anthropologists as embedded in both physical and social structures, as well as in myths. These were developed into a framework of mutual interaction by Levi-Strauss' [10] structural anthropology, though diametric and concentric systems were treated mainly as structures more than spaces as such. A diametric spatial structure is one where a circle is split in half by a line, which is its diameter, or where a square or rectangle is similarly divided into two equal halves (see **Figure 1**). In a concentric spatial structure, one circle is inscribed in another larger circle (or square); in pure form, the circles share a common central point (see **Figure 2**), a co-centre.

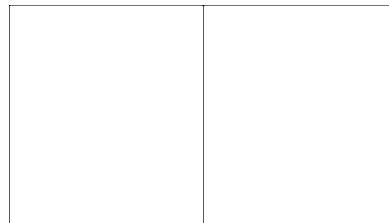


Figure 1. Diametric dualism.

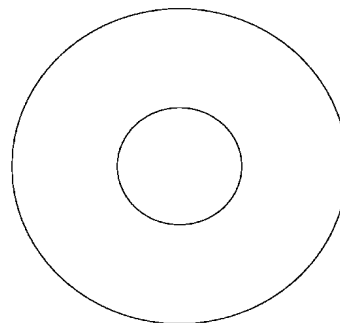


Figure 2. Concentric dualism.

A purportedly key distinguishing feature of concentric and diametric spaces, observed by Lévi-Strauss, is that they tend to co-exist in 'functional relation' [11] and not simply in isolation. They are structures of relations as part of a system of relations. In other words, this relational interaction offers a conception of movement and interplay between these spaces.

Lévi-Strauss observed two key contrasts between concentric and diametric structured systems. Diametric spaces are i) relatively more closed and with firmer boundaries than the more interactive with background and open concentric spatial systems. For concentric systems, 'its frame of reference is always the environment ... In a diametric system ... virgin land constitutes an irrelevant element; the moieties are defined by their opposition to each other, and the apparent symmetry of their closed structure creates the illusion of a closed system' [10]. Diametric space offers ii) a feature of mirror image symmetry [11]. A mirror image is not an identical one but a left-right inversion of polar opposites, for example, hierarchies of good/bad,

success/failure, powerful/powerless. Diametric mirror image oppositions include weak/strong, sacred/profane, above/below, love/hate [2].

A further contrast is as follows: iii) A concentric spatial relation between poles is one of assumed connection, of mutual overlap around a common centre, a co-centre; in contrast, any interaction between diametrically oppositional poles is one of assumed separation and splitting [2]. Though Lévi-Strauss did not explicitly highlight this difference, it is geometrically evident that the inner and outer poles of concentric structures are more fundamentally attached to each other than diametric structures. Both concentric poles coexist in the same space around a common centre so that the outer circle overlaps the space of the inner one. The outer circle surrounds and contains the inner circle. The opposite that is within the outer circle or shape cannot detach itself from being within this outer shape. And though the outer circle or shape can move in the direction of greater detachment from the inner circle, it cannot fully detach itself from the inner circle (even if the inner circle becomes an increasingly smaller proportion of the outer). A concentric relation assumes connection between its parts, and any separation is on the basis of assumed connection, whereas diametric opposition assumes separation, and any connection between the parts is on the basis of this assumed separation [2]. Concentric space offers a relation that allows for distinction between an inner and outer pole, while retaining an underlying connection.

These geometric and empirical contrasts are between concentric space as assumed connection between poles and relative openness and interaction with background on the one hand, and diametric space as assumed separation, an oppositional process of splitting, a mirror image inverted symmetry of us/them, above/below and of relative closure and noninteraction with background. This expands the cross-cultural observations of these structural contrasts in Lévi-Strauss' structural anthropology, though not confining the importance of a spatial turn to the framework of structuralism.

3. Sustainable social development as promoting a shift towards concentric spatial systems and away from diametric spatial systems

Diametric spaces of opposition, closure, and fragmentation are less sustainable socially than more concentric spaces of assumed connection and relative openness. This emerging spatial turn to promote a shift from diametric spatial systems to concentric relational system spaces is gaining notable momentum in education, as part of a focus also on local community outreach spaces. The European Commission's Education and Training Expert Panel Paper 2019 [12] calls for a spatial reconfiguration away from diametric spaces in education and towards concentric spaces, as does a focus on social and emotional education as relational spaces in another paper published in 2021 by the EU Commission [12]. The question arises regarding the expansion of concentric spatial systems for more domains to promote sustainable social systems as part of a concentric spatial turn.

More fluid, relatively open, and flexible concentric spatial systems are required for sustainable social development than the desiccated rigid boundaries of closed diametric oppositional spatial systems. The European Commission's Education and Training Expert Panel 2019 recognises the importance of "creating concentric spaces,

which will bring people together, can create feelings of social and emotional belonging” [12].

Concentric and diametric spatial structures invite application to relations between self and other [13], thereby entwining the spatial and relational, as with the Japanese concept of *ma* [3]. Diametric opposition as a relational space of assumed separation can pertain to the domain of interpersonal relations. For example, diametric space emerged in Conquergood’s three-year ethnographic portrayal of how male teenage street gangs in Chicago divide into diametric structured opposition, even though there is no tangible reason for the content of these oppositions such as ethnic, socio-economic, racial, or regional differences. Observing that ‘there are hundreds of gangs in Chicago, but all of them align with one of two nations: people or folks’ [14], Conquergood emphasises that ‘the division between the two nations, people and folks, is absolutely arbitrary and constructed’ [14].

Bronfenbrenner’s [15] hugely influential social-ecological systems framework in psychology and education conceptualises in concentric spatial terms of nested systems containing the individual. These nested systems include the individual’s microsystem environment in which the person directly participates, as well as relations between wider social systems. It is notable, however, that Bronfenbrenner completely overlooked the contrasts between diametric and concentric structured systems identified crossculturally by Levi-Strauss’ earlier structural anthropology. An implication of this neglect in Bronfenbrenner’s ecological systems model is that the system interplay between connective concentric systems and more split, blocked, and fragmented diametric oppositional spatial systems was left unaddressed [2].

A spatial turn to develop sustainable inclusive systems for migrants in education internationally [16] has highlighted the need for a shift towards promoting concentric spatial system features of assumed connection for migrants to include spaces of social and emotional connection such as clubs, sports and social events for migrant youths to address loneliness and promote stronger social bonds; this promotes local community spaces for dialogue, including community based assertive outreach and lifelong learning centres; these sustainable concentric spaces of belonging are also sought in education through warm, supportive school climates and to challenge diametric oppositional spaces of not belonging, including bullying and authoritarian fear and anger based teaching in classrooms. This focus on inclusive systems for migrants in spatial terms also challenges the diametric structured oppositional spaces of social class discrimination and linguistic hierarchy importing a within-school segregation along language as a medium of instruction lines [16]. The antithesis of inclusive systems is the diametric space of school segregation based on race, ethnicity, or social class; diametric spatial processes of excluding students from school through school suspensions and expulsions and fractured relational spaces from the violence of school bullying must also be addressed to change relational spaces [2].

There is a need to reconstruct diametric mirror image above/below hierarchies in school systems to promote students’ voices and marginalised parents’ engagement [2]. A further system shift towards concentric spaces of assumed connection rather than diametric systems of assumed separation includes the expansion of multidisciplinary team wrap-around services for schools as part of a systems of care approach bridging health and education. This combats diametric spatial split systems of fragmentation

where services are in silos side-by-side in parallel distance of assumed separation from each other [2].

A concentric spatial relation between nature and culture places nature more central to the spaces of schools, such as with school gardens, so that access to nature is treated as an equity issue pertinent to sustainable social systems [17]. Treating school as the repository of culture, in opposition to nature, is a residue of a Roman colonialist legacy splitting nature and culture in diametric oppositional spatial terms. This is no longer a sustainable social environment for schools.

These examples of an ongoing shift in education and community systems towards promoting concentric relational spaces of assumed connection and relative openness and to challenge diametric oppositional spaces of splitting, closure, hierarchy, and us/them divisions offer a key lens for a spatial turn in the future development of sustainable social systems. Space matters, and relational space is a malleable system condition affecting causal trajectories and social meanings.

4. Developing a focus on challenge to diametric oppositional spaces in local communities to promote concentric relational spaces of assumed connection

Without strong empirical studies in psychology and education, a focus on relational spaces to facilitate local community outreach is an emerging one from a bullying and violence prevention perspective [18]. Bullying is a fracturing of concentric relational spaces of assumed connection [19]. Similarly, prejudice and discrimination embed diametric oppositional spaces in communities divided into us versus them, spaces requiring challenge in a shift towards concentric relational and physical spaces in local communities.

Research on prejudice highlights that building bridges between different social class, ethnic, or religious groups needs more than just opportunities for contact but also requires that this contact be structured around shared cooperative tasks [20]. This insight needs development as part of a community outreach approach to bridge-building between different groups. Intergroup structured cooperative activities to overcome prejudice [21] need to be wider than a community approach as awareness through social marketing approaches [18,22]. Relevant questions here include: Are there high levels of community services (such as sports, arts, community centers, libraries) as mediating spaces where intergroup cooperation takes place in a structured way for the relevant age group? A background system focus already takes place to some degree in the socio-ecological approach of Swearer et al. [23], with a focus on community profiles of school attendance in the district, crime, etc. Poverty, mobility, crime, singleparent families, and racial diversity have all been measured and linked to youth outcomes, while US census data has been used on the community profile, as well as area school attendance data and crime statistics [24]. However, this lens interrogating background systems supporting and hindering conditions is still underdeveloped in psychology and education [2].

