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Research Article

Eco-Design Screening and Material-Balance Analysis of a Hand-Made Rattan Food Cover in Aceh Besar, Indonesia

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ABSTRACT

Studies of environmental burdens in Indonesia have largely focused on medium and large industries, leaving household-scale non-timber forest product industries underexamined. This study examines a handmade rattan food cover (tudung saji) produced in Lamgaboh Village, Lhoknga District, Aceh Besar Regency, where the renewability of rattan is often assumed to ensure environmental soundness. The study is not an ISO 14040/14044 life-cycle assessment; no life-cycle inventory database or characterized impact assessment was used. Instead, it combines Eco-Design PILOT screening with an independently constructed quantitative material balance. Measured evidence comprised gravimetric weighing of components and offcuts, production-stage observations, and interviews with artisans and rattan farmers. Of 0.572 kg of rattan entering production, 73.4% became product and 26.6% was discarded, corresponding to approximately 1.46 tonnes of solid waste annually at cluster scale. Material loss was concentrated in the main frame, which had a 60.0% yield, compared with 90.9% for the handle. Separately, Eco-Design PILOT outputs classified the product as hybrid SM, identified significant life-cycle phases, generated a relative global warming potential profile, and ranked improvement strategies. Because the tool rejects empty fields, four inputs with true zero values-additional hazardous materials, external parts, hauling distance, and packaging-were entered at the lowest available settings. These forced inputs were flagged and their implications examined. Across 15 checklist items, none was fulfilled; 13 were considered easy to implement and seven required no additional cost, indicating predominantly organizational improvement opportunities. Four structural limitations of the tool for handmade products were identified, together with compensatory measures.

Keywords: *circular production, eco-design screening, Eco-Design PILOT, household industry, material balance, material efficiency, rattan handicraft*

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INTRODUCTION

Attention to the environmental burden of production in Indonesia has largely been directed at medium and large industry. That is understandable, since energy consumption and waste volumes are easiest to measure there. Small and household-scale industries, however, are a different matter. A single unit generates little waste, but the units are very numerous and environmental oversight barely reaches them. The problem becomes more awkward still when such an enterprise draws on a renewable natural resource, because the belief that the raw material is "already environmentally friendly" tends to close the enquiry before it has properly begun.

Rattan handicraft illustrates the difficulty well. Rattan grows quickly, can be harvested repeatedly without replanting, and decomposes naturally once its service life ends. Aceh Province holds an estimated 200,000 to 250,000 tonnes of rattan potential per year, while the national sustainable harvesting quota was set at 143,120 wet tonnes through Ministerial Decree of Forestry Number 25 of 2012. Given a raw material of this character, rattan products are almost always presumed to satisfy environmental criteria automatically. The presumption is mistaken. The environmental standing of a product is determined by its life cycle as a whole, not by the origin of its raw material alone.

Eco-design offers a way through this by building environmental considerations into product design from the earliest stage. Fiksel, as cited by Morbidoni (2012), defines it as a development process that satisfies cost, performance, and quality criteria alongside environmental ones. Wimmer et al. (2004) translate the principle into twelve operational steps, from selecting the product to be studied through to communicating the resulting improvements to the market. To support implementation, Wimmer et al. (2002) developed the Eco-Design PILOT (Product Investigation, Learning and Optimization Tool), an online instrument that identifies the most significant life-cycle phase of a product and converts that finding into a ranked list of improvement strategies. Instruments of this kind belong to the family of simplified or screening tools rather than to full life-cycle assessment. They trade quantitative precision for speed and accessibility, and they are intended for settings in which inventory data, software licenses, and specialist expertise are all scarce (Suppipat et al., 2021; Camañes et al., 2024). That trade-off is what makes them attractive for household industry, and it is also what makes their built-in assumptions worth examining.

This study takes the rattan craft cluster of Lamgaboh Village, Lhoknga District, Aceh Besar Regency as its case, with the food cover as the object of observation. Three objectives follow. The first is to construct a material balance and map the environmental performance of the product across the five phases of its life cycle. The second is to derive prioritized improvement strategies together with realization ideas that make sense at household-industry scale. The third is to evaluate both the applicability and the limitations of the Eco-Design PILOT when it is applied to a product made entirely by hand. It should be stated at the outset that this study is not a life-cycle assessment in the sense of ISO 14040 and ISO 14044 (International Organization for Standardization, 2006a, 2006b). No life-cycle inventory database was consulted, no characterization factors were applied by the authors, and no comparative assertion is made against any other product. What is reported is an eco-design screening performed with the Eco-Design PILOT, whose outputs are qualitative and relative, combined with a material balance whose figures are measured. The two are kept distinct throughout the article, and the word “life-cycle” is used here in the sense of life-cycle thinking, that is, of attending to every phase in turn, and not in the sense of a standardized quantitative assessment.

LITERATURE REVIEW

2.1 Eco-design and the Eco-Design PILOT

Eco-design has moved well beyond its origins as a waste-management concern. Contemporary practice treats it as a design discipline in which environmental performance is one design variable among cost, quality, and function, addressed at the point where roughly eighty percent of a product’s eventual environmental burden is already determined, namely the design stage itself. Sherwin and Evans (2000) had already raised the question of whether early intervention is always best; the intervening decades have largely settled it in the affirmative, on the grounds that later intervention can only optimize decisions that have already foreclosed most alternatives. The proposition now rests on more than argument. Casamayor and Su (2021), following a lighting manufacturer over two years of participatory observation, found that environmental outcomes were shaped more decisively during concept development than by any downstream optimization, while also documenting the barriers that keep such methods out of smaller firms: long learning curves, the cost of software, and a requirement for environmental expertise that small enterprises rarely possess.

