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Eco-pavement Bricks from Waste: Assessing Demographic Determinants of Adoption in Bunso, Ghana

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Abstract

The exponential growth in solid waste generation, driven by rapid industrialisation, population expansion and economic development, has severe consequences for human health, biodiversity and environmental sustainability. In response, this study investigates the feasibility of reusing solid waste materials to develop eco-pavement bricks. A survey-based approach was employed to assess the influence of demographic factors on the willingness of individuals to pay for eco-pavement bricks. Conducted at Bunso, Abuakwa South Municipality in Ghana, the study utilised a questionnaire-based methodology to collect data, which was subsequently analysed using descriptive statistics and binomial logistic regression. The study's results reveal that 89% of the respondents were willing to pay for eco-pavement bricks, suggesting a strong potential for the adoption of sustainable waste management practices and environmentally conscious products. Notably, the findings indicate that demographic factors do not significantly influence the willingness to pay with all p-values > 0.05, implying a broad-based support for eco-friendly infrastructure solutions. This suggests that eco-pavement bricks could be a viable option for promoting sustainable development and reducing environmental impacts associated with traditional pavement materials.

Keyword: Circular Economy; Demographic determinants; Eco-pavement bricks; Sustainable waste management; Willingness to Pay (WTP).

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Introduction

The rapid growth of urban populations and increasing anthropogenic activities have led to a significant generation of various types of waste. The world generates approximately 2.01 billion tonnes of municipal solid waste annually, with predictions suggesting this number will grow to 3.8 billion tonnes by 2050 (Rahman and Ahmed, 2024). This staggering volume of waste highlights the pressing need for effective waste management strategies to mitigate the environmental and health impacts associated with waste disposal. Decay of the organic proportion of solid waste is contributing to about 5 per cent of global greenhouse gas (GHG) emissions, which in turn accelerates climate change and other adverse effects on human health and the environment (Gautam and Agrawal, 2020). There is the necessity to develop a municipal solid waste management structure that utilises the waste management hierarchy, sustainable development principles and integrated solid waste management approach (Oji et al., 2020).

The concept of circular economy is an emerging notion that has the potential to be utilised as waste minimisation approach (Esa et al., 2017), which has led to the concept of eco-pavement bricks as a means of recycling waste materials. Eco-pavement bricks are paving bricks designed to be eco-friendly. They are usually made from various materials, such as concrete, brick, stone, or recycled plastic, offering flexibility in design and functionality. The long service-life, fast and easy production and easy replacement for maintenance purposes of eco-pavement bricks have increased its popularity for use (Yeo et al., 2021). This has made individuals adapt to using waste materials as substitutes in building. Manjunatha et al. (2021) stated that, cement is a commonly used binding material for the preparation of concrete. They stated further that the manufacture and utilisation of cement in concrete can be contributor to Greenhouse Gas (GHG) emission and climate change. Hence, when cement is partially or totally replaced with other materials, such ecological problems were reduced. Therefore, the state of the art for sustainable, unconventional, natural and recycled building materials should be taken into account (Kawereaki & Achal, 2020).

According to conclusions by Khan et al. (2021), Solid Waste Management (SWM) is a significant challenge that arises from local issues but with global consequences for a society. In low-income countries, over 90% of waste is often disposed of at unregulated dumps or openly burnt, creating serious health, safety and environmental consequences (World Bank Group, 2019).

As global population growth persists, resulting in a corresponding surge in waste production, there is an increasing need for innovative solutions that can effectively manage waste while promoting sustainability. In response to this challenge, this study aims to assess the willingness to patronize pavement bricks made from waste materials, thereby exploring the potential for waste reduction and resource conservation through the adoption of sustainable products manufactured using recycled waste materials. By exploring the relationship between demographic characteristics and willingness to pay, this research seeks to provide valuable insights into the potential demand for sustainable infrastructure solutions and inform strategies for promoting environmentally responsible practices among diverse population segments.

General Properties of Eco-Pavement Bricks

Ecological pavements represent a sustainable approach to infrastructure development, characterized by the incorporation of waste materials as additives in their construction. This innovative method not only reduces the environmental footprint of pavement construction but also promotes the efficient

use of resources. To ensure their sustainability, the construction and maintenance of ecological pavements must be carried out in a manner that minimizes natural resource depletion and energy consumption (Pratico et al, 2020).

Moreover, the production process associated with ecological pavements should prioritize the reduction of harmful emissions and by-products, thereby safeguarding the environment from adverse impacts. The design of these pavements is also crucial, as it must be carefully planned to avoid disrupting the natural surroundings and ecosystems (Austin, 2014).