The potential utility of smaller units of community analysis has been acknowledged [24]. In a Canadian context, a community outreach programme to situate social and emotional learning in diverse community contexts such as girl guides,

etc. has been initiated [25]. An exploratory study in a community context involved 30 children, aged between 7 and 12, in Paris [26] that sought to develop community education mediating spaces of assumed connection, tantamount to concentric spatial systems. The intervention took place over 7 months in 3 social centres in Paris. These socio-educational centres were also attended by a large number of children from Muslim populations. The intervention focused on corporeal activities, routine, space to talk, thinking, and group work. The activities were bodily focused, meaning that movement was always a big part of the proposed games. Some relaxing activities were also included. Though not conducted with a control group, this exploratory study found gains regarding improvement on behavioural problems, emotional symptoms, and pro-social behaviour, as well as psychomotor skills. Though gains on these dimensions were found, the children did not all present as aggressive or related to bullying. There were children that showed some anxiety symptoms and that were not aggressive at all. It was a community intervention in the sense that it was developed in a social centre. However, neither schools nor families were engaged [26].

In a small-scale Irish study [27] in a rural community context, the Iorras Le Cheile Community Development Project developed a broad strategic plan to help prevent bullying in the entire Erris community. The sample involved 95 primary school students and 207 post-primary students. There was an attempt to include the whole Erris community in all aspects of the initiative's planning and implementation, via the work of a local steering committee (involving members from youth and community development groups, the police, the Gaelic Athletic Association and soccer clubs, teachers, and Board of Management members from local primary and post-primary schools, psychotherapists, and parents), and the ongoing work of the Community Development Project. A basic relational space of assumed connection at local community level was promoted, a concentric space to challenge diametric spatial oppositions and splits as system fragmentations. It was found that, following the implementation of the programme, there were reductions in frequencies of reports of having been involved in all categories of bully/victim problems amongst primary school students. Amongst post-primary students, there were reductions in frequencies of reports in two categories of bully/victim problems [27].

These studies offer initial examples of a research focus in education and psychology. On local community spaces for development to challenge diametric oppositional, exclusionary spaces of bullying, violence, and prejudice as part of a wider inclusion agenda for promoting sustainable systems. This is an area ripe for further development for research on developing sustainable inclusive systems in education and community psychology contexts. Space requires understanding as being itself a system, a system framing and impacting relations within and between systems, such as in schools and communities.

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References

1. Massey D. *For Space*. Sage Publications; 2005. doi: 10.1177/0309132507077092
2. Downes P. *Reconstructing Agency in Developmental and Educational Psychology: Inclusive Systems as Concentric Space*, 1st ed. Routledge; 2019. doi: 10.4324/9781315101088

3. Morioka M. Commentary: Constructing Creative Appropriations. *Culture & Psychology*. 2007; 13(2): 189-196. doi: 10.1177/1354067x07076606
4. Downes P, Anderson J, Nairz-Wirth E. Conclusion: Developing conceptual understandings of transitions and policy implications. *European Journal of Education*. 2018; 53(4): 541-556. doi: 10.1111/ejed.12305
5. Vendra MC, Furia P. Introduction – Ricœur and the Problem of Space. Perspectives on a Ricœurian “Spatial Turn.” *Études Ricoeuriennes/Ricoeur Studies*. 2021; 12(2): 1-7. doi: 10.5195/errs.2021.576
6. Ferrare JJ, Apple MW. Spatializing critical education: progress and cautions. *Critical Studies in Education*. 2010; 51(2): 209-221. doi: 10.1080/17508481003731075
7. Descartes R. *Descartes: Philosophical Writings*. Nelson; 1954.
8. Descola P. *Beyond Nature and Culture* Chicago and London: University of Chicago Press; 2005.
9. Teo T. From Speculation to Epistemological Violence in Psychology. *Theory & Psychology*. 2008; 18(1): 47-67. doi: 10.1177/0959354307086922
10. Lévi-Strauss C. *Structural Anthropology: Vol. 1*. Allen Lane; 1963. pp. 385-398.
11. Levi-Strauss C. *Structural Anthropology (Volume II)*. Basic Books; 1976. doi: 10.2307/3032172
12. European Commission. European Education and Training Expert Panel. Available online: https://www.dcu.ie/sites/default/files/edc/pdf/european_union_postet2020_expert_panel_inclusion_and_citizenship_issue_per.pdf (accessed on 2 April 2024).
13. Cefai C, Downes P, Cavioni V. A Formative, Inclusive, Whole School Approach to the Assessment of Social and Emotional Education in the EU. Publications Office of the European Union; 2021.
14. Conquergood D. For the nation: How street gangs problematize patriotism. In: Simons HW, Billig M (editors). *After Postmodernism: Reconstructing Ideology Critique*. Sage Publications; 1994. pp. 200-221.
15. Bronfenbrenner U. *The Ecology of Human Development: Experiments by Nature and Design*. Harvard University Press; 1979. doi: 10.4159/9780674028845
16. Downes P, Anderson J, Behtoui A, et al. *Promoting Inclusive Systems for Migrants in Education*. Routledge; 2024. doi: 10.4324/9781003263999
17. Downes P, Li G, Van Praag L, Lamb S. *The Routledge International Handbook of Equity and Inclusion in Education*. Routledge; 2024.
18. Downes P, Cefai C. Strategic Clarity on Different Prevention Levels of School Bullying and Violence: Rethinking Peer Defenders and Selected Prevention. *Journal of School Violence*. 2019; 18(4): 510-521. doi: 10.1080/15388220.2019.1566915
19. Downes P. Prevention of Bullying at a Systemic Level in Schools: Movement from Cognitive and Spatial Narratives of Diametric Opposition to Concentric Relation. In: Jimerson SR, Swearer SM, Espelage DL (editors). *Handbook of Bullying in Schools: An International Perspective*. Routledge; 2009. pp. 517-533.
20. Amir Y. The Role of Intergroup Contact in Change of Prejudice and Ethnic Relations. In: Katz PA (editor). *Towards the Elimination of Racism*. Pergamon Press; 1976. pp. 245-308. doi: 10.1016/b978-0-08-018316-9.50016-3
21. Brown, R. Social identity theory: Past achievements, current problems and future challenges. *European Journal of Social Psychology* 16 November 2000; 30(6): 745-778. doi: 10.1002/1099-0992(200011/12)30:6<745::AID-EJSP24>3.0.CO;2-O
22. Bradshaw CP. Preventing Bullying through Positive Behavioral Interventions and Supports (PBIS): A Multitiered Approach to Prevention and Integration. *Theory Into Practice*. 2013; 52(4): 288-295. doi: 10.1080/00405841.2013.829732
23. Swearer SM, Espelage DL, Vaillancourt T, et al. What Can Be Done About School Bullying? *Educational Researcher*. 2010; 39(1): 38-47. doi: 10.3102/0013189x09357622
24. Swearer SM, Peugh J, Espelage DL, et al. A socioecological model for bullying prevention and intervention in early adolescence: An exploratory examination. In: Jimerson SR, Furlong M (editors). *Handbook of School Violence and School Safety: From Research to Practice*. Lawrence Erlbaum Associates Publishers; 2006. pp. 257-273.
25. Hughes J, Rahbari N. SEAK Canada: An Exploration of the Effects of PATHS on Health Service Use, Conference presentation. In: *Proceedings of the 5th ENSEC (European Network for Social and Emotional Competence) International Conference*; 1–4 July 2015; Lisbon, Portugal.
26. Fonseca A. Resilience and psychomotricity in children from disadvantaged background, Conference presentation. In: *Proceedings of the 5th ENSEC (European Network for Social and Emotional Competence) International Conference*; 1–4 July 2015; Lisbon, Portugal.

27. Minton SJ, O' Mahoney M, Conway-Walsh R. A 'whole-school/community development' approach to preventing and countering bullying: the Erris Anti-Bullying Initiative (2009–2011). *Irish Educational Studies*. 2013; 32(2): 233-249. doi: 10.1080/03323315.2013.784637

Review

Troubled waters? The disproportionate impact of lead water pollution: Evidence from three American communities

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Abstract: Although water is considered essential to life and an important natural resource, disadvantaged communities, such as low-income and minority communities, are disproportionately burdened by lead exposure in drinking water. In this paper, we highlight case studies that have received national press coverage as well as recent examples of community lead poisoning hazards that are still ongoing across various regions of the US. We show through these three case studies of Flint, Michigan, Washington, D.C., and Birmingham, Alabama, that the severity and frequency of this pervasive public health problem are highly concentrated in minority and low-income populations, and thus they bear the brunt of the socio-economic impacts. We identify the use of sensors to improve detection of hazardous materials and decrease inequities in drinking water contamination. To address water-related equity issues, we call for a sustainable community capacity approach that consists of shared governance between those who live in a community and stakeholders, such as businesses and health services, who have vested interests in it. We conclude by highlighting ways that a community could build collective social capital, safeguarding its environment from lead poisoning through health literacy education. Promoting water literacy is highly significant since water knowledge is crucial towards achieving water sustainability and equity.

Keywords: lead poisoning; water quality; environmental justice; community engagement; community building capacity; water sustainability; environmental hazards; health literacy

1. Introduction

Lead, historically, has been one of the most versatile and useful metals across the globe. Lead decorative items predate civilization itself. Lead has also been used in water distribution systems since ancient times. Even though lead's toxicity has been known for decades, lead-bearing units are still common in drinking water distribution systems worldwide. Any distribution system with elements installed before 1941 will likely have at least lead service lines [1].