The Eco-Design PILOT operationalizes this position through two linked modules. The Assistant module receives product data across five life-cycle phases, classifies the product type, and determines which phases are environmentally significant. From that classification, it recommends improvement strategies, separated into high-priority and supplementary sets. The Pilot module then supplies a checklist for each high-priority strategy, to be scored item by item on relevance and fulfilment. The product of the two scores yields a priority ranking that tells the designer where to begin.

The tool has not escaped criticism. Benmoussa (2022) identifies two weaknesses in the Eco-Design PILOT: the assessment of proposed measures rests on subjective judgement, and the checklist structure does little to stimulate creative solutions; he proposes coupling the tool with TRIZ and ASIT to address both. Camañes et al. (2024), reviewing eco-design software more broadly, observe that the usefulness of any such instrument depends on how closely its database and its input structure match the product being assessed, and mismatch is precisely the condition under which a screening tool begins to mislead. Suppipat et al. (2021) reach a similar conclusion from teaching practice, reporting that simplified tools fail when a product falls outside the material and component categories the tool anticipates. All of these observations, however, were made about conventional manufactured goods. Whether they hold, and in what form, for a product made without machinery has not been examined.

Applications of the method in Indonesia have concentrated on manufactured goods. Rusdiyantoro and Nurcahyanie (2015) applied eco-design methodology to metal-based furniture and concluded that integrating design for assembly, manufacturing, and maintenance extends product life while reducing energy consumption. Santoso (2012) applied the concept to packaging design, and Marlita and Jatiningsih (2025) tested eco-design in new product development through an experimental study. Each of these addresses a product made with machinery.

2.2 Life-cycle approaches in small industry and the research gap

Life-cycle thinking has also entered the Indonesian small-industry literature, though through a different route. Adiwinata et al. (2021) assessed wet-processed robusta coffee at a small and medium enterprise in Lampung, while Adi et al. (2024) calculated the carbon footprint of tofu production in Mataram and found soybean boiling to be the largest source of emissions. Astuti et al. (2022) developed a cleaner production plan for a tofu enterprise in Central Java, and Puspaningrum et al. (2026) did the same for a rolling-door workshop. Two features recur across this body of work. The improvements identified are procedural and low-cost rather than capital-intensive, and the dominant environmental variable is almost always energy. The pattern is not confined to Indonesia. Chakraborty et al. (2025), reviewing 188 studies of circular-economy adoption in small and medium enterprises, report that the field remains dominated by qualitative case work and that the barriers most often recorded are cost, technological capacity, and weak policy support rather than any absence of technical options. Nurkomariyah et al. (2026), tracing polyester waste through the Indonesian textile and clothing sector by material flow analysis, demonstrate what a quantified balance makes visible that a qualitative assessment does not, namely the precise points in a chain at which material integrity is lost.

That second feature matters here. Lestari and Pulansari (2024), analyzing an Indonesian furniture manufacturer through life-cycle assessment, identified electricity consumption as the principal contributor to environmental impact. Findings of this kind cannot be transferred directly to a product whose every operation is performed by hand. The point generalizes beyond furniture. Gan et al. (2022), harmonizing the life-cycle assessment literature on bamboo products, show that the environmental performance of a renewable lignocellulosic material depends far more on processing intensity and end-of-life route than on the renewability of the feedstock, and Deng et al. (2023), applying a design-for-sustainability framework to bamboo furniture, state the matter plainly: bamboo furniture is not necessarily environmentally friendly. Rattan occupies the same position, and there is no reason to expect the conclusion not to transfer.

Research on Indonesian rattan handicraft, meanwhile, has moved in an entirely different direction. Yusuff et al. (2022) developed rattan basket designs in the Cirebon cluster through a visual aesthetics approach, while Safri and Syarfan (2023) examined the effect of product innovation on business performance among rattan artisans in Pekanbaru. Both are sound pieces of work, and both place rattan within a framework of aesthetics and commercial performance. The environmental dimension remains untouched. The international literature on craft and non-timber forest products has begun to occupy part of this space, though it approaches from a socio-economic direction. Araujo-Santos et al. (2025), studying a piassava palm value chain in Brazil, identify twenty threats to its sustainability, the great majority of them economic rather than ecological; Anand et al. (2026), analyzing Indian Dhokra craft, likewise find economic sustainability the weakest of the three dimensions. Pinho et al. (2025), working on furniture wood waste in Brazil, stand closer to the present study in method and show that recovery routes for lignocellulosic residues can be evaluated and ranked once the residue flow itself has been quantified. What is still missing, for rattan as for craft materials generally, is that quantification.

The gap addressed here therefore has two layers. The first is empirical: no quantitative data exist on material efficiency in Indonesian rattan production, although such data are precisely what is needed to judge whether a product made from a renewable material actually performs well environmentally. The second is methodological. The Eco-Design PILOT was designed around the assumptions of industrial production. It requests electrical and thermal energy inputs, energy per use, and the mass and type of packaging material. A product that is woven by hand, uses no electricity, requires no energy in use, and is sold without packaging satisfies none of these assumptions. No study has yet asked whether the tool still yields valid recommendations when most of its input fields must be left empty. This methodological layer is sharpened by the criticisms already noted. Benmoussa (2022) questions the subjectivity of the tool's assessment step; the difficulty raised here is prior to that one, and concerns whether the input structure itself can represent a product for which several of its mandatory fields have no meaning at all.