The performance and durability of ecological pavements are determined by their physical and mechanical properties (Jiang et al, 2018). Key physical properties include water absorption, porosity, and specific gravity, while mechanical properties such as compressive strength, density, and tensile strength are essential for assessing their structural integrity (Akinyele et al, 2021). By understanding and optimizing these properties, it is possible to develop ecological pavements that are not only sustainable but also durable and functional.

Ultimately, the development of ecological pavements offers a promising solution for sustainable infrastructure development, one that balances the needs of human activity with the imperative of environmental protection. By adopting sustainable design principles and prioritizing environmental stewardship, ecological pavements can play a vital role in creating a more sustainable future. The findings of this study contribute to a better understanding of the influence of demographic factors on individuals' willingness to adopt eco-friendly technologies and practices, ultimately informing policy and decision-making processes aimed at reducing waste and promoting sustainable development.

Composition of Solid Waste Materials for Eco-pavement Bricks

Tailings

The processes involved in mining activities generate more and more solid wastes, which mainly include waste rock, tailings and slag. Tailings are by-products of the ore beneficiation processes. According to Jones and Boger (2012), 14 billion tons of tailings are produced annually, worldwide. The overall utilisation of reduced storage amounts of tailings has become the focus of research as construction materials. For example, it is used in brick production (Zhu et at al., 2017). Most published researches have revealed that mortar or concrete containing tailings as fine aggregate, have a higher water absorption percentage due to capillarity.

The process of cement production consumes a lot of energy and emits a significant amount of CO_2. According to Aprianti et al. (2015), to lessen these amounts, all kinds of industrial solid wastes, containing high silica are used to replace cement as supplementary cementitious materials (SCMs). Gayana (2018) investigated the properties of interlocking concrete block paver mixed with iron ore tailings as partial replacement of cement. According to the summarised findings, the utilisation of tailings as aggregate often resulted in an increase in the compressive strength.

Coconut shell powder

Coconut (*Cocos nucifera*) is a highly versatile and widely cultivated palm tree species, renowned for its multifaceted utility and significance. According to Bheel et al. (2021), coconut has been aptly described as "the most useful tree for humanity". Globally, coconut is extensively cultivated in over 92 countries, with optimal growth conditions requiring adequate sunlight and soil rich in calcium and phosphorus, typically found in sandy coastal areas (Gummadi & Srikanth, 2012).

The global coconut production is substantial, with an estimated 51 billion nuts produced annually across 12 million hectares of cultivated land. Notably, more than 50% of the global coconut production is processed into dried coconuts, highlighting the significance of this commodity in international trade (Rogers et al., 2012). Furthermore, coconut shell is a valuable natural filler material, with considerable potential for utilization in various industrial applications (Leman et al., 2017).

A coconut shell refers to the non-food hard part of a coconut which is considered as agricultural waste. Coconut shells have no economic value and their disposal causes ecological problems. Hence, there is the need to recycle them into useful materials to minimise their negative impacts on the environment. In short, both the cost of construction materials and disposal of waste can be reduced if agricultural waste can be reused. Research conducted by Itam et al. (2022) demonstrates that the utilization of coconut shell as a constituent material in ecobrick production leads to notable improvements in strength development, thereby underscoring its potential as a valuable additive in ecobrick manufacture.

Plastic waste

According to Agyemang et al. (2019), Ghana generates approximately 22,000 tons of plastic waste annually, with a recycling rate of only 2%. Furthermore, the study reported that the national waste generation rate for non-recyclable materials is estimated to be 0.096 kg per person per day. The high rate of population growth and increasing per capita income have resulted in the generation of huge volumes of heaped solid wastes. This is a serious menace to environmental quality and human health (Agyemang et al., 2019). Plastic manufacturing accounts for 6% of global oil consumption and is one of the world's fastest-growing waste streams (Hossain et al., 2022).

Wood ash dust/sawdust

Wood ash is generated as a by-product of combustion in wood-fired power plants, paper mills, and wood-burning factories (Ghorpade, 2012). Wood is a potential source of energy and environmentally friendly material. There will be an increased usage of wood in energy production in the future. As a result, the quantity of ash generated will also increase concurrently, raising the issues of disposal. Currently, wood ashes are frequently used as soil supplement to improve the alkalinity of soil for agriculture applications and also as a filler material in the construction of flexible pavements for roads and highways. (Ghorpade, 2012).
According to Subramanian et al. (2015), several studies have analysed the suitability of wood ash as a partial cement replacement material in the production of structural grade concrete and self-compacting concrete for use in building construction.