Lead contaminates the environment via fossil fuel burning, mining, agriculture, and manufacturing. It is also used in lead-acid batteries, solder, metal pipes, and electronic devices. Furthermore, 16.4 million US homes (~25%) have a substantial amount of lead-based paint [2]. Ingestion of lead paint chips and dust is the largest source of lead poisoning in children. Additionally, the aging US water infrastructure releases lead into tap water, which has reached hazardous levels in many cities, such

as Flint, MI [3]. Adults absorb 35% to 50% of this heavy metal through drinking water, and in children, absorption may exceed 50% [4]. Ingested lead is highest in the kidney, followed by the liver, heart, and brain [5,6]. Notably, the nervous system is the most susceptible to lead poisoning. Moreover, according to the US Environmental Protection Agency (EPA), there is no known “safe” level of lead for children [4]. The wide-ranging effects of lead toxicity create significant societal burdens, especially in communities that are ill-equipped to provide services to people who are adversely affected [7].

Adverse health effects identified with lead contamination [8,9] include increased blood pressure and other cardiovascular effects, decreased kidney function, and anemia in adults. Furthermore, lead accumulation in bones can accelerate osteoporosis [10]. For men, elevated lead levels can reduce sperm count. For pregnant women, lead exposure can result in reduced growth of the fetus and increased chances of miscarriage and premature birth [8,9]. Chronic effects of lead in children include decreased, delayed, or impaired neurobehavioral development, a decrease in intelligence quotient, speech and language deficits, anti-social behaviors, and a poor attention span [7,11].

The World Health Organization estimates that nearly one million people die every year due to lead poisoning [12], with millions more (many who are children) exposed to low levels of lead causing life-long health problems. Populations at higher risk for lead contamination include children, immigrant and refugee children, pregnant women, and people who work in lead-related industries [13].

The Safe Drinking Water Act (SDWA) was passed by the United States (US) Congress in 1974, with amendments added in 1986 and 1996, to protect our drinking water. Under the SDWA, the EPA sets the standards for drinking water quality and monitors states, local authorities, and water suppliers who enforce those standards [14]. In 1986, Section 1417 of the federal SDWA was amended to limit the content of lead in pipes and other materials used in water supplies, defining “lead-free” as being less than 8% lead in pipes and fixtures and less than 0.2% in solder.

In 1991, the US Environmental Protection Agency (EPA) established the Lead and Copper Rule (LCR) to “protect public health and reduce exposure to lead in drinking water”. Revisions to the LCR took place in 2000, 2004, 2007, and 2021. The Maximum Contaminant Level Goal is zero due to there being no level of exposure to lead that is without risk. The treatment technique for the rule requires systems to monitor drinking water at customer taps; action levels occur if the lead concentration exceeds 15 parts per billion (ppb). Since its implementation, lead level exceedances have decreased by over 90% [15], see above.

Primary sources of lead in drinking water include copper pipe with lead solder, lead water service lines, faucets, galvanized pipe, and lead goosenecks [16]. The release of lead into water systems is affected [17] by the acidity or alkalinity of the water, the types and amounts of minerals in the water, the amount of lead that the water comes into contact with, the water temperature, the amount of wear in the pipes, how long water stays in pipes, and the presence of protective scales or coatings in the pipes.

The EPA has estimated that there are at least 6 to 10 million lead service lines, and a 2021 Natural Resources Defense Council (NRDC) survey found that this number

could be 12 million or more. The practice of using lead-based solders was not abandoned until 1986 [1]. Any brass fixture with less than 8% brass was considered to be “lead free” under federal government regulation before 2014. So, any brass plumbing fixtures in the US can contain up to 8% lead. Although lead is ubiquitous in most US water systems, it remains dormant in stable systems. Whenever a utility changes or adjusts its source water, changes its finished water chemistry, or employs different treatment or distribution strategies, the lead in pipe scales can be disturbed, resulting in high lead residuals in a community’s water. Without careful testing and sampling, disasters can happen. One such disaster played out in Flint, Michigan, from 2014 to present. Flint, MI, made headlines in 2016 when it was revealed that blood levels in children had nearly doubled since the city started pumping in drinking water from a new source without properly treating it [18]. The inadequate treatment and testing of the water resulted in a number of water quality and health issues. Citizens complained of foul-smelling, discolored, and off-tasting water for more than 18 months. Even as late as 2020, Flint, MI, does not have safe drinking water [19].

2. Case studies

We examine three case histories of lead contamination in water sources: Flint, MI; Washington, D.C.; and Birmingham, AL. High lead levels have been found in tap water in other US metropolitan areas, including Baltimore, MD; Detroit, MI; Milwaukee, WI; New York, NY; Pittsburgh, PA; Chicago, IL; Washington D.C. [18], Durham, NC; Greenville, NC; and Lakeland Acres, ME [20,21]. A map indicating the extent of lead contamination in water is shown in **Figure 1**, while **Figure 2** shows the number of lead service lines in each of the states in the US. Approximately 20% of US water systems have tested above the 15-ppb action level [22]. NRDC reports that 56% of the US population drinks from water systems with detectable levels of lead. The extent of lead contamination is not confined to major cities; NRDC reports that lead service lines are likely in use in every US state; many states and utilities do not know where their lead service lines are located [18]. In fact, the US Government Accountability Office [23] reports that less than 20 of the largest water systems have data publicly available related to their lead in drinking water.

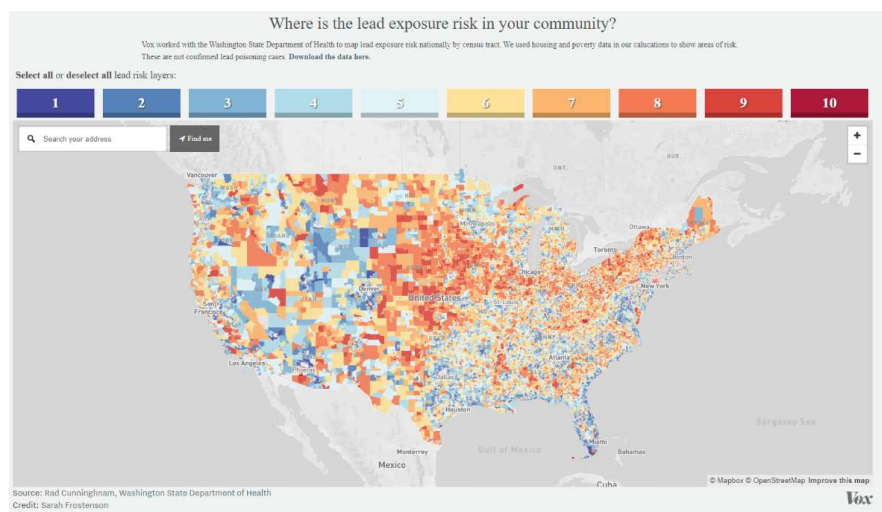


Figure 1. Map showing US lead exposure risk [24].

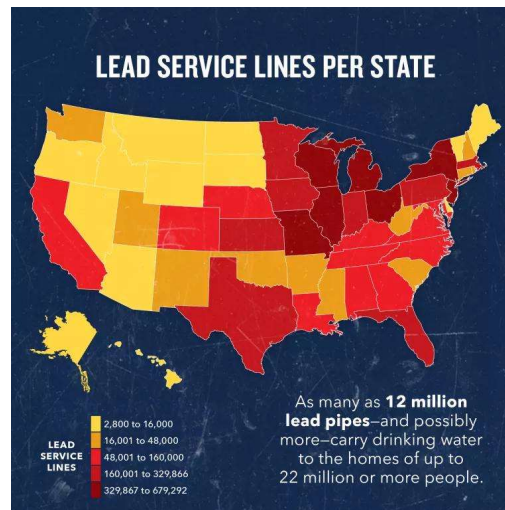


Figure 2. Lead service lines per state in the US [18].

2.1. Incident in Flint, Michigan

The Flint disaster represented a failure on all government levels, resulting in tragic implications for thousands of predominately poor, mostly minority residents in Flint, Michigan. A city manager was appointed in late 2011 by the State of Michigan in an attempt to reduce costs of city operations. One of the areas targeted for cost reduction was drinking water. The Flint city manager suspended the purchase of Detroit city water and approved the use of water from the Flint River [25]. An aqueduct to Lake Huron was still under construction and was not an option. On 25 April 2014, Flint River water was introduced into the city distribution system. Within days, the first customer water quality complaints were lodged [26].

When Flint, Michigan, switched to the Flint River as a temporary drinking water source, it did so without implementing corrosion control. Ten months later, lead concentrations in collected water samples progressively increased (104, 397, and 707 mg/L). This coincided with increasing water discoloration. All samples collected had lead concentrations exceeding the 15-ppb action level, and several samples had lead concentrations exceeding 5000 ppb. The US EPA has estimated that the blood lead level in a child will increase 1 mg/dL for every 5 mg/L lead increase in water [27]. The lead concentration (90th percentile) was 31.7 ± 4.3 mg/L [25].

By August 2014, boil orders were issued to Flint residents. Notably, boiling water has no effect on lead levels. Olson et al. [28] observed that the pipe scale was relatively depleted of lead compared to the scale from 26 public utilities. The stripping of scales by the relatively more corrosive Flint River water resulted in high bacterial counts. *E. coli* counts increased and Legionnaire's disease cases were recorded. Additional chlorine was added, resulting in increases of disinfection by-products (DBP's), a known carcinogen. A high DBP warning was issued in January 2015.

By 1 October 2014, General Motors suspended use of Flint City water due to its corrosiveness. On 9 January 2015, the University of Michigan at Flint discovered lead concentrations in Flint's drinking water above allowable federal levels. By 9 September 2015, high lead levels were discovered in the blood of Flint residents. Later that month, a lead advisory was issued. On 1 October 2015, a public emergency was declared. The following day, the governor of Michigan, Rick Snyder, blamed the high

lead levels on household plumbing, despite overwhelming contrary evidence. Later in October, Flint reconnected to Detroit water. Despite this, another state of emergency was declared on 14 December 2015. The National Guard was activated on 12 January 2016 to distribute bottled water to Flint residents. Well into 2017, Flint residents were still without safe drinking water from their water taps [26].