METHOD

Fieldwork was carried out in the rattan craft cluster of Lamgaboh Village, Lhoknga District, Aceh Besar Regency, between July and December 2015. The cluster is one of two supported by the Aceh Besar Regency Office of Industry and Trade, the other being Lamcok Village. It lies 14.2 km from Banda Aceh, directly on the Banda Aceh to Meulaboh trunk road, which allows finished products to be displayed in front of the workshops.

The cluster comprises roughly fifteen workshops, all individually owned, each employing two to three workers. No machinery of any kind is used; the tools are knives, shears, and simple aids. Data were collected at four workshops that were actively producing during the observation period, which ran from morning until midday. Artisans generally stop after noon and turn to other work, so observation hours followed their rhythm rather than the reverse. Raw material is supplied by rattan farmers from Leupung District, 14.8 km away.

The object of observation was a food cover 700 mm in diameter and 300 mm high. It was not chosen at random. Demand for it runs at roughly three times that for baskets, so artisans make it most frequently and most skillfully. This matters because it ensures that the measured waste reflects established practice rather than variation in skill or the errors of a novice.

Primary data were gathered in three ways. The first was direct observation of every production stage, from receipt of raw material through cleaning, sun-drying, sorting by size, cutting, weaving, and handle-making to the finished article. The second was gravimetric measurement, using a mechanical balance, of the mass of each product component and of the offcuts each component generated in a single production cycle. The third was structured interviews with artisans, using a question list built around the input attributes the Eco-Design PILOT requires.

A rattan farmer in Tapaktuan District, South Aceh Regency, was also interviewed. This respondent was obtained incidentally, since rattan farmers are difficult to meet at the study site, and questions were confined to the passage of rattan from forest harvesting to the artisan's hands. We recognize that a single respondent cannot characterize the upstream supply chain, so this material is used as background only and forms no part of the calculations.

Secondary data were drawn from the Aceh Provincial Office of Industry and Trade, Statistics Indonesia, and the Forestry Office, covering rattan distribution in Aceh Province and the number of small and medium enterprises producing woven rattan and bamboo goods.

Before the analytical procedure is set out, the scope of the assessment should be made explicit. This study does not perform a life-cycle assessment as defined by ISO 14040 and ISO 14044 (International Organization for Standardization, 2006a, 2006b). No life-cycle inventory database was used, no characterization model was applied by the authors, no impact categories beyond the tool's own internally generated global warming potential profile are reported, and no comparative assertion is made. The analysis has two components, and they carry different evidential status. The first is a material balance built from gravimetric measurement, which yields quantitative figures for material input, product mass, waste mass, yield, and waste ratio. The second is an eco-design screening performed with the Eco-Design PILOT, which yields a product-type classification, a designation of significant life-cycle phases, a relative global warming potential profile computed internally by the tool from generic assumptions, and a ranked set of improvement strategies. The first component is measurement; the second is a structured qualitative screening whose numerical outputs are relative and must not be read as characterized impact results. The two are reported separately in the Results and are nowhere combined into a single indicator.

Analysis was carried out using the online version of the Eco-Design PILOT. Five input criteria were required: raw material, covering the components of the product with their masses and material classes; manufacture, covering energy inputs, waste per unit, production volume, and hazardous material use; distribution, covering transport mode, hauling distance, and packaging type; product use, covering use frequency, energy per use, and waste arising in use; and end of life, covering the treatment of each component once its service life ends.

A data-entry protocol was adopted so that actual and forced values would remain distinguishable. Each input field was first assigned its actual value as established by measurement, observation, or interview. Where that actual value was zero and the tool refused to accept it — the online Eco-Design PILOT validates several fields against a minimum permissible entry and will not run otherwise — the lowest available setting was entered instead and the field was recorded as forced. Four fields fall into this category: additional hazardous materials, percentage of external parts, hauling distance for external parts, and packaging type. Table 1 accordingly reports the actual condition alongside the value entered and marks the data status of every parameter, so that any reader can see which of the tool's outputs rest on measured input and which rest on an entry made only to satisfy a validation rule. No forced value enters the material balance at any point; that calculation is built entirely from weighed data.

