Empowering Meru Farmers

Design and development of a context-adapted manual groundnut thresher for smallholder farmers in the Meru Region, Kenya.

--> Front image 1. Women harvesting groundnuts on a farm in Meru, Kenya.
Photograph by Marte Lanning.

Image 2. Groundnut plant on farm in Meru, Kenya.
Photograph by Marte Lanning.

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Graduation Project
Integrated Product Design
TU Delft

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Glossary.

Smallholder farmers	While there is no universally accepted definition of 'smallholder farmers' (Morton, 2007), most cultivate small areas of land (usually less than 100.000 m2, often less than 20.000 m2), use family labour, and depend on their farms as their main source of both food security and income generation (Cornish, 1998, Nagayets, 2005).
Groundnut	Another term for peanut, a North American plant of the pea family, which yields a sweet edible tuber (Oxford University Press, n.d.).
Threshing	The separation of grain or seeds from the husks and straw.
Thresher	A tool that separates the (groundnut) pods from the plant. This is different from a machine that shells the pods.
Co-creation	The practice of collaborating with other stakeholders to guide the design process. Participants with different roles align and offer diverse insights, usually in facilitated workshops. Designers can therefore get more holistic views of what a product or service should include. (Interaction Design Foundation, 2021).

Image 3. Groundnut farm in Meru, Kenya.
Photograph by Marte Lanning.

Preface.

This report marks the graduation project of my master's program in Integrated Product Design at Delft University of Technology. Executed in collaboration with Bopinc, an organisation committed to fostering inclusive innovation, the project delves into a partnership involving 2SCALE, a coalition of organisations, and Batian Nuts Limited (Batian). This collaborative effort unfolds in the context of designing a manual groundnut thresher tailored explicitly for smallholder farmers in Kenya. Positioned at the intersection of academia and practical application, this project embodies a multifaceted approach, integrating academic research with real-world impact and exemplifying the ethos of applied design thinking.

The reason behind embarking on the "Empowering Meru Farmers" project is rooted in my personal commitment to engaging with low-income communities in the pursuit of meaningful design solutions. Central to my design philosophy is the principle of co-creation, reflecting a profound belief that designers should not act as external creators but rather collaborate intimately with the intended users throughout the design process. This takes on heightened significance when operating within cultural landscapes distinct from my own, underscoring the necessity to grasp design preferences and deliver context-adapted solutions authentically.

This project stands as a harmonious merging of two of my profound interests and, next to that, fields of study: cultural anthropology and industrial design engineering. The prospect of synthesizing insights from cultural anthropology with the technical aspects of industrial design engineering fueled my enthusiasm to delve into a project where these subjects intersect. By integrating these disciplines, my goal extends beyond the development of a customised manual groundnut thresher for Meru farmers. This project not only aims to deliver a comprehensive report but also seeks to contribute valuable insights to the realm of research. It serves as an example illustrating how co-creation and cultural anthropological research can significantly enhance design projects targeting emerging markets, aiming to be a source of inspiration for similar endeavours.

Before delving further into the project, I would like to express my gratitude to the people who have played pivotal roles in shaping and supporting this project. Special thanks to James Karanja from Batian and the entire Batian team for their collaboration on this exciting project. Next, gratitude to Eliud from 2SCALE for his valuable contributions throughout the preparation of research and fieldwork in Kenya. I also want to express my appreciation to my colleagues at Bopinc Kenya for their warm welcome and assistance with practical matters, as well as to my counterparts at Bopinc Utrecht. A heartfelt thank you to Nick for providing me with this fantastic opportunity for my graduation project and the continuous support throughout.

I would like to express my gratitude to Johan, my coach at Bopinc, for his invaluable assistance and guidance throughout my project. Our weekly meetings were filled with insightful discussions and practical advice, which played a significant role in shaping the project's success. Johan's genuine support and encouragement were truly motivating, keeping me engaged and enthusiastic throughout the entire process.