The raw water from the Flint River was considerably more corrosive than the Detroit city water. This is possibly due to the high concentration of chlorides used in road salts. However, the Flint River water might have been usable if the corrosion inhibitor applied in previous treatments had not been suspended. It is unknown if the suspension of the corrosion inhibitor was intended as a cost-saving maneuver. The City of Flint and the Michigan Department of Environmental Quality (DEQ) did not address the suspension of corrosion inhibitors until two months after the switch to Flint water. Over a year and a half after the switch to Flint River water, the DEQ acknowledged that it misinterpreted a rule on water treatment. The DEQ admitted in an e-mail that they should have required the city to implement corrosion control during the switch and afterward. It has been speculated that if the corrosion inhibitors were applied, the Flint disaster would have never happened [29]. Regardless, no pilot testing was performed before a major change was implemented in the Flint water treatment and distribution system. This is a dangerous practice regardless of the activity. For Flint, hundreds of millions of dollars in permanent damage was done to the distribution system, likely because a few hundred dollars worth of chemical additives was eliminated. The distribution pipe corrosion is permanent, and the damage will likely result in a complete rehabilitation and replacement of the drinking water distribution system. However, the cost to human health and dignity may never be fully realized [26].

Phosphate-based corrosion inhibitors

For decades, hexametaphosphates were the primary phosphate-based corrosion inhibitors used in water distribution systems. The effectiveness of hexametaphosphates was largely determined by their ability to reduce “red water” (iron staining and discoloration) complaints. However, hexametaphosphates likely increase the release of both particulate and soluble lead [30,31]. Phosphate corrosion inhibitors arrest metal corrosion in two ways; by sequestration and passivation. Sequestration is the prevention of metallic ion precipitation by forming a compound that remains dissolved in water. Since the compound remains in solution, no discoloration from precipitation occurs. Passivation is the formation of an inorganic film, which essentially coats the inner surface of a metal component, much like paint applied for surface protection [32,33]. Sequestration is a problematic strategy with dissolved metals that are toxic at relatively low concentrations. This is why hexametaphosphates should never be used to prevent lead corrosion.

Three commonly used phosphate-based inhibitors are polyphosphate, polyphosphate blends (blends), and orthophosphate. Hexametaphosphates are the active ingredient in polyphosphates. Phosphoric acid is the active ingredient in orthophosphate. Blends are made of a mixture of polyphosphates and orthophosphates and have the advantage of the passivation chemistry of orthophosphate and the sequestration properties of polyphosphates. Blends are generally described as a

percentage of polyphosphate versus orthophosphate [32]. Several studies have suggested that polyphosphates and polyphosphate blends should never be used to prevent lead corrosion. In fact, polyphosphates and blends may actually cause increased lead residuals [31,34–38].

The crisis in Flint, Michigan, killed 12 people, according to data from the Michigan Department of Health and Human Services [39]. Five officials, including the head of the state's health department, were charged with involuntary manslaughter on 14 June 2017.

2.2. Washington, D.C.

More than a decade before the Flint, MI, case, a lead contamination crisis occurred in Washington, D.C. Over 157 households had lead levels exceeding 300 ppb, with thousands exceeding the 15-ppb action level. In 2001, the Washington Aqueduct and the District of Columbia Water and Sewer Authority switched from chlorine to chloramines as the disinfectant for their water system. The change was made to minimize the formation of DBPs [22]. Replacing free chlorine with chloramines changes the chemistry by raising the pH and lowering the water's oxidizing potential. Increased lead content in water may have been caused by increased corrosion related to the introduction of chloramines. Two-thirds of the households tested (4075 homes) in summer 2003 had lead levels exceeding the 15-ppb action level [40].

In the past, lead oxide (PbO_2) scales formed due to the high oxidizing potential of their water. As long as the water remains highly oxidizing, the lead oxide scales are stable and insoluble. With the shift to chloramines, the water's oxidizing potential decreased, which meant that the water could dissolve the PbO_2 scale, thereby raising the water's lead concentration. Renner indicated that the change in water chemistry and old lead pipes was the source of the crisis. Furthermore, chloramines may be prone to mobilizing lead from brass [21]. Additionally, insufficient monitoring to address the LCR, gaps in controlling corrosion and leaching of lead, and poorly designed lead sampling and testing programs exacerbated the problem [21,41]. Washington, D.C., is still working to fix this problem [18].

To reduce the exposure to lead, the Washington Aqueduct used source and treated water containing very low lead levels. Brown et al. [42] observed that when chloramine alone was used to disinfect the water in Washington, D.C., the risk for blood lead levels was greater than when chlorine or chloramine with orthophosphates were used. Changes in water disinfection can enhance the effect of blood lead levels. Washington, D.C., now utilizes corrosion control treatment (maintaining constant pH and addition of orthophosphate), monitors the source and treated waters, and reports results to the EPA [43].

Figure 3 shows the effect of implementing orthophosphate treatment to control corrosion in Washington, D.C. In January 2015, the District of Columbia reported that 90% of the water samples had lead levels of 4 ppb or less [43]. Independent testing at six Washington, D.C., public schools in 2008 indicated that problems with elevated lead persisted at 2% to 41% of taps in each school [44]. The highest lead concentration detected in the public schools was 1987 mg/L, significantly higher than the 15-ppb action level.

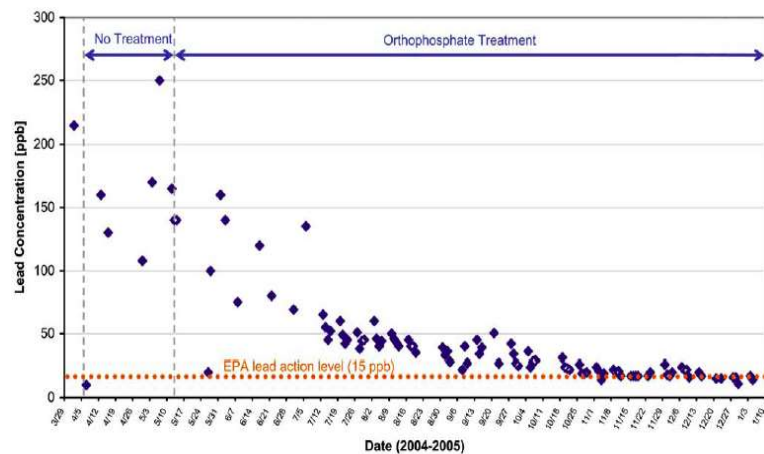


Figure 3. Lead concentration in water decreased markedly after implementing orthophosphate treatment to control corrosion in Washington, D.C. [43].

Incidence in elevated blood levels exceeding 10 mg/dL in Washington, D.C., for children less than 1.3 years old increased more than fourfold for 2001–2003, when lead in their water was high, versus in 2000, when lead levels in the water were low [45]. Guidotti et al. [46] reported that of 2342 children aged 6 months to 6 years in age, 65 had blood lead levels exceeding 10 mg/dL, and the highest blood level was 68 mg/dL. Additionally, two nursing mothers had blood lead levels exceeding 10 mg/dL.

2.3. Birmingham Water Works Board (BWVB) pilot study

One particularly dramatic illustration of the ineffectiveness of polyphosphate blends in preventing lead corrosion was discovered during a pilot study by the Birmingham Water Works Board in Birmingham, Alabama (BWVB). In an attempt to determine if a switch from chlorine to chloramines would have detrimental effects on the distribution system, a pilot study was conducted using elements harvested from the BWVB distribution system and brass hardware. A flow-through system was constructed equipped with cast iron, brass, and lead piping and fixtures. The apparatus was designed to mimic a distribution system with twelve-hour flow (approximately 3000 gallons) and twelve hours of stagnation (zero flow condition, **Figure 4**). Finished water and phosphate-based corrosion inhibitors were introduced to the pipe rack. Weekly samples were collected from the brass fixtures, cast iron, and lead pipes and analyzed for total and dissolved lead [38]. The brass hardware in this study was produced before 2014. Until 2014, brass fixtures were legally sold with up to 8% lead content. None of the effluent reached the distribution system and was discharged to wastewater.



Figure 4. BWVB flow through system [38].

The pipe rack was divided into five sections, each consisting of one ten-foot unlined cast iron pipe (two-inch inner diameter), three 2.5-foot pipes of lead service line (one-inch inner diameter), and an assembly of brass fixtures. The cast iron pipes were designated Cast Iron 1-5 from the top of the rack to the bottom. The lead pipes were labeled Lead 1-1, Lead 1-2, Lead 1-3, Lead 2-1, ... Lead 5-3. The brass fixture assemblies were labeled Brass 1-5 (**Figure 5**). Each section was tapped with sampling valves. Additional valves separated the pipes during sampling. Valves were installed between each pipe section for pressure release during sampling. The flow-through design was intended to give the best possible approximation of settings and materials found in the BWB distribution system [47].