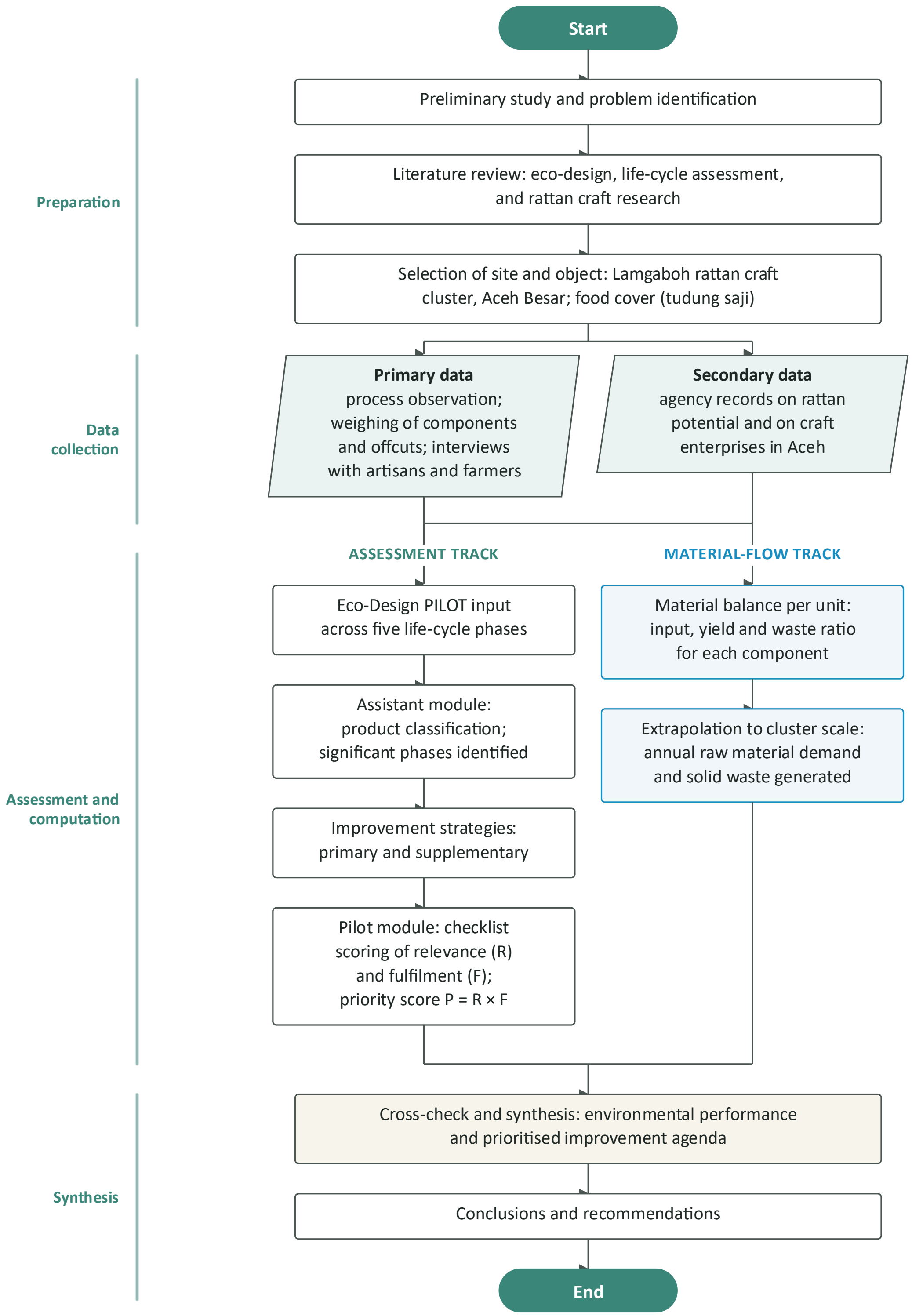

Figure 1. Stages of the research procedure

Each checklist item was scored on two dimensions. Relevance (R) expresses how important the item is for the product under study, on a scale of 10 for very important, 5 for less important, and 0 for not relevant. Fulfilment (F) expresses how far the actual condition of the product already satisfies the item, on a scale of 1 for fulfilled, 2 for rather yes, 3 for rather no, and 4 for not fulfilled. The priority score is the product of the two: The scoring was carried out jointly by the author team from observation and interview records, and is therefore an expert judgement rather than a measurement. Benmoussa (2022) identifies this subjectivity as an intrinsic weakness of the tool; it is treated here as a limitation of the present design rather than as something that design could remove, and its implications are set out in the Limitations section.

$$\mathbf{P = R \times F} \qquad (1)$$

where P is the priority score, R the relevance value, and F the fulfilment value. The highest attainable score is 40, marking an item that is very important yet entirely unfulfilled. For each item, we also recorded a realization idea, its cost consequence, implementation feasibility, timing, and the party responsible.

One further analysis was constructed outside the tool's output, namely a material balance per unit of product. The raw material input for each component was taken as the sum of the component mass in the finished product and the mass of offcuts that component generated. Material yield is the ratio of component mass to its raw material input, and the waste ratio is its complement. Results were then extrapolated to cluster scale using the production volume reported by the artisans. Because the balance is built from weighed masses alone, it is independent of every input the tool requires, and in particular of the four forced entries described above. The complete methodological flow of the research is presented in Figure 1.

RESULT

The food cover comprises three components: the main frame, the woven frame, and the handle. All three use the same material, rattan slimit, known locally as rotan cacing. It falls within material class 1 in the tool because its character resembles wood, with the added advantage of an elasticity that allows it to be softened and bent. The components differ only in diameter: the main frame uses rattan of 5 mm, the woven frame 2 to 5 mm and 2 mm, and the handle a combination of large and medium sizes.

Product life was set at ten years on the basis of artisan and consumer accounts, although the figure depends heavily on how the product is handled. The functional unit was defined as the capacity to protect a meal of approximately ten plates. Use frequency was assumed at five times daily, giving 1,825 uses per year. Table 1 summarizes the full set of input parameters.