Eco-Pavement Brick Preparation

The eco-pavement brick was formulated by incorporating a composite mixture of tailings, shredded plastics, coconut husk powder, and sawdust. The production process adhered to the standards outlined by the Ghana Standards Authority for brick manufacturing. The mixture was moulded into a brick shape, similar to conventional concrete bricks, using a standardized moulding procedure. These components were combined in a specific ratio to achieve the desired properties. The mixture was then moulded into a brick shape, following established protocols for brick production.

Conformity to Standards

The production process and material composition of the eco-pavement bricks adhered to the Ghana Standards Authority specifications, as outlined by Danso and Akwaboah (2021). The incorporation of waste materials, including tailings, shredded plastics, coconut husk powder, and sawdust, aimed to mitigate waste disposal issues and promote sustainable

construction practices. A comparative analysis with conventional concrete bricks (Figure 1) highlights the benefits of utilizing waste materials in pavement brick production, including reduced environmental impact, enhanced sustainability, and improved aesthetic appeal. This innovative approach underscores the potential for waste-to-resource applications in sustainable infrastructure development.

Eco-Pavement Brick (EPB) Concrete Pavement Brick (CPB)

Figure 1: Eco-pavement brick and concrete pavement brick.

Materials and Methods

Study area

The study was conducted in Bunso, a notable ecozone community situated in the Abuakwa South Municipality of Ghana's Eastern Region. This ecologically significant area is distinguished by its rich biodiversity, featuring a diverse array of plant and animal species that thrive in harmony with the built environment. Bunso's unique blend of natural and constructed elements creates an eco-friendly enclave. Geographically, Bunso is located between longitude 0.56° West and 0.15° West, and latitude 6.03° North and 6.35° North, within the Wet semi-equatorial climatic zone characterized by a bimodal rainfall pattern (Abass, 2009). The area experiences an average annual temperature of 29.06°C (84.31°F), slightly higher than Ghana's national average. The Eastern Region of Ghana, where Bunso is located, generally exhibits a high rainfall pattern due to its tropical location and proximity to the coast.

As an ecozone community, Bunso showcases a harmonious relationship between its residents and the natural environment, with community members deriving various benefits from ecosystem services that support their livelihoods. The area's eco-friendly environment and biodiversity make it an attractive location for eco-tourism, promoting sustainable practices and environmental conservation. This unique setting provides an ideal context for studying sustainable infrastructure development and assessing the community's willingness to adopt and pay for environmentally friendly solutions, such as eco-pavement bricks.

Sampling and Data collection

The data collection process employed a questionnaire survey methodology, utilizing a convenience sampling approach to select

household heads from the study area. This technique was chosen primarily due to its practical advantages, including ease of access to respondents, time efficiency and cost-effectiveness, which were important considerations given the study's limited resources and field logistics. Convenience sampling enabled the research team to reach participants who were readily available and willing to participate, thereby facilitating smooth data collection within the study's timeframe.

Trained university students administered the questionnaires, which were designed to elicit information on respondents' willingness to pay for pavement bricks produced from waste materials compared to conventional concrete pavement bricks. To support informed decision-making, the data collection team presented respondents with tangible samples of both eco-pavement bricks and conventional bricks, allowing participants to visually inspect and physically examine the materials. This hands-on approach enhanced respondents' comprehension and improved the reliability of their expressed preferences.

Before data collection, the questionnaire was peer-reviewed to ensure clarity, logical flow, and validity of items. The target population comprised residents of Bunso Township, and a sample size of 150 respondents was determined to ensure a statistically adequate subset of the population. According to Bartlett et al. (2001), a sample size of 150 provides a reasonable balance between precision and resource constraints, yielding reliable estimates for many social science studies.

The convenience sampling approach employed in this study facilitated the collection of insightful data on community attitudes toward eco-pavement bricks in Bunso Township. By engaging with readily available participants, the research team was able to gather valuable preliminary insights into the community's perceptions and willingness to adopt sustainable building materials. This approach enabled the study to achieve its exploratory objectives, providing a foundation for future research and informing strategies to promote environmentally sustainable practices in the region.

Data analysis

The data was analysed and summarised using Microsoft Excel 2016 package and with descriptive statistics in Statistical Package for the Social Sciences. Binomial logistic regression was used to predict factors that influence WTP for the eco-pavement bricks by regressing the independent variables against the dependent variable. That is, to assess associations or relationships between demographic variables and WTP for eco-pavement bricks.