Wim, as my mentor, his creative ideas and our enjoyable conversations were truly enriching. His insights and encouragement added depth and perspective to my project, making it a more fulfilling journey. Last but not least, JC, thank you for your enthusiastic guidance along this journey. Throughout the entire project, I felt fortunate to have a wonderful team around me with Johan, Wim and JC. I always found our meetings were not only positive, energizing, and educational but also very relaxed, making the project even more valuable to me.

Image 4. Participants co-creation workshop. *Photograph by Sospeter Wachira.*

Summary.

In a collaborative effort spanning between the Netherlands and Kenya, this project aimed to enhance the livelihoods of smallholder farmers in the Meru region by designing a manual groundnut thresher. Recognising the importance of cultural context, I embarked on a journey guided by a cultural anthropological research approach, placing a strong emphasis on co-creation and iterative prototyping to ensure the tool's effectiveness and usability.

Through research, several challenges faced by smallholder farmers in Meru were uncovered. Handpicking groundnuts is labour-intensive and time-consuming, limiting productivity and income generation. Additionally, there is a lack of tools available to aid in the harvest of groundnuts, and the options found in other regions, such as Asia, were prohibitively expensive or unsafe.

This project fostered a collaborative environment where stakeholders from diverse backgrounds actively participated in the design process. Farmers, engineers, and students from a local technical institute worked together to co-create solutions tailored to the specific needs and preferences of the community. This inclusive approach ensured that the final product addressed the real challenges faced by farmers on the ground.

Prototyping played a prominent role in refining the design concepts and iterating towards the final prototype. We experimented with various mechanisms and configurations to optimise the thresher's performance and usability. Continuous feedback loops enabled us to make iterative improvements, ensuring that the final product met the standards of quality and functionality.

After multiple iterations and rigorous testing, we developed a working final prototype: the Manual Groundnut Harvester. This innovative tool streamlines the harvesting process, reducing the time and labour required to thresh groundnuts. Its design allows for easy operation by farmers of all skill levels, empowering them to increase their productivity and income. Additionally, the thresher's cultural sensitivity ensures seamless integration into the local farming practices, further enhancing its adoption and impact.

Image 5. Co-creation workshop.
Photograph by Marte Lanning.

Image 6. Prototyping in workshop.
Photograph by Marte Lanning.

Looking ahead, the project holds promising prospects for the future. The Manual Groundnut Harvester and its redesign have the potential to significantly improve groundnut farming in Meru, offering a sustainable solution to enhance productivity and livelihoods. Moreover, the collaborative approach serves as a model for future design projects, emphasising the importance of co-creation and cultural sensitivity in addressing complex socio-economic challenges.

In conclusion, this journey to design and develop the Manual Groundnut Harvester exemplifies the power of inclusive design and collaborative innovation. By leveraging local knowledge, expertise, and resources, we have created a solution that not only improves agricultural practices but also fosters economic empowerment and community resilience in the Meru region.

Image 7. Testing the final prototype at a groundnut farm.
Photograph by Marte Lanning.

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Image 8. Groundnuts.
Photograph by Marte Lanning.

01. Introduction

This report, created in collaboration with project partners Bopinc, 2SCALE, and Batian, explores the efforts to empower Meru farmers through innovative agricultural solutions. The primary focus lies in the (re)design of a locally manufactured manual thresher tailored to the specific needs of groundnut smallholder farmers in the Meru region of Kenya.

This project is based on the belief and personal vision that effective design solutions can only be developed through active collaboration with end-users. The vision of co-creation is at the heart of this project. It recognizes the significance of designing solutions that align with the realities of low-income consumers. To achieve this, the project strongly emphasises combining anthropological research methods with design methodology to engage local communities and relevant partners throughout the design process.

To facilitate this, the project unfolds in a dual setting, with initial research and refinement conducted in the Netherlands followed by two months of immersive fieldwork in Kenya. During the fieldwork phase, all activities are centred around co-creation, ensuring that local insights, preferences, and needs shape every aspect of the thresher's design.