Table 1. Input parameters for the Eco-Design PILOT screening: actual conditions, values entered, and data status

Phase	Parameter	Actual condition (measured/observed)	Value entered in Eco-Design PILOT	Data status
Description	Product name	Food cover, 700 mm diameter, 300 mm height	As actual	Observed
	Product lifetime	10 years	10 years	Interview-based estimate
	Functional unit	Protecting a meal of approximately 10 plates	As actual	Defined by authors
Raw material	Main frame	0.150 kg; rattan slimit; class 1	As actual	Measured (weighed)

	Woven frame	0.250 kg; rattan slimit; class 1	As actual	Measured (weighed)
	Handle	0.020 kg; rattan slimit; class 1	As actual	Measured (weighed)
	Packaging material	None; product sold unpackaged (zero)	Entered under Distribution	Observed; actual value zero
	Hazardous components	None (zero)	None	Observed; accepted by tool
Manufacture	Electrical energy	0 kWh; no machinery used	0 kWh	Observed; accepted by tool
	Thermal energy	0 MJ; sun-drying only	0 MJ	Observed; accepted by tool
	Waste, main frame	0.100 kg per unit	As actual	Measured (weighed)
	Waste, woven frame	0.050 kg per unit	As actual	Measured (weighed)
	Waste, handle	0.002 kg per unit	As actual	Measured (weighed)
	Production volume	200 units per week; 800 per month; ≈ 9,600 per year	10–10,000 units per year (tool band)	Interview; entered as nearest tool band
	Additional hazardous materials	None (zero)	"Few" (lowest setting available)	**Forced - actual value zero**
	Percentage of external parts	None (zero)	"< 10%" (lowest setting available)	**Forced - actual value zero**
Distribution	Transport mode	Pickup truck	Pickup truck	Observed
	Hauling distance, finished product	14.6 km, cluster to Pasar Aceh	14.6 km	Measured route distance
	Hauling distance, external parts	Not applicable; no external parts (zero)	Lowest setting available	**Forced - actual value zero**
	Packaging type	None; product sold unpackaged (zero)	"Disposable packaging"	**Forced - actual value zero**
Use	Use frequency	5 times daily; 1,825 times per year	1,825 times per year	Interview-based assumption
	Energy per use	0 (none)	0	Observed; accepted by tool
	Waste per use	0 (none)	0	Observed; accepted by tool
	Potential env. hazard in use	None	"Impossible"	Observed
End of life	Main frame	Discarded with household refuse	Landfill	Observed
	Woven frame	Discarded with household refuse	Landfill	Observed
	Handle	Discarded with household refuse	Landfill	Observed

Source: primary data, processed. Rows marked "Forced" carry an entry made solely to satisfy the tool's validation rules; the actual value of each of these parameters is zero.

Four rows in Table 1 are marked as forced, and they require careful reading because they are the only points at which the input set departs from the actual condition of the product. The true value of all four is zero. The production of food covers uses no additional hazardous materials and incorporates no external parts, so no hauling distance for such parts exists, and the product is sold exactly as it leaves the workshop, without packaging of any kind. The online Eco-Design PILOT nevertheless refuses to run while any of these fields are empty and offers no zero or “none” setting for them, so each was entered at the lowest value the interface permits. Every other row in Table 1 records an actual value: the component and waste masses were weighed, the electrical and thermal energy fields were genuinely zero and were accepted as such by the tool, and the remaining entries were established by observation or interview. The distinction matters because the tool's classification of significant phases and its global warming potential profile are computed from the full input set, forced entries included, whereas the material balance reported in Table 2 is computed from weighed masses alone and is unaffected by them. The consequences of the forcing for the tool's output are examined in the Discussion.

Weighing the components and offcuts allowed a material balance to be constructed per unit of food cover, as set out in Table 2. This calculation is not produced by the Eco-Design PILOT; it was assembled independently from the raw weighing data.

Table 2. Material balance and raw material efficiency per unit of product

Component	Product mass (kg)	Waste mass (kg)	Material input (kg)	Yield (%)	Waste ratio (%)
Main frame	0.150	0.100	0.250	60.0	40.0
Woven frame	0.250	0.050	0.300	83.3	16.7
Handle	0.020	0.002	0.022	90.9	9.1
Total	**0.420**	**0.152**	**0.572**	**73.4**	**26.6**

Source: primary data, processed.

Of the 0.572 kg of rattan entering the process, only 0.420 kg, or 73.4 percent, becomes finished product. The remainder, 0.152 kg or 26.6 percent, is discarded. More than a quarter of the rattan an artisan pays for never turns into anything saleable.

The distribution of that loss is more revealing than its total. Yield on the main frame is only 60.0 percent, far below the 83.3 percent of the woven frame and the 90.9 percent of the handle. Four kilograms in every ten allocated to the main frame end up as offcuts. The figure matches what is visible in the workshop: solid waste above 5 mm in diameter is by far the most abundant, and its source is the main-frame cutting stage. The cause is simple and entirely procedural. Artisans cut rattan by eye, without a standard measuring device. Lengths are frequently cut long, and the remainder is then too short to serve as any other component.

Raised to cluster scale the picture becomes clearer still. At the reported production volume of 200 units per week, or 800 units per month, the cluster discards some 121.6 kg of rattan monthly, or 1.46 tonnes annually, from a raw material requirement of about 5.49 tonnes per year. As far as our observation extends, none of this waste is managed. Some accumulates around the work area and the rest is disposed of with household refuse.

Alongside solid waste, the process generates a liquid effluent from the stage at which weaving patterns are colored, consisting of thinner and oil-based paint together with water mixed with Malo powder. Its volume is far smaller than that of the solid waste, but its character is altogether different. Rattan offcuts are inert and decompose on their own. The coloring effluent does not. It is discharged directly onto the ground with neither containment nor any defined procedure, and it is this stream, despite its small volume, that carries the greatest potential to damage the surrounding environment.