Results

Responses from the survey

Analysed submissions made by the respondents from the survey are presented in **(Table 1).** Majority of the respondents were males (68 %, n=102) and the rest were females (32%, n=48). From the responses and observations of the survey, it was observed that the male population was higher than that of the female because most of the interviewed houses were owned or rented by the males.

Also, greater number of respondents who answered to the questions were in the ages of 36 years and above (60); followed by those in the ages of 15 to 25 (51). Those in the ages 26-35 years (39) were the least group that responded to the questionnaire. Likewise, (86) of the respondents were single; (48) were married; (12) were

divorced; the remaining (4) respondents were separated.

Respondents who had no formal education were quite less than those with some education. Table 1 clearly indicates that, tertiary respondents were the highest 56% (n=84); followed by JHS respondents with (n=33); SHS/Vocational respondents were (n=23); (n=10) were respondents who had no formal education. Similarly, out of the total number of respondents over the survey period, (70) were employed; (69) were students; (9) were unemployed; (2) were retired.

Moreover, (n=73) respondents had 2 to 10 years of experience in their profession; (57) of the respondents had less than a year experience; (10) had 11 to 20 years of experience; whereas only (1) respondent had over 21 years of experience.

Based on the occupation or current job status of the respondents, (47) said that, they receive a monthly income of 20 to 299 Ghana cedis; (41) receive 1000 Ghana cedis and above as their monthly income; (31) also stated that, they receive 300 to 599 Ghana cedis; the remaining (31) obtain a monthly income of 600 to 999 Ghana cedis.

Table 1: Demographic Characteristics of Sampled Household Heads at Bunso.

Parameters		**Frequency**	**Percent**
Total Respondents		**150**	**100**
Gender	Female	48	32
	Male	102	68
Age Group(Years)	15 to 25	51	34
	26 to 35	39	26
	36 and above	60	40
Marital Status	Single	86	57.3
	Married	48	32
	Divorced	12	8
	Separated	4	2.7
Highest Educational Level	No formal education	10	6.7
	JHS	33	22
	SHS/Vocational education	23	15.3
	Tertiary	84	56
Occupation/ Current Job Status	Student	69	46
	Unemployed	9	6
	Retired	2	1.3
	Employed	70	46.7
Monthly Income (GH¢)	20 to 299	47	31.3
	300 to 599	31	20.7
	600 to 599	31	20.7
	1000 and above	41	27.3

The survey results indicate that 95% of respondents endorse eco-pavement bricks as a viable solid waste management solution, with only 5% expressing disagreement. Majority of the respondents (89%) stated that, they will be willing to pay for bricks made from waste materials as compared to bricks made from concrete but the remaining 11% of the population responded no. **(Figure 2)**

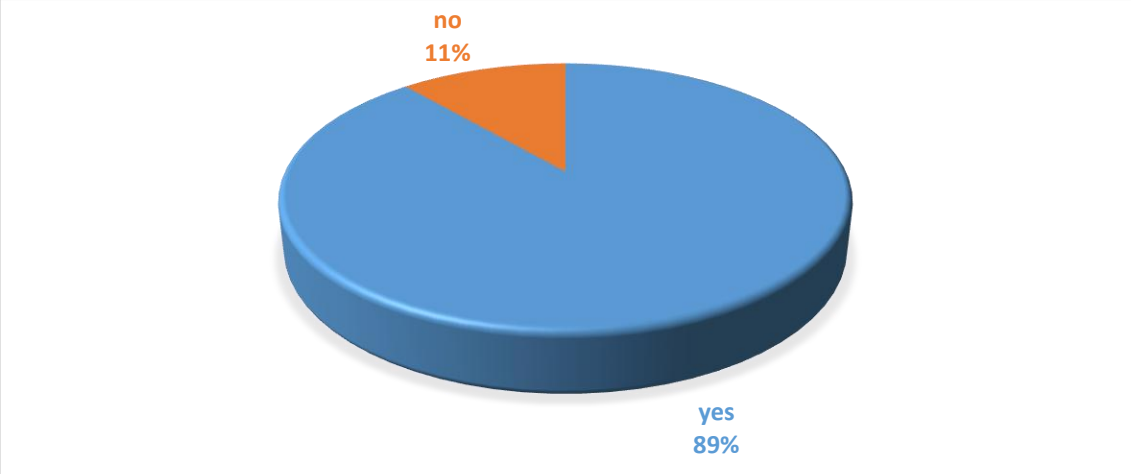

Figure 2: Willingness to pay for an eco-pavement brick.