The overarching objective of this project is to develop a manual thresher that is not only simple to use and efficient but also affordable and culturally relevant. To achieve this goal, the project is guided by five key subgoals:

- *Understanding challenges:* Investigating the specific challenges faced by smallholder farmers in Meru concerning groundnut farming.

- *Designing effectively:* Designing a manual groundnut thresher that effectively addresses these identified challenges.

- *Embracing co-design:* Exploring the role of co-creation in the development process of the manual groundnut thresher.

- *Maximising economic value:* Maximising economic value creation for smallholder farmers through the introduction of the manual groundnut thresher.

- *Culture-sensitive design:* Examining how a culture-sensitive design approach contributes to the success and adoption of the manual groundnut thresher in Meru.

Through a comprehensive exploration of these subgoals, this report aims to shed light on the intricate dynamics of agricultural innovation and the potential it holds for empowering farming communities.

02. Report structure

In this chapter, I will give a brief overview of the report's structure, which comprises three main phases: research, co-creation, and evaluation and recommendation. Each phase follows a structured methodology, starting with a description of the ecosystem at the highest level, moving on to a detailed analysis of the human-centred and technical aspects, and concluding with a focus on product-specific details. Just before diving into the product level, a brief interlude discusses the product requirements, which aid in the concretising of information and product-specific design guidelines.

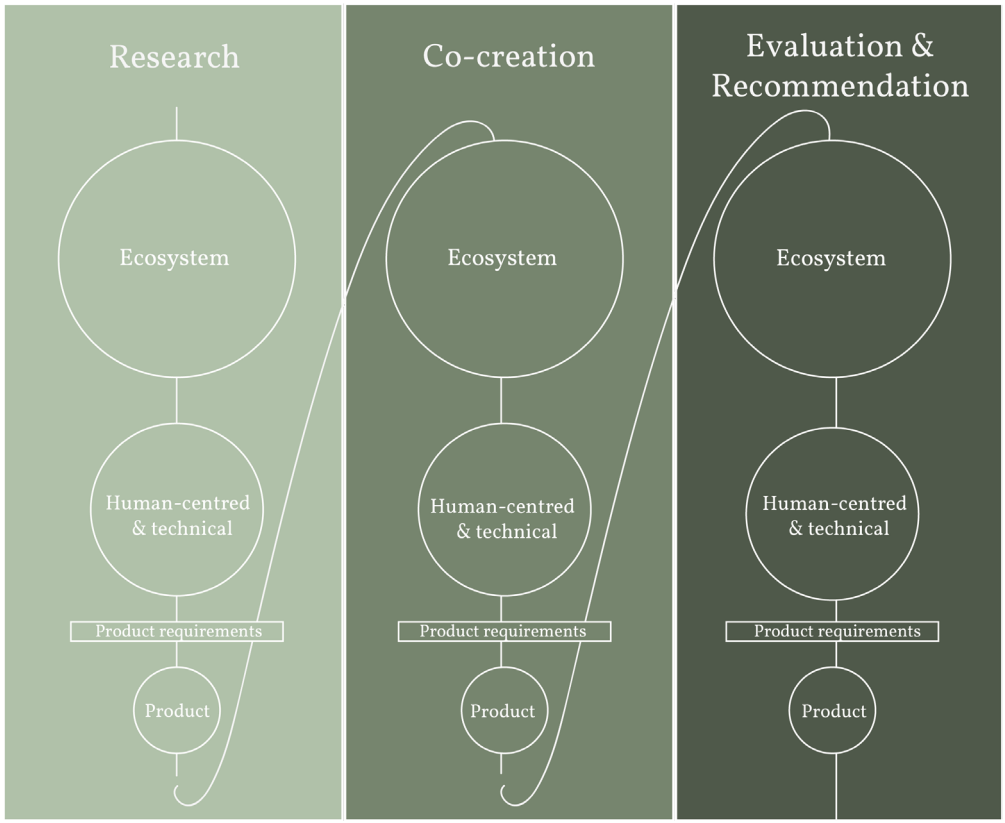


Image 9. Schematic overview of the report structure.