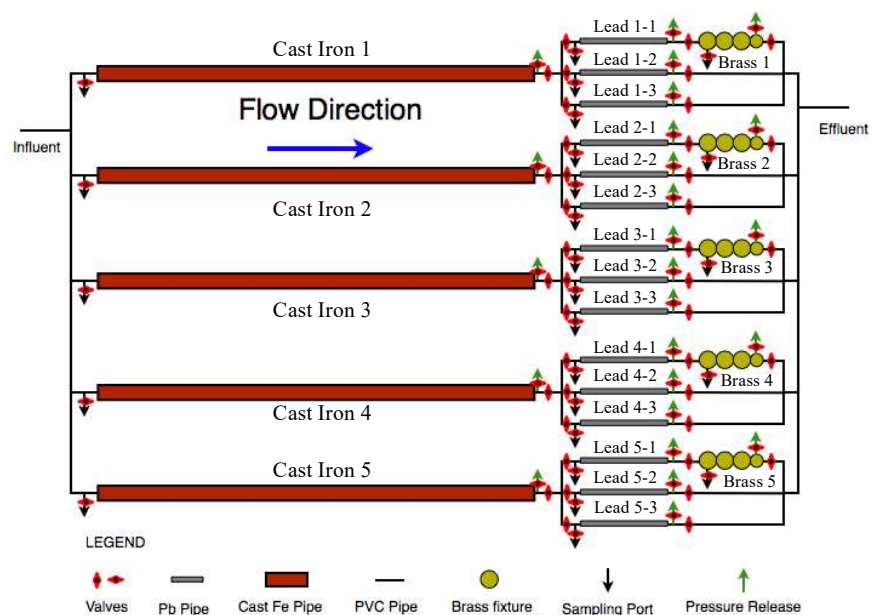


Figure 5. H. Y. Carson Filter Plant (CFP) pipe rack schematic [48].

Findings of the BWB study

The management at the BWB was aware of the 2004 incident that occurred in Washington, D.C., where high levels of lead were discovered in city drinking water. The suspected cause was the change in primary disinfectant from chlorine to chloramines. To avoid this, the BWB selected a corrosion inhibitor recommended by a consultant. The corrosion inhibitor was marketed for its professed ability to “reduce lead corrosion”. The chemical selected was a polyphosphate blend of 70% polyphosphate and 30% orthophosphate (70/30). Pure orthophosphate was rejected due to a reputation (largely contradicted in peer-reviewed literature) for exacerbating “red-water”. The 70/30 was introduced to chlorinated water entering the flow-through at 4 parts per million (ppm) after six months without any corrosion inhibitor in chlorinated water [47].

Within two weeks, total lead concentrations in samples collected significantly increased. After the concentration of 70/30 was doubled, lead concentrations spiked 1500% in samples collected from the lead pipes. Lead concentrations exceeding 6000 ppb following the introduction of polyphosphate blends were obtained [47]. All cast iron pipes and brass fixtures showed concentration levels significantly higher than the

maximum allowable limit of 15 ppb. The lead concentrations in Section 4 of the flow-through, which consistently showed higher turbidity, were even greater. The 70/30 was replaced with a 30/70 blend, increasing the concentration of orthophosphate by 40% relative to the polyphosphates. There was no measurable reduction in lead residuals as lead concentrations continued to reach over 10 ppm in the lead pipes (even greater in the high turbidity Section 4). The BWWB replaced the blends with orthophosphate, and within weeks the lead concentrations in all sections and materials stabilized to concentrations below original levels. After chloramines were introduced, lead residuals continued to decrease in all sections and all arterials. By the end of the study, all sample lead concentration levels were consistently below 15 ppb [47].

Other cities in Alabama, such as Leeds, Alabama, have reported blood levels of lead in the range of 10.86 ± 4.14 mcg/dL [49]. In addition, Casey Toner [50] reported that there were more than 24,000 cases of young children from 595 Alabama zip codes with lead in their blood. This information was submitted to the Alabama Department of Public Health from 2010 to 2014. Furthermore, the counties of Choctaw, Sumter, Mobile, Monroe, Morgan, Limestone, and Montgomery reported the highest number of children under five years of age who were diagnosed with lead health issues. Notably, Cabrera [51] points out that no amount of lead exposure is safe.

2.4. Techniques to reduce exposure to lead in drinking water

The Pennsylvania Department of Environmental Protection [25] has identified several techniques to reduce lead exposure:

- Run water to flush out lead;
- Use cold water for cooking and preparing baby formula;
- Do not boil water to remove lead (lead concentrations in water will increase with increases in temperature);
- Test the water for lead;
- Identify if the plumbing fixtures contain lead.

3. Socio-economic impact of environmental hazards

A body of literature on the social, health, and economic impact of environmental hazards on individuals and communities has been established. There has been a recognition of social disparities associated with the impacts of environmental toxins, with race and class as greater predictors of exposure to toxins. A fact sheet from the Environmental Defense Fund notes that children and racial minorities bear a disproportionate burden of lead exposure because of poverty and substandard housing [52]. The impact of contaminated drinking water, particularly the presence of lead, has been highlighted in the literature. However, the magnitude and extent of this entered the public discourse with the Flint water crisis, which attracted a great deal of attention. The contamination of residential water supply in Flint, Michigan, violated the right to clean water [53].

The incident in Flint exposed how significantly the lead crisis disproportionately impacts marginalized communities (mostly racial minorities and low-income neighborhoods). Empirical researchers such as Hannah-Attisha et al. [54] estimated that the change in the water source in the Greater Flint area caused an increase in the

incidence of elevated blood levels from 2.4% to 4.9% ($p < 0.05$) in children. They also conducted a spatial analysis, which revealed that children in low-income communities experienced the greatest increase in blood lead levels. The 2018 NRDC report [52] reveals that about 45% of the Flint population lived below the poverty line with majority black populations. The report further documents that the Michigan Civil Rights Commission established that the poor response from the state government was a “result of systemic racism”. Children are at a particular disadvantage when it comes to lead pollution because it leads to health, behavioral, and social impairments [55]. Hanna-Attisha et al. [54], who studied blood lead levels in children, concluded that the percentage of children with elevated blood lead levels increased after water source changes, particularly in socioeconomically disadvantaged neighborhoods. They also noted that water is a growing source of childhood lead exposure due to an aging water supply infrastructure.

Researchers, including Schaider et al. [56], have revealed that low-income and minority communities are impacted disproportionately by high pollutant exposures. The extent to which residential segregation is linked with lead exposure has further been investigated by Murray [57]. The study discovered that neighborhoods with higher proportions of Black and Hispanic residents were associated with an increased percentage of elevated blood lead levels. Marshall et al. [58] corroborated these findings in a research article that utilized the Adolescent Brain Cognitive Development study. This is a US-based, large-scale study of brain development and child health funded by the National Institutes of Health. Their research on a sample of 9712 children between the ages of 9 and 10 showed that children from lower-income neighborhoods have a higher risk of lead exposure. They also found that these children suffer more from distortions in their brain development, as evidenced by their lower cognitive test scores, smaller cortical volumes, and smaller cortical surface area. Although access to drinking water is a universal human right, there are several challenges surrounding drinking water systems in the US. They include aging infrastructure and polluted source water [59]. Nonetheless, the burdens are not equally distributed [60]. Despite the link between socio-demographic characteristics and water contamination, particularly drinking water quality, there is less attention paid to drinking water systems and more research directed at agricultural water use or environmental water quality of rivers, streams, and aquifers [61].

The active and growing literature on disparities in drinking water violations and compliance reflects the extent of these inequities. Research has identified types of communities disproportionately burdened by water contaminants. An analysis of community water systems in the U.S. from 2011 to 2015 reveals that counties with a disproportionate percentage of minorities had a higher percentage of drinking water violations [62]. Switzer and Teodoro [63] capture this trend by showing that racial/ethnic and income composition of populations predict drinking water quality and are therefore more likely to violate the Safe Drinking Water Act (SDWA) compliance. The findings particularly highlight the fact that there is a strong prediction that there will be SDWA violations for Black and Hispanic populations. Research across the Southeastern region of the United States maintains that minority and low-income communities have poor ambient water quality [64]. Bae and Lynch’s analyses of safe drinking water violations from 2016–2018 conclude that socio-economic

factors impact the distribution of SDWA violations in the US [59]. Their research notes that concentrated poverty negatively impacts access to safe drinking water and that racial minorities, as well as low-income populations, are disproportionately exposed to unsafe drinking water and have more safe drinking water violations. Blair's [65] research demonstrates this trend by showing that cities with higher minority populations are three times more likely to have a water standard violation. Addressing disparities associated with water infrastructure has not been equitable as well. A study published by the Environmental Defense Fund [66] and the School of Public Health in Washington, D.C., reveals that Lead Service Line Replacement programs are not equitable and benefit mostly wealthy and advantaged populations. In low-income and black-dominated communities, only 0.1% of residential service lines were voluntarily replaced. The results of the study show significant correlations between median household income and identification of residents as African Americans.

The recognition of these inequalities has expanded the range of scholars interested in studying the impact of environmental contaminants on humans. The environmental justice/racism movement has been crucial in highlighting inequities in terms of the impact of environmental hazards. Balazs [61,67] however argue that there is a paucity of information about inequities in drinking water contamination in the environmental justice literature, as opposed to the plethora of studies about the extent and causes of the disproportionate burden of environmental hazards.

3.1. Community empowerment

One important solution the environmental justice movement has advanced to addressing disproportionate access to clean water is to eschew top-down initiatives that do not influence the growth of community capacity nor long-term sustainability and replace them with bottom-up approaches. The Biden-Harris administration has established the "Get the Lead Out Partnership" as of 27 January 2023 to replace lead water pipes within 10 years. The partners in this campaign include state, city, county, and national water organizations in cities and rural areas, as well as non-governmental organizations [66]. The active engagement of communities and grassroots organizations in addressing environmental issues will ensure community involvement in deciding, planning, and evaluating projects. Involving the community includes engaging all stakeholders, recognizing their expertise, and allowing them to come up with solutions to addressing environmental problems. Williams et al. [68] note the importance of including diverse voices, especially those from underrepresented groups, to effectively engage in water dialogues. One way to prioritize disadvantaged communities impacted by poor water quality is to have community members and stakeholders advocate for the funding of grassroots and local organizations who are actively involved in ensuring water equity but encounter financial barriers to achieving clean water in their communities [69].