A binomial logistic regression analysis at 95% confidence level reveals in **(Table 2)** that, all the demographic features did not have any impact on the willingness to pay (p-values >0.05).

From the **(Table 2)**, there was no significant differences between the demographic characteristics (independent variables) that is, gender, age group, marital status, highest educational level, occupation and monthly income against the willingness to pay (dependent variable) for eco-pavement bricks.

Table 2: Results from the binomial logistics regression analysis performed using SPSS.

Parameter	B	S.E.	Wald	df	Sig.	Exp(B)
Gender	.630	.562	1.256	1	.262	1.877
Age Group	.371	.405	.840	1	.359	1.449
Marital Status	-.242	.494	.240	1	.625	.785
Highest educational level	-.218	.285	.587	1	.444	.804
Occupation/Current job status	-.124	.290	.183	1	.669	.884
Monthly income (GHC)	-.190	.264	.518	1	.472	.827
Constant	-2.775	1.786	2.415	1	.120	.062

Discussion

The survey findings indicate a positive perception of eco-pavement bricks as a viable initiative for solid waste management. A significant majority of respondents recognised the numerous benefits of eco-pavement bricks, including their extended service life, rapid and effortless production and easy replacement for maintenance purposes. As indicated by Yeo (2021), these attributes have collectively contributed to the growing popularity of eco-pavement bricks for various applications.

A significant proportion of respondents expressed a willingness to pay for eco-pavement bricks, demonstrating a potential

market demand for this innovative product. The positive response suggests that consumers are increasingly recognising the value of sustainable and environmentally friendly solutions, such as eco-pavement bricks, which can effectively mitigate the environmental impacts associated with traditional waste management practices (Agyemang et al., 2019).

The binomial logistic regression analysis conducted to investigate the factors influencing respondents' willingness to pay for eco-pavement bricks yielded positive results. Contrary to expectations, the analysis revealed that the willingness to pay for eco-pavement bricks was not significantly dependent on any of the independent variables examined.

The insignificant p-values (> 0.05) obtained for all independent variables in the logistic regression analysis imply that the willingness to pay for eco-pavement bricks is a robust and consistent phenomenon, unaffected by external influences. This outcome has important implications for marketing strategies and consumer behaviour, as it highlights the potential for eco-pavement bricks to transcend traditional market segments and appeal to a broader audience.

The survey findings and logistic regression analysis collectively underscore the immense potential of eco-pavement bricks as a game-changing innovation in solid waste management. The willingness to pay for this product demonstrate a growing demand for sustainable solutions, which can be leveraged to drive environmental stewardship and promote eco-friendly practices in various sectors as asserted by (Ramakrishna, 2022).

Conclusions and recommendation

The pursuit of sustainable development, including initiatives like eco-pavement bricks, is essential for building a brighter future for generations to come. The findings of the study revealed a notable absence of a significant association between demographic factors and willingness to pay for eco-pavement bricks. Specifically, the analysis showed that variables such as gender, age group and monthly income did not have a statistically significant impact on individuals' willingness to pay for eco-pavement bricks. This outcome suggests that the decision to pay for eco-pavement bricks is not influenced by demographic characteristics, rather by a broader commitment to environmental protection.

The lack of a significant association between demographic factors and willingness to pay for eco-pavement bricks has important implications for environmental policy and sustainability initiatives. It suggests that individuals are willing to prioritise environmental quality and pay for products that promote sustainability, regardless of their demographic backgrounds. This finding is consistent with the growing body of research on environmental behaviour, which highlights the increasing awareness and concern of environmental issues among individuals.

Further research is necessary to comprehensively assess the environmental and economic implications of eco-pavement bricks. Specifically, it is recommended that future studies conduct thorough Life Cycle Assessment (LCA) studies to evaluate the

environmental benefits and potential drawbacks of eco-pavement bricks in comparison to traditional bricks. Additionally, a detailed cost-benefit analysis should be performed to determine the economic feasibility and potential cost savings associated with adopting eco-pavement bricks in construction projects.

Moreover, to facilitate the widespread adoption of eco-pavement bricks, it is essential to develop and refine regulatory frameworks and standards governing their production and use. This would provide clarity on quality control, material specifications and environmental standards, thereby instilling confidence in stakeholders and promoting the uptake of eco-pavement bricks in the construction industry. By addressing these knowledge gaps, future research can help unlock the full potential of eco-pavement bricks as a sustainable alternative to traditional building materials.

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Declarations

Human and animal rights: The author confirm that humans and animals were not used for experiments in this study.

Additional information: Questionnaire used for data collection is available and can be requested from the author.

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