Each level of the report structure, indicated in the spheres, provides a comprehensive understanding of project development and its implications.

Ecosystem-level
This initial overview sets the stage by examining the broader context and systemic factors that influence the project. Understanding the larger ecosystem in which the project operates is crucial for identifying opportunities and challenges.

Human-centred and technical level
This level delves deeper into the human-centred aspects, such as user needs, preferences, and cultural context, alongside the technical considerations related to product design and functionality. By exploring both dimensions, the project ensures that the resulting solutions are not only feasible from a technical standpoint but also resonate with the intended users.

Product Requirements
The product requirements serve as a guiding framework throughout the design and development process of the thresher prototype. The product requirements act as a reference point for evaluating design concepts, making design decisions, and assessing the performance of the prototype. Therefore, the report is structured so that for each phase, the report outlines the product requirements after the two higher levels, providing specific guidance for that phase's product level. Furthermore, the product requirements play a crucial role in guiding the iterative design process, ensuring that the prototype evolves in a way that maximises its potential impact and relevance to the target users.

Product-level
At this level, the focus shifts to the specific details of the product

design and implementation. Analysing the product features and specifications allows for a detailed examination of how the project objectives translate into tangible outcomes.

To help readers keep track of the reports' structure, the pages of each phase are given a specific colour and the corner of each page displays the current level. By structuring the report in this layered approach, the project can be systematically explored from different perspectives, enabling a holistic understanding of its complexities and facilitating informed decision-making throughout the process. The report maintains a consistent and comprehensive approach throughout each phase to examine the project's progression.

03. Research

This chapter describes the research phase that was mostly conducted prior to the fieldwork in Kenya. The information gathered at the ecosystem level and human-centred and technical level serve as the basis for the initial product requirements, which further guide the ideation process on the product level in this research phase. Image 10 illustrates the topics discussed at each project level during this phase. In this phase, subquestion one and two, which are discussed in the subsequent subchapter, are being addressed.