3.2. The opportunity cost of environmental crises

Environmental crises have a direct impact on health. Resolving them is, therefore, usually prioritized, and the process often calls for large funding. These funds represent an "opportunity cost" for underprivileged communities. When resources are limited

and choices need to be made, the opportunity cost of a choice represents the best alternative forgone. The funds could potentially be used to significantly improve the lives of the aforementioned low-income communities. However, they are used for the resolution of the crisis.

In the case of the Flint, Michigan, crisis, the total expenditure directed towards the resolution of the crisis was significant. For example: (1) the city received \$100 million through the EPA [70]; (2) the state of Michigan increased its budget by over \$350 million for water quality improvement and pipe replacement, among others [71]; (3) the crisis cost the state \$626 million in settlements [72]. This non-exhaustive list of taxpayer dollars utilized for the resolution of the crisis amounts to over \$1 billion. This represents an important opportunity cost for underprivileged communities, as approximately 40% of the population of Flint, Michigan, lives in poverty [73]. The water crisis had other economic effects. Christensen et al. [74] found evidence that the housing market was greatly affected. They estimated a decrease in the value of the housing stock by \$520 million and determined that home prices remained depressed for 16 months even after the water was declared safe for consumption. Moreover, there is evidence that small businesses in the city were significantly impacted, which prompted the US Small Business Administration to provide an economic relief package [75].

4. Call to action for community empowerment

Exposing to environmental hazards is an ongoing challenge and one that must be actively addressed. The negative health outcomes of lead-contaminated water poisoning, especially in racial and ethnic minority communities [76], received heightened attention after Flint, Michigan, exposed the seriousness of environmental racism [77]. Low-income racial ethnic communities across the US have had the unpleasant experience of confronting the fear of exposure to toxic chemicals in their water supply with no solution in sight [78].

Also, the mounting cognitive and physical health burdens that come with these environmental hazards negatively affect community residents throughout their life span [51]. After the crises in Flint, Michigan, a sustained focus on this particular event and ensuing health risks to community residents became the prime example that spearheaded national attention to the environmental racism and associated health implications that had long been underacknowledged [77].

The national media coverage that followed the water crisis in Flint further legitimized environmental activists claims regarding excessive exposure to lead poisoning in impoverished racial ethnic communities. The Flint water crisis also strengthened alliances between community activists and health policy experts. These partnerships with local community groups and public health practitioners catalyzed bolder and more effective outcomes in confronting EPA legislation that had been in the making for decades. With this greater backing, increased momentum and sustained attention regarding environmental hazards in low-income, black, and brown communities took hold [52,79]. Environmental activists now have more social and political power to intervene and prevent the problems of high exposures of lead contamination in community water supply systems. Although many positive strides

have been made on behalf of disenfranchised communities, there is still much more work to be done in the area of environmental justice, especially as it relates to lead poisoning in racially segregated communities.

Realizing the urgent needs of these communities, health protection agencies at the local, state, and national level are creating more academic space through interdisciplinary partnerships. These partnerships will enable us to better support vulnerable communities and work alongside them in understanding the problem and how to prevent further health problems through culturally tailored interventions that welcome community participation and knowledge of local community health issues that have long been ignored or poorly addressed. Educating community members about technological advances will also improve their health literacy and drive the community's engagement toward greater investment in their health outcomes through the use of interventions such as point-of-use sensor technology that could be used to detect lead-based water contamination.

The problems of lead contamination in water supply systems have been under the radar of environmental protection agencies and public health scientists for over 15 years. Interdisciplinary research scientists at the National Institute of Aging are also raising the alarm about the effects of lead toxicity in water and related exposome risks on brain and physical health [79]. This highlights the importance of research that also addresses environmental exposures linked to cognitive health outcomes across the life span. For example, lead poisoning has been associated with cognitive development problems in young children, resulting in lower school performance and test scores [80] and cognitive impairment in older adults [81]. Hence, there is a pressing need for public health and environmental community health agencies to collaborate together for sustained community action and engagement to prevent unsafe exposures such as these in human population environments, which are disproportionately black and brown [51].

A community's collective social capital is its' resource

Community social capital is a powerful resource in racially segregated communities and is vital to a community's empowerment at combating environmental injustice issues such as lead water contamination and related exposome threats to its' resident's health outcomes [82]. Racial ethnic communities in low-income segregated areas are most often cut off from mainstream sources of power and access to local government authorities, including water municipal companies, business districts, local civic governments, and council leaders with agency, that could provide effective solutions [83]. When a community has nowhere else to turn, its' only hope and ironically the greatest source of collective strength is in the social capital that its' community residents possess. In fact, social capital is a "vital component and characteristic of the community itself" [84], and it is through this type of community empowerment that black and brown low-income residents could actively demand environmental justice around lead-contaminated water problems and ongoing exposomic risks to its health [85].

The collective unity that a community's social capital could bring is needed to build alliances around racial and ethnic local community problems [86], such as lead-

contaminated water and exposome risks that affect human health outcomes [79]. The human health effects of contaminated drinking water and other environmental hazards require that local community agencies also actively participate in its' demand for safe drinking water and removal of toxic dumping sites where residents reside [82]. Community grass roots organizing and partnering public health and environmental sustainability programs are needed to help communities address the cognitive and physical health implications of lead-contaminated water and exposome threats that are lurking at disproportionately higher levels in impoverished racial and ethnic communities across the United States.

Developing cost-effective sensors and related technology that easily detect noxious chemicals in the water and air could reduce human environmental health hazards and decrease neurological diseases and cancers. This technology could also support the long-standing environmental justice efforts to address environmental racism and the declining health and well-being of black and brown communities across the US [87].

5. Can technology help?

Lead can be measured in blood, urine, saliva, and other tissues [4,88,89]. However, the measurement methodologies associated with using these bodily fluids/tissues often include lengthy sample preparation and laboratory testing. Similarly, measuring heavy metals in water supplies entails time-consuming collection and sample preparation. Currently, accurate detection of heavy metals in fluid samples relies on expensive atomic absorption spectroscopy or inductively coupled plasma mass spectrometry in commercial testing laboratories operated by highly skilled staff [90]. It takes time to ship samples, run the tests, and send the results. The cost of \$100 or more per test is prohibitive for many individuals and for communities that must sample water at numerous points in their water systems. Furthermore, in the two weeks, or more, that it takes to receive results, people remain at risk [79].

Enabling communities to directly monitor lead concentration in their municipal and agricultural water supplies would enable them to know if and when lead levels reach the point where action is required. In addition, people in the community need to know if they have ingested high levels of lead. Having reliable data will empower them to seek assistance in protecting themselves and their communities. They need an economical, easy-to-use method of detecting lead that will tell them if their water level exceeds the actionable level set by the EPA of 15 ppb and if individuals have high levels of lead.

We envision the creation of two types of point-of-use sensors that would optimally monitor the situation in low-resource communities. This would avoid the expense and time delays of sending samples to a lab for analysis, both of which would be burdens for communities with little or no ability to pay for expensive sample collection and lab services. The first type would be used to frequently measure lead levels in water sources for domestic and farm use. The second would be for human use. Community screening events could be held that would both train residents to sustainably manage their environmental safety and identify individuals at risk, including children. As residents are trained, they could even perform the tests in their

own homes, similar to COVID tests. These tests could also identify potential hot spots for lead exposure that would warrant immediate action, such as changing their water treatment methods.

6. Conclusion

Three case histories have been presented in which elevated lead concentrations were observed in municipal water systems: Flint, MI; Washington, D.C.; and Birmingham, AL. Issues impacting the increased lead concentrations included changes in the water supply sources, aging infrastructure, changes in the disinfection systems used, and inadequate corrosion control. The elevated lead concentrations in the municipalities resulted in elevated blood lead levels, impacting the health of their residents. The disproportionate impact of aqueous lead pollution on low-income and minority communities has been described, and poor responses from the state regulatory agencies exacerbated the problems created by lead contamination. Failing to address the environmental lead contamination crisis has a direct negative impact on public health. Children and racial minorities often bear the brunt of lead contamination exposure. Concentrated poverty negatively impacts public access to safe drinking water throughout people's lifespan. Several techniques were presented for reducing exposure to lead in drinking water. Additionally, we proposed the creation of low-cost, point-of-use sensors that could provide a faster and more frequent means for low-resource communities to monitor lead levels and to act before widespread harm ensues. Lastly, to address these issues, community involvement of the stakeholders involving public alliance partnerships is required.