On the basis of the inputs in Table 1, the Eco-Design PILOT classified the food cover as a hybrid SM product type, with three phases declared significant: manufacture, distribution, and end of life. Raw material and use were not classified as significant. This classification is an output of the tool rather than a measurement, and one element of it should be treated with reserve. Distribution was declared significant although the only real distribution activity is a single 14.6 km journey by pickup truck, and the packaging field that feeds this phase was forced to "disposable packaging" for a product that is in fact sold unpackaged. The classification of manufacture and of end of life, by contrast, rests on inputs that were measured or observed directly.

The global warming potential profile across phases reinforces that classification for two of the three phases. The largest contribution comes from manufacture, followed by end of life, while raw material, distribution, and use contribute almost nothing. These profiles are generated internally by the tool from generic assumptions and are reported here as relative magnitudes only. They are not characterization impact results; they are not expressed in kilograms of carbon dioxide equivalent, and they should not be compared with figures obtained from an inventory-based assessment.

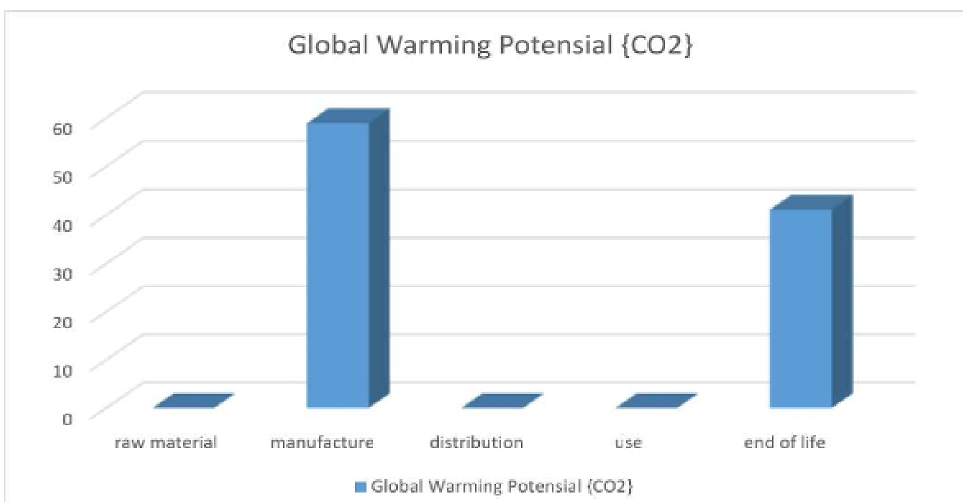

Figure 2. Global warming potential across life-cycle phases

The tool recommended two high-priority strategies: S5, avoiding waste in the production process, and S19, recycling of materials. Both align with the material balance and with the global warming potential profile, each of which points to manufacture and end of life. Strategy S5 was elaborated into eight checklist items and strategy S19 into seven. The assessment of all fifteen appears in Tables 3 and 4.

Table 3. Checklist assessment of strategy S5 (avoiding waste in the production process)

No	Evaluation item	R	F	P	Realisation idea	Feasibility
1	Use low material input, low emission production technologies	10	2	20	Use a cutting tool fitted with a standard gauge before cutting rattan into components	Difficult
2	Avoid environmentally hazardous production technologies	10	4	40	Provide containers for solid rattan waste sorted by diameter	Easy
3	Avoid waste and emissions in the production process	10	4	40	Measure each component to its true length and adopt natural rattan colourants	Easy
4	Close material cycles in the production process	10	3	30	Use solid offcuts as raw material for patterns or motifs in the weave	Easy
5	Recycle or reuse waste for new materials	10	3	30	Use offcuts for smaller crafts such as accessories or lamp covers	Difficult
6	Dispose of unavoidable waste in an environmentally acceptable manner	10	4	40	Build a dedicated disposal point for liquid effluent that cannot be reused	Easy
7	Sort and separate waste wherever possible	5	4	20	Separate waste manually and group it by diameter	Easy
8	Reduce the fraction of rejects in the production process	10	3	30	Inspect for physical defects and dimensions during raw material cleaning	Easy

R = relevance, F = fulfilment, P = priority score (P = R × F). Source: primary data, processed.

Table 4. Checklist assessment of strategy S19 (recycling of materials)

No	Evaluation item	R	F	P	Realization idea	Feasibility
1	Ensure labelling of materials conforming to standards	5	4	20	Add a product label stating that the product is environmentally sound and recyclable	Easy
2	Make possible the separation of materials for recycling	5	4	20	Separate materials manually, then group them by raw material diameter	Easy
3	Ensure simple extraction of harmful and valuable substances	10	3	30	Reuse rattan dye water and break down products that have reached the end of their service life	Easy
4	Ensure that materials are suitable for recycling	5	4	20	Use process waste as raw material for existing products and for new ones	Easy
5	Ensure that surface coating and base material are suitable for recycling	10	4	40	Adopt colourants made from natural raw materials	Easy
6	Make possible extraction of process materials and	10	4	40	Sun-dry the rattan to remove moisture and other residual content	Easy

No	Evaluation item	R	F	P	Realization idea	Feasibility
	unavoidable harmful substances					
7	Take into account the end user's opportunities for disposal and provide instructions	10	4	40	Add information to the product label on end-of-life handling	Easy

R = relevance, F = fulfilment, P = priority score (P = R × F). Source: primary data, processed.

Read one by one, the fifteen items look like an ordinary list of things to put right. Read as a distribution, they say something else. Table 5 sets out the pattern.