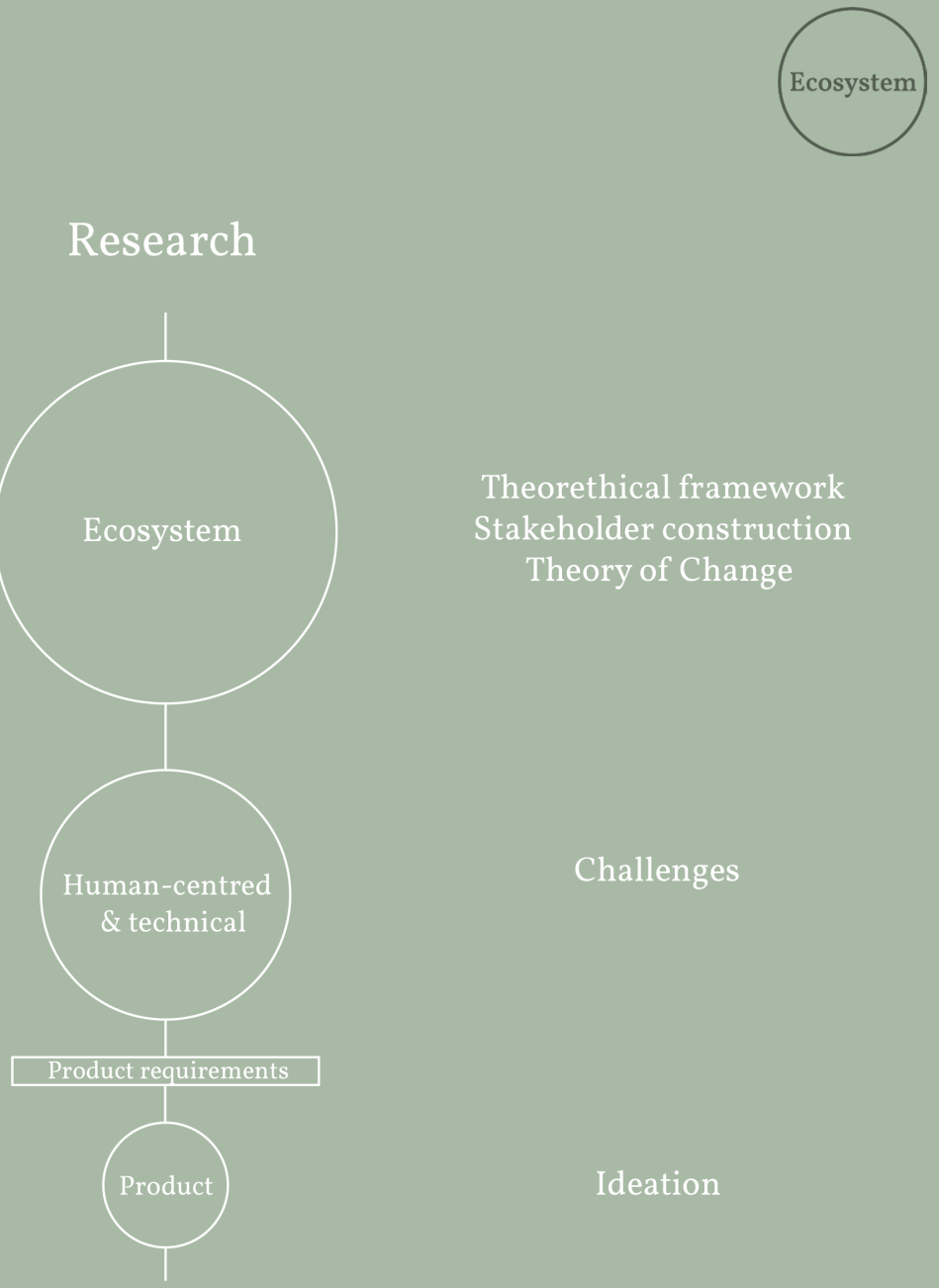


Image 10. Schematic overview of the research phase.

Ecosystem level

Theoretical framework

To provide direction to the research phase, the first step is to describe the theoretical framework and frame the overall project ecosystem. The theoretical framework provides a foundation for understanding the primary objective, sub-questions and key concepts.

The following main research question guides this thesis around addressing the challenges faced by smallholder farmers in Meru, Kenya, with the introduction of groundnut as a cash crop. The primary objective of this project is, to

"(Re)design a locally manufactured manual thresher which is simple-to-use, efficient, but affordable and fits the specific cultural context to create economic and social value for groundnut smallholder farmers in the Meru region in Kenya."

To give this project guidance, the main research question I ask myself during this project is: "How can the design and implementation of a locally manufactured manual groundnut thresher contribute to economic and social value creation for smallholder farmers in the Meru Region, Kenya?".

This overarching question can be broken down into several sub-questions to guide the research more effectively. By organising the sub-questions under thematic categories, I highlight different aspects of the project's impact and relevance, ranging from technical innovation to socio-economic development and cultural integration.

Sub-questions:

01. What are the specific challenges faced by smallholder farmers in Meru related to groundnut farming? (Socio-economic development)

02. How can a manual groundnut thresher be designed to address the identified challenges? (Technical innovation)

03. How effectively does the practice of co-creation contribute to the technical innovation and development of the manual groundnut thresher? (Technical innovation)

04. How can economic value creation be maximised for smallholder farmers through the introduction of the manual groundnut thresher? (Socio-economic development)

05. In what ways does a culture-sensitive design approach contribute to the success and adoption of the manual groundnut thresher in Meru? (Social and cultural integration)

The sub-questions discussed guide further research and development for this project. In this first phase 'Research', sub-question number one and two are addressed, mainly in the human-centred and technical level.