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References

1. United States Environmental Protection Agency. Stagnation Time, Composition, pH and Orthophosphate Effects on Metal Leaching from Brass. United States Environmental Protection Agency; 1996.
2. Jacobs DE, Clickner RP, Zhou JY, et al. The prevalence of lead-based paint hazards in US housing. *Environmental Health Perspectives*. 2002; 110(10): A599-606.
3. The aging water infrastructure: Out of sight, out of mind? Available online: <https://www2.deloitte.com/us/en/insights/economy/issues-by-the-numbers/us-aging-waterinfrastructure-investment-opportunities.html> (accessed on 16 January 2024).
4. Wani AL, Ara A, Usmani JA. Lead toxicity: A review. *Interdisciplinary Toxicology*. 2015; 8(2): 55-64.
5. Jaishankar M, Tseten T, Anbalagan N, et al. Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*. 2014; 7(2): 60-72. doi: 10.2478/intox-2014-0009
6. Tchounwou PB, Yedjou CG, Patlolla, et al. Heavy Metal Toxicity and the Environment. In: Luch A (editor). *Molecular, Clinical and Environmental Toxicology*. Experientia Supplementum. Springer; 2012.
7. Mason LH, Harp JP, Han DY. Pb neurotoxicity: Neuropsychological effects of lead toxicity. *BioMed Research International*. 2014; 840547. doi: 10.1155/2014/840547
8. DC Water. Health Effects of Exposure to Lead in Drinking Water. Available online: <https://www.dewater.com/health-effects-exposure-lead-drinking-water> (accessed on 16 January 2024).
9. United States Environmental Protection Agency. Basic Information about Lead in Drinking Water. Available online: <https://www.epa.gov/ground-water-and-drinking-water/basic-information-about-lead-drinking-water> (accessed on 16 January 2024).
10. Rodriguez J, Mandalunis PM. A Review of Metal Exposure and Its Effects on Bone Health. *Journal of Toxicology*. 2018;

4854152. doi: 10.1155/2018/4854152
11. Sanders T, Liu Y, Buchner V, et al. Neurotoxic effects and biomarkers of lead exposure: A review. *Reviews on Environmental Health*. 2009; 24(1): 15-45. doi: 10.1515/REVEH.2009.24.1.15
12. World Health Organization. Almost 1 million people die every year due to lead poisoning, with more children suffering long-term health effects. Available online: <https://www.who.int/news/item/23-10-2022-almost-1-million-people-die-every-year-due-to-lead-poisoning--with-more-children-suffering-long-term-health-effects> (accessed on 15 January 2024).
13. Center for Disease Control and Prevention. Populations at Higher Risk 2021. Available online: <https://www.cdc.gov/nceh/lead/prevention/populations.htm> (accessed on 15 January 2024).
14. Center for Disease Control and Prevention. Lead in Drinking Water. Available online: <https://www.cdc.gov/nceh/lead/prevention/sources/water.htm> (accessed on 16 January 2024).
15. United States Environmental Protection Agency. EPA OGWDW, Understanding the Lead and Copper Rule (40 CFR Part 141 Subpart 1) lcr101_factsheet_10.9.19.final_.2 September 2020. Available online at: www.epa.gov (accessed on 15 January 2024).
16. United States Environmental Protection Agency. Sources of Lead in Drinking Water, epa_lead_in_drinking_water_final. Available online: www.epa.gov (accessed on 15 January 2024).
17. Center for Disease Control and Prevention. Drinking Water Standards and Regulations. Available online: <https://www.cdc.gov/healthywater/drinking/public/regulations.html> (accessed on 16 January 2024).
18. Mulvihill K. Causes and Effects of Lead in Water. Natural Resources Defense Council, Washington DC. 2023. Available online: <https://www.nrdc.org/stories/causes-and-effects-lead-water#problem> (accessed on 16 January 2024).
19. Pascoe A. Six Years Later, Flint Still Doesn't Have Clean Water: One of the Worst Environmental Injustices in the 21st Century. *Climate-Xchange*; 2020.
20. Renner, R. Out of Plumb: When Water Treatment Causes Lead Contamination. *Environmental Health Perspectives*. 2009; 117(12): A542-A547. doi: 10.1289/ehp.117-a542
21. Renner R. Plumbing the Depths of DC's Drinking Water Crisis. *Environmental Science and Technology*. 2004; 38(12): 225A-227A. doi: 10.1021/es040525h
22. Shaver K, Hedgpeth D. DC's Decade-Old Problem of Lead in Water Gets New Attention during Flint Crisis. *The Washington Post*; 2016.
23. US Government Accountability Office. Drinking Water: EPA Could Use Available Data to Better Identify Neighborhoods at Risk of Lead Exposure. Available online: <https://www.gao.gov/products/gao-21-78> (accessed on 16 January 2024).
24. Frostenson S, Cunningham R. Where is the lead exposure risk in your community? Washington State Department of Health. Available online: <https://publichealthmaps.org/motw-2021/2021/4/7/7-april-2021-where-is-the-lead-exposure-risk-in-your-community-united-states> (accessed on 15 January 2024).
25. Pieper KJ, Martin R, Tang M, et al. Evaluating Water Lead Levels during the Flint Water Crisis. *Environmental Science & Technology*. 2018; 52: 8124-8132. doi: 10.1021/acs.est.8b00791
26. Flint Water Advisory Task Force, State of Michigan. Final Report 21 March 2016. Available online: www.michigan.gov (accessed on 15 January 2024).
27. Pieper, KJ, Tang, M, Edwards, MA. Flint Water Crisis Caused by Interrupted Corrosion Control: Investigating "Ground Zero" Home. *Environmental Science & Technology*. 2017; 51: 2007-2014. doi: 10.1021/acs.est.6b04034
28. Olson TM, Wax M, Yonts J, et al. Forensic Estimates of Lead Release from Lead Service Lines during the Water Crisis in Flint, Michigan. *Environmental Science & Technology Letters*. 2017; 4: 356-361. doi: 10.1021/acs.estlett.7b00226.
29. Wisely J. Was Flint River Water Good Enough to Drink? *Detroit Free Press*; 2016.
30. Hatch GB. Inhibition of Lead Corrosion with Sodium Hexametaphosphate. *Journal American Water Works Association*. 1941; 33(7): 1179-1187. doi: 10.1002/j.1551-8833.1941.tb19643.x
31. Edwards M, McNeill LS. Effect of Phosphate Inhibitors on Lead Release from Pipes. *Journal American Water Works Association*. 2002; 94(1): 79-90. doi: 10.1002/j.1551-8833.2002.tb09383.x
32. The Water Works Research Foundation. Chemistry of Corrosion Inhibitors in Potable Water. Available online: <https://www.waterrf.org/resource/chemistry-corrosion-inhibitors-potable-water> (accessed on 16 January 2024).
33. Mishra D, Kommineni S. Strategies to control red water occurrences in distribution system. In: *Proceedings of the Water Quality Technology Conference and Exposition 2007: Fast Tracks to Water Quality*; 4-8 November 2007; Charlotte, North Carolina, USA.

34. Office of Research and Development, United States Environmental Protection Agency. Control of Lead and Copper in Drinking Water. Available online: <https://nepis.epa.gov/Exe/ZyNET.exe/30004L0M.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1991+Thru+1994&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C91thru94%5CTxt%5C00000009%5C30004L0M.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL> (accessed on 15 January 2024).
35. Holm TR, Schock MR. Potential Effects of Polyphosphate Products on Lead Solubility in Plumbing Systems. *Journal American Water Works Association*. 1991; 83(7): 76-82. doi: 10.1002/j.1551-8833.1991.tb07182.x
36. Cantor A, Denig-Chakroff F, Vela R, et al. Use of Polyphosphate in Corrosion Control. *Journal American Water Works Association*. 2000; 92(2): 95-102. doi: 10.1002/j.1551-8833.2000.tb08820.x
37. Hozalski R, Esbri-Amador E, Chen CF. Comparison of Stannous Chloride and Phosphate for Lead Corrosion Control. *Journal American Water Works Association*. 2005; 97(3): 89-103. doi: 10.1002/j.1551-8833.2005.tb10847.x
38. Heberling JA, Barron P, Peters RW. Pipe Flow-Through Investigation: Determining Potential Water Quality Problems Involved with Switching from Chlorine to Chloramines at the Birmingham Water Works Board (BWVB) Part II. In: *Proceedings of the AWWA 2009 Water Quality Technology Conference*; 15-18 November 2009; Seattle, Wash, USA.
39. Lee J, Negussie T, Zaru D. Flint Residents Grapple with Water Crisis 9 Years Later: 'No Justice'. Available online: <https://abcnews.go.com/US/water-crisis-plagues-flint-residents-decade/story?id=98724950> (accessed on 15 January 2024).
40. Nakamura D. Exceeds EPA Lead Limit. *The Washington Post*. Available online: <https://www.washingtonpost.com/archive/politics/2004/01/31/water-in-dc-exceeds-epa-lead-limit/1e54ff9b-a393-4f0a-a2dd-7e8ceedd1e91/> (accessed on 15 January 2024).
41. Baron V. DC Water's Own Data Suggest Widespread Lead Contamination. *Natural Resources Defense Council*. Available online: <https://www.nrdc.org/bio/valerie-baron/dc-waters-own-data-suggest-widespread-lead-contamination> (accessed on 15 Jan 2024).
42. Brown MJ, Raymond J, Homa D, et al. Association between Children's Blood Lead Levels, Lead Service Lines, and Water Disinfection, Washington, DC, 1998–2006. *Environmental Research*. 2011; 111(1): 67-74. doi: 10.1016/j.envres.2010.10.003
43. United States Environmental Protection Agency. Lead in DC Drinking Water. Available online: https://archive.epa.gov/region03/dclead/web/pdf/printable_reducing_pb-roles_jul09.pdf (accessed on 15 January 2024).
44. Triantafyllidou S, Lambrinidou Y, Edwards MA. Lead (Pb) Exposure through Drinking Water: Lessons to be Learned from Recent US Experience. *Global NEST Journal*. 2009; 11(3): 341-348.
45. Edwards MA, Triantafyllidou S, Best D. Elevated Blood Lead in Young Children due to Lead-Contaminated Drinking Water: Washington, DC, 2001–2004. *Environmental Science & Technology*. 2009; 43(5): 1818-1823. doi: 10.1021/es802789w
46. Guidotti TL, Calhoun T, Davies-Cole JO, et al. Elevated Lead in Drinking Water in Washington, DC, 2003–2004: The Public Health Response. *Environmental Health Perspectives*. 2007; 115(5): 695-701. doi: 10.1289%2Fehp.8722
47. Heberling J. Chloramination and Corrosion: Case Studies, Utility Experience, and Statistical Comparisons with Chlorination [PhD thesis]. University of Alabama at Birmingham; 2014.
48. Heberling J, Barron P. Measuring Metal Release and Biological Activity in Decades Old Cast Iron Pipes Subjected to a Disinfectant Change. 2012; 122: 9. doi: 10.2495/UW120121
49. Woernle C, Rao R, White J, et al. Final Report: Child Lead Exposure Study. Available online: <https://www.cdc.gov/niosh/docket/archive/pdfs/NIOSH-071/0071-090191-Williamson-Attach4.pdf> (accessed on 15 January 2024).
50. Toner C. Children in these Alabama ZIP codes had lead in their blood. Available online: https://www.al.com/news/2016/02/alabama_lead_exposure_children.html (accessed on 15 January 2024).
51. Cabrera, Y. Lead keeps poisoning children. It doesn't have to Grist. Available online: <https://grist.org/solutions/soil-lead-contamination-poison-children/> (accessed on 15 January 2024).
52. Denchak M. Flint Water Crises: Everything You Need to Know. Available online: <https://www.nrdc.org/stories/flint-water->