Table 5. Distribution of ratings across the fifteen checklist items

Dimension	Category	Items	Percentage
Priority score (P)	P = 40 (highest)	6	40.0%
	P = 30	4	26.7%
	P = 20	5	33.3%
Relevance (R)	R = 10 (very important)	11	73.3%
	R = 5 (less important)	4	26.7%
Fulfilment (F)	F = 1 (fulfilled)	0	0.0%
	F = 2 (rather yes)	1	6.7%
	F = 3 (rather no)	4	26.7%
	F = 4 (not fulfilled)	10	66.7%
Feasibility	Easy	13	86.7%
	Difficult	2	13.3%
Cost consequence	Increased	8	53.3%
	Unchanged	7	46.7%
	Reduced	0	0.0%

Source: primary data, processed.

Priority scores range from 20 to 40 with a mean of 30.7. No item scored low, which is to say that no aspect can be considered settled.

The most striking result lies in the fulfilment dimension. Not one of the fifteen items received a fulfilment value of 1, the rating for a criterion that has been met. Ten items, or 66.7 percent, fall into the unfulfilled category, four items or 26.7 percent into rather no, and only one item or 6.7 percent reaches rather yes. On that reckoning, 93.3 percent of the evaluated items sit on the negative side of the scale.

The second result is more encouraging. Thirteen items, or 86.7 percent, were judged easy to implement, and seven items or 46.7 percent require no additional expenditure whatsoever. Only two items were judged difficult: acquiring a cutting tool with a standard gauge, and developing offcuts into new derivative products. Neither is difficult for technical reasons; both are constrained by the artisans' limited capital.

DISCUSSION

The first result of consequence is that the assumption with which this article opened does not survive contact with the measurements. Rattan handicraft is not environmentally benign by default. Its raw material is renewable, but the way it is produced and the way it is handled at the end of its service life meet none of the eco-design criteria applied here. A renewable input, in other words, guarantees nothing about the process that converts it.

The comparison with Lestari and Pulansari (2024) is worth setting out. In the furniture industry they examined, the dominant contributor was electricity consumption. In the food cover no electricity is used at all, and yet manufacturing still emerges as the most problematic phase. The source has shifted entirely from energy to material. This suggests that in hand-made products, material efficiency occupies the position that energy efficiency occupies in machine-made ones, and that measurement of material waste should therefore be the point of entry to the analysis rather than an accessory to it.

The two results from the checklist distribution, taken together, point to a conclusion of some practical importance: the environmental performance gap in this cluster is organizational, not technological. The interventions with the greatest effect, such as cutting to measured lengths, separating waste by diameter, using offcuts as weaving motifs, and inspecting raw material for defects during the cleaning stage, demand no machinery, no meaningful investment, and no new skills. What they demand is a change in working practice and consistent accompaniment.

This is consistent with cleaner production experience in Indonesian small industry elsewhere. Astuti et al. (2022) found that improvements in tofu processing rested on simple equipment modification and the reordering of process flow, while Puspaningrum et al. (2026) placed the drafting of standard operating procedures among the principal measures for a rolling-door enterprise. By contrast, in the metal-based furniture studied by Rusdiyantoro and Nurcahyanie (2015), improvement required changes to assembly and manufacturing design methods, which is a far heavier undertaking. The distinction carries a policy implication: eco-design support programs for household industry are better directed at strengthening working procedures than at technology transfer.

One further finding deserves separate mention. The highest-scoring items under strategy S19 include replacing synthetic colorants with natural ones. Interviews established that alternatives are available locally, among them jernang fruit and the rattan fruit itself, both known to earlier generations of artisans. This substitution resolves two problems at once: it removes the source of hazardous liquid effluent at the manufacturing stage and restores the compatibility of the product's surface coating with recycling at end of life. Whether the color fastness is adequate for a product with a ten-year service life would need to be tested, and that lies outside the scope of this study.

The third objective of this study was to assess how far the Eco-Design PILOT can be relied upon for a hand-made product. Four structural limitations emerged from the analysis, and subsequent users should be aware of them. Two of them have counterparts in the international literature on eco-design tools; two appear to be specific to the case of hand-made production.

1. There is no explicit zero option. The tool offers no "none" setting for packaging, so we were obliged to select "disposable packaging" for the analysis to run at all. The tool consequently accounts for a packaging burden that does not exist, and this appears to be why distribution was classified as a significant phase even though its global warming potential is close to zero. We cannot demonstrate this directly, since the tool's internal algorithm is not open, but the consistency with the input pattern is strong enough to record.
2. Minimum values are forced onto irrelevant fields. Additional hazardous materials, percentage of external parts, and hauling distance for external parts were all filled with the smallest available value rather than zero, which reflects reality. One such forcing might be disregarded; three at once introduce a systematic bias whose direction is to overstate the product's environmental impact.
3. The tool is oriented towards energy consumption. Its analytical structure treats energy as the principal explanatory variable in both manufacture and use. For a product made entirely by human effort and consuming nothing in use, both fields stand empty, and the tool's discriminating power across those phases effectively disappears. In this case, the assessment of manufacture came to rest wholly on waste mass data. Suppipat et al. (2021) report a structurally similar failure in simplified tools applied to products whose materials lie outside the anticipated categories; the mechanism is the same one, displaced from materials to energy.
4. There is no quantitative material-efficiency output. The tool accepts waste mass per component as an input but returns neither a yield nor a waste-ratio indicator. Yet it is precisely these indicators, as Table 2 shows, that are most useful for household industry, since they point directly to the stage requiring attention and translate readily into the monetary value of raw material lost.