Stakeholder construction

This graduation project originates from a collaboration involving multiple organisations. Therefore, it involves various stakeholders, each with distinct interests in the project.

I am conducting my graduation project through Bopinc, an organisation dedicated to delivering quality products and services to low-income consumers. Bopinc collaborates with The International Fertiliser Development Center (IFDC) and SNV in the field of food and agriculture. The collaborative effort has given rise to the 2SCALE program, which serves as the framework for my graduation project. 2SCALE is an incubator program managing public-private partnerships in the agri-food sectors, emphasizing inclusive business practices.

The program's approach involves establishing agribusiness clusters around business champions and supporting small and medium-sized enterprises (SMEs) and farmer groups in producing high-quality food products for local and regional markets. The consortium implementing 2SCALE comprises the IFDC, Bopinc, and SNV, each contributing unique expertise to empower smallholder farmers in developing countries.

In this project, the business champion supported by 2SCALE is Batian Nuts Limited (Batian), an agro-processing company founded in 2017. Batian is mainly aiming to bridge the gap in off-taking macadamia nuts from smallholder farms in the Meru region, contributing to the livelihoods of farmers and environmental conservation. This graduation project leverages Batian's focus on the groundnut market, which they have been concentrating on for several years now next to macadamia.

To understand the structure of this graduation project, it is vital to note that Bopinc facilitated my connection with Batian, a business champion, through the 2SCALE initiative. This collaboration forms the foundation of the project.

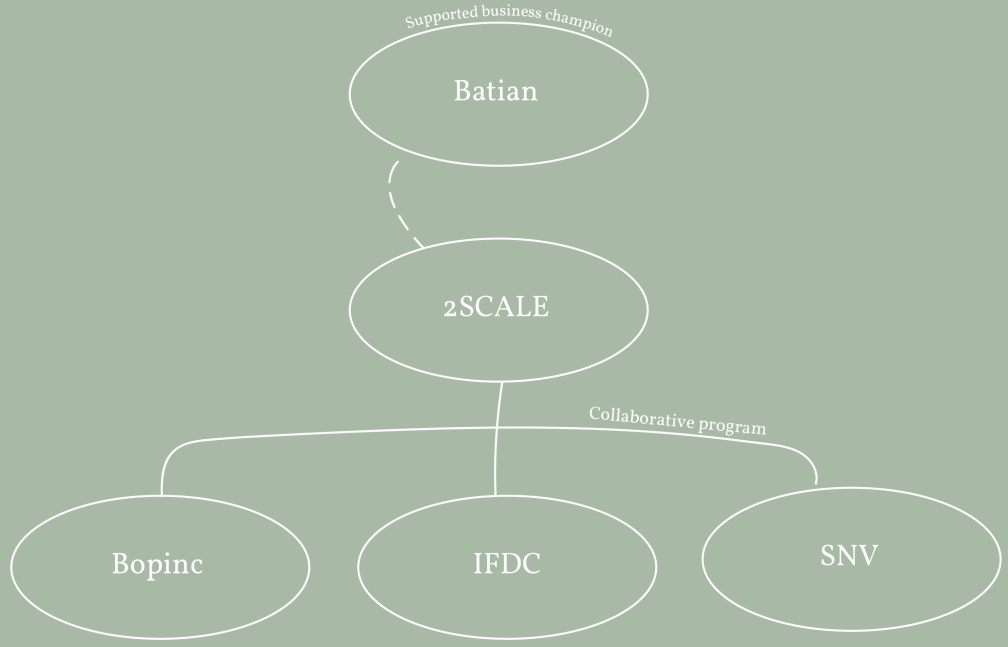


Image 11. Stakeholder construction.

Theory of Change

It is crucial to acknowledge that this project represents a single step towards a broader goal: enhancing the quality of life for low-income consumers. Therefore, I provide an overview of the Theory of Change (ToC) developed for this project. The ToC offers a framework to comprehend the various levels of impact this project aims to accomplish, ranging from immediate outcomes to broader systemic changes.