- crisis-everything-you-need-know (accessed on 15 January 2024).
53. Mock. Short Cuts Could Cause Permanent Damages: The water crisis in Flint, Mich., is the latest in a long history of African Americans being exposed to toxic poisoning. *Crisis*. 2016; 123(1): 5-6.
 54. Hanna-Attisha M, LaChance J, Sadler RC, et al. Elevated Blood Lead Levels in Children Associated with the Flint Drinking Water Crisis: A Spatial Analysis of Risk and Public Health Response. *American Journal of Public Health*. 2016; 106(2): 283-290. doi: 10.2105/ajph.2015.303003
 55. Kittilstad E. Reduced Culpability without reduced punishment: A case for why lead poisoning should be considered a mitigating factor in criminal sentencing. *Journal of Criminal Law & Criminology*. 2018; 108(3): 569-95.
 56. Schaider LA, Swetschinski L, Campbell C, et al. Environmental justice and drinking water quality: Are there socioeconomic disparities in nitrate levels in US drinking water? *Environmental Health: A Global Access Science Source*. 2019; 18(3): 1-15. doi: 10.1186/s12940-018-0442-6
 57. Murray E. Racism and Health: The Influence of Residential Segregation on Lead Exposure. *American Sociological Association*. 2019; 1-35.
 58. Marshall AT, Betts S, Kan EC, et al. Association of lead-exposure risk and family income with childhood brain outcomes. *Nature Medicine*. 2020; 26: 91-97. doi: 10.1038/s41591-019-0713-y
 59. Bae J, Lynch MJ. Ethnicity, Poverty, Race, and the Unequal Distribution of US Safe Drinking Water Act Violations, 2016–2018. *The Sociological Quarterly*. 2023; 64(2): 274-295. doi: 10.1080/00380253.2022.2096148
 60. Balazs CL, Ray I. The Drinking Water Disparities Framework: On the Origins and Persistence of Inequities in Exposure. *American Journal of Public Health*. 2014; 104(4): 603-611. doi: 10.2105/2FAJPH.2013.301664
 61. Balazs CL. Just Water? Social Disparities and Drinking Water Quality in California's San Joaquin Valley 2011 [PhD thesis]. University of California; 2011.
 62. McDonald YJ, Jones NE. Drinking Water Violations and Environmental Justice in the United States, 2011–2015. *American Journal of Public Health*. 2018; 108(10): 1401-1407. doi: 10.2105/ajph.2018.304621
 63. Switzer D, Teodoro MP. Class, Race, Ethnicity, and Justice in Safe Drinking Water Compliance. *Social Science Quarterly*. 2018; 99(2): 524-535. doi: 10.1111/ssqu.12397
 64. Neville JA, Guz J, Rosko HM, et al. Water quality inequality: A non-targeted hotspot analysis for ambient water quality injustices. *Hydrological Sciences Journal*. 2022; 67(7): 1011-1025. doi: 10.1080/02626667.2022.2052073
 65. Blair T, Beni R, Guha S. Diversifying clean water: An examination of drinking water quality and social disparities in Michigan. *Journal of Geoscience and Environment Protection*. 2022; 10(5): 125-138. doi: 10.4236/gep.2022.105010
 66. Environmental Defense Fund. Lead Pipes and Environmental Justice: A Study of Lead Pipe Replacement in Washington, DC. Available online: https://www.edf.org/sites/default/files/u4296/LeadPipe_EnvironJustice_AU%20and%20EDF%20Report.pdf (accessed on 15 January 2024).
 67. Balazs CL, Morello-Frosch R, Hubbard AE, et al. Environmental justice implications of arsenic contamination in California's San Joaquin Valley: A cross-sectional, cluster-design examining exposure and compliance in community drinking water systems. *Environmental Health*. 2012; 11(1): 84. doi: 10.1186/1476-069X-11-84
 68. Williams SA, Eden S, Megdal S, et al. Diversity, Equity, Inclusion, and Justice in Water Dialogues: A Review and Conceptualization. *Journal of Contemporary Water Research & Education*. 2023; 117(1): 113-139. doi: 10.1111/j.1936-704X.2022.3386.x
 69. Sobol S. Examining Systemic Environmental Racism Through Inequities in Access to Clean Water Domestically and Globally: Exhibiting Erasure, Highlighting Concrete Disparities, and Field Study in Uniontown [PhD thesis]. Dartmouth College; 2019.
 70. US Environmental Protection Agency. EPA awards \$100M Flint water upgrade. Available online: <https://www.epa.gov/archive/epa/newsreleases/epa-awards-100-million-michigan-flint-water-infrastructure-upgrades.html> (accessed on 19 January 2024).
 71. Taking action on Flint water. Available online: <https://www.michigan.gov/flintwater> (accessed on 19 January 2024).
 72. Stelloh T. Judge approves \$626 million settlement in Flint water crisis. Available online: <https://www.nbcnews.com/news/us-news/judge-approves-626-million-settlement-flint-water-crisis-rcna5183> (accessed on 19 January 2024).
 73. US Census Bureau Quick Facts. Available online:

- <https://www.census.gov/quickfacts/fact/table/flintcitymichigan/INC110218> (accessed on 19 January 2024).
74. Christensen P, Keiser DA, Lade GE. Economic effects of environmental crises: Evidence from Flint, Michigan. *American Economic Journal: Economic Policy*. 2023; 15(1): 196-232.
75. US Small Business Administration. Small Business Administration Announces Economic Support Package to Spur Growth in Flint. Available online: <https://www.sba.gov/article/2016/feb/26/small-business-administration-announces-economic-support-package-spur-growth-flint-0> (accessed on 19 January 2024).
76. Doctrow B. Racial segregation makes consequences of lead exposure worse. Available online: <https://www.nih.gov/news-events/nih-research-matters/racial-segregation-makes-consequences-lead-exposure-worse> (accessed on 19 January 2024).
77. Eligon J. A Question of Environmental Racism in Flint. Available online: <https://www.nytimes.com/2016/01/22/us/a-question-of-environmental-racism-in-flint.html> (accessed on 19 January 2024).
78. Villarreal M. Toxic mess near Los Angeles left dangerous levels of lead in soil. Available online: <https://www.cbsnews.com/news/toxic-mess-near-los-angeles-left-dangerous-levels-of-lead-in-soil/> (accessed on 19 January 2024).
79. US National Institute on Aging Virtual Workshop. Understanding the role of the exposome in Brain Aging, Alzheimer's Disease and AD-Related Dementias. National Institute on Aging; 2020.
80. Bravo MA, Zephyr D, Kowal D, et al. Racial residential segregation shapes the relationship between early childhood lead exposure and fourth-grade standardized test scores. *PNAS*. 2022; 119(34): e2117868119. doi: 10.1073/pnas.2117868119
81. Vig EK, Howard H. Lead toxicity in older adults. *Journal of the American Geriatrics Society*. 2000; 48: 1501-1506. doi: 10.1111/jgs.2000.48.11.1501
82. White BM, Hall ES. Perceptions of environmental health risks among residents in the "Toxic Doughnut": Opportunities for risk screening and community mobilization. *BMC Public Health*. 2015; 15: 1230. doi: 10.1186/s12889-015-2563-y
83. Ramirez R. There's a clear fix to helping Black communities fight pollution. Available online: <https://www.vox.com/22299782/black-americans-environmental-justice-pollution> (accessed on 19 January 2024).
84. Portes A. The Two Meanings of Social Capital. *Sociological Forum*. 2000; 15(1): 2-12. Available online: <http://www.jstor.org/stable/3070334> (accessed on 19 January 2024).
85. Skelton R, Miller V. The Environmental Justice Movement. Natural Resources Defense Council; 2023.
86. Bullard RD. Race and Environmental Justice in the United States. *Yale Journal of International Law*. 1993; 18(1): 12.
87. Xu J, Murphy SL, Kochanek KD, et al. Mortality in the United States, 2021. National Center for Health Statistics; 2022.
88. Genuis SJ, Birkholz D, Rodushkin I, Beesoon S. Blood, urine, and sweat (BUS) study: Monitoring and elimination of bioaccumulated toxic elements. *Arch Environ Contam Toxicol*. 2011; 61(2): 344-357. doi: 10.1007/s00244-010-9611-5
89. James KA, Meliker JR, Marshall JA, et al. Validation of estimates of past exposure to arsenic in drinking water using historical urinary arsenic concentrations. *Journal of Exposure Science & Environmental Epidemiology*. 2013; 23(4): 450-454. doi: 10.1038/jes.2013.8
90. Peng G, He Q, Zhou G, et al. Determination of heavy metals in water samples using dual-cloud point extraction coupled with inductively coupled plasma mass spectrometry. *Analytical Methods*. 2015; 7(16): 6732-6739.

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