Because all three forced entries were set to the lowest value the tool accepts, the direction of the resulting bias can be stated with confidence even though its magnitude cannot. Every forced entry adds a burden that does not exist: a packaging stream for an unpackaged product, a hazardous-material presence where there is none, and a transport distance for parts that are never brought in. None of them can be subtracted. The tool's picture of the product's environmental burden is therefore an overstatement, and the phase most affected is distribution, since two of the three forced fields feed it directly. A quantitative sensitivity analysis, in which each field would be varied and the change in output observed, is not possible with the online version, which exposes neither its algorithm nor its intermediate values. What can be said is that the two phases the tool identified as most significant, manufacture and end of life, draw on no forced input whatsoever, so the principal conclusion of the screening is not disturbed by the forcing. The two high-priority strategies follow in the same way from the waste masses and the end-of-life route, both of which were established directly.

None of this invalidates the tool. Its strategic recommendations, S5 and S19, proved consistent with a material balance constructed separately, and the process of completing the checklist compels the researcher to examine aspects that might otherwise be overlooked in an unguided analysis. For hand-made products, however, its use should always be accompanied by a material balance, and the classification of significant phases should be cross-checked against physical data before it is used as a basis for decisions. Benmoussa (2022) arrives at a comparable position from a different direction, proposing that the tool be coupled with structured ideation methods rather than set aside.

The tool also proposed thirteen supplementary strategies for implementation once the primary strategies are complete. Some are not relevant to this case. Packaging reduction means nothing for a product that is not packaged, and reducing energy consumption means nothing for a process that uses none. Their appearance in the recommendation list follows directly from the first two limitations above and serves as further evidence that those limitations affect the tool's output. The most worthwhile of the supplementary strategies are appropriate material selection, improved product durability, and reuse of product parts, since all three bear directly on extending service life and delaying the product's entry into the end-of-life phase that proved problematic.

Several limitations of this study should be stated openly. The primary data were collected in 2015 and therefore describe the cluster as it was in that period; subsequent changes in production practice, market structure, or the number of enterprises are not captured. The results are best positioned as a historical baseline against which later work can be compared. Waste was weighed for a single production cycle at the workshops observed, so the data carry no information on variation between artisans or over time; the 60.0 percent yield on the main frame, for instance, may well differ between a senior artisan and one only a few years into the trade. Repeated measurement across an adequate sample would be needed for a more reliable estimate with a measure of dispersion. The relevance and fulfilment ratings are expert judgements made by the researchers from observation and interview and carry an element of subjectivity that cannot be wholly removed; independent multiple raters with a test of inter-rater agreement would strengthen their reliability. Finally, the study stops at the point of recommendation and has not tested whether the proposed strategies are effective in practice. Two points of scope should be restated here. First, what has been carried out is a screening and not an ISO-compliant life-cycle assessment: the global warming potential profile is a relative, internally generated output based on the tool's generic assumptions, and it cannot be set against characterized results from an inventory-based study. Second, three input fields were forced to non-zero values against an actual value of zero, which biases the tool's output towards overstatement in the manner set out above. Neither limitation touches the material balance, which rests on weighed data alone. As to the age of the primary data, it should be added that the cluster's technology has not changed in the interval; production remains entirely manual, with knives and shears and no machinery of any kind, so the material-balance figures may well have remained stable; but that is an inference rather than a verified claim, and re-measurement would be required to establish it.

CONCLUSION

Based on the findings and discussion presented in this study, the following conclusions are derived:

1. The material balance shows that of the 0.572 kg of rattan entering the process, only 0.420 kg or 73.4 percent becomes product, while 0.152 kg or 26.6 percent is discarded as solid waste. The loss is concentrated in the main frame, whose yield is 60.0 percent, and originates from cutting performed without a standard measuring device. At cluster scale, this represents roughly 1.46 tonnes of rattan waste per year.
2. The Eco-Design PILOT classified the product as a hybrid SM type with manufacture, distribution, and end-of-life as significant phases, and recommended two high-priority strategies, avoiding waste in the production process and recycling of materials, supported by thirteen further strategies. These recommendations proved consistent with the independently constructed material balance. These are the outputs of a screening tool and are reported as such; they were not produced by an inventory-based life-cycle assessment, and the consistency noted here is a consistency of direction rather than of magnitude.
3. Across fifteen checklist items with priority scores from 20 to 40 and a mean of 30.7, not one item was rated as fulfilled, and ten items, or 66.7 percent, were rated unfulfilled. Yet thirteen items, or 86.7 percent, were judged easy to implement and seven, or 46.7 percent, require no additional cost. The environmental performance gap in this cluster is therefore organizational rather than technological.
4. The Eco-Design PILOT carries four structural limitations when applied to hand-made products: the absence of an explicit zero option, the forcing of minimum values onto irrelevant fields, an orientation towards energy consumption, and the absence of any quantitative material-efficiency output. Its use in comparable settings should be accompanied by a material balance and by cross-checking against physical data.

For the artisans, the sequence of actions we would suggest begins with the cheapest and most effective: introducing a standard measuring device at the main-frame cutting stage, separating solid waste by diameter, using offcuts as weaving motifs, providing containment for liquid effluent, and progressively replacing synthetic colorants with natural ones based on jernang and rattan fruit.

For further research, three directions are open. Repeated waste measurement across several workshops would yield an estimate with a measure of dispersion. Action research could test whether the proposed strategies actually reduce the waste ratio in the field. And, perhaps most needed of all, the development of an eco-design assessment framework designed for hand-made products with no energy input, so that the next researcher need not wrestle with input fields that do not fit.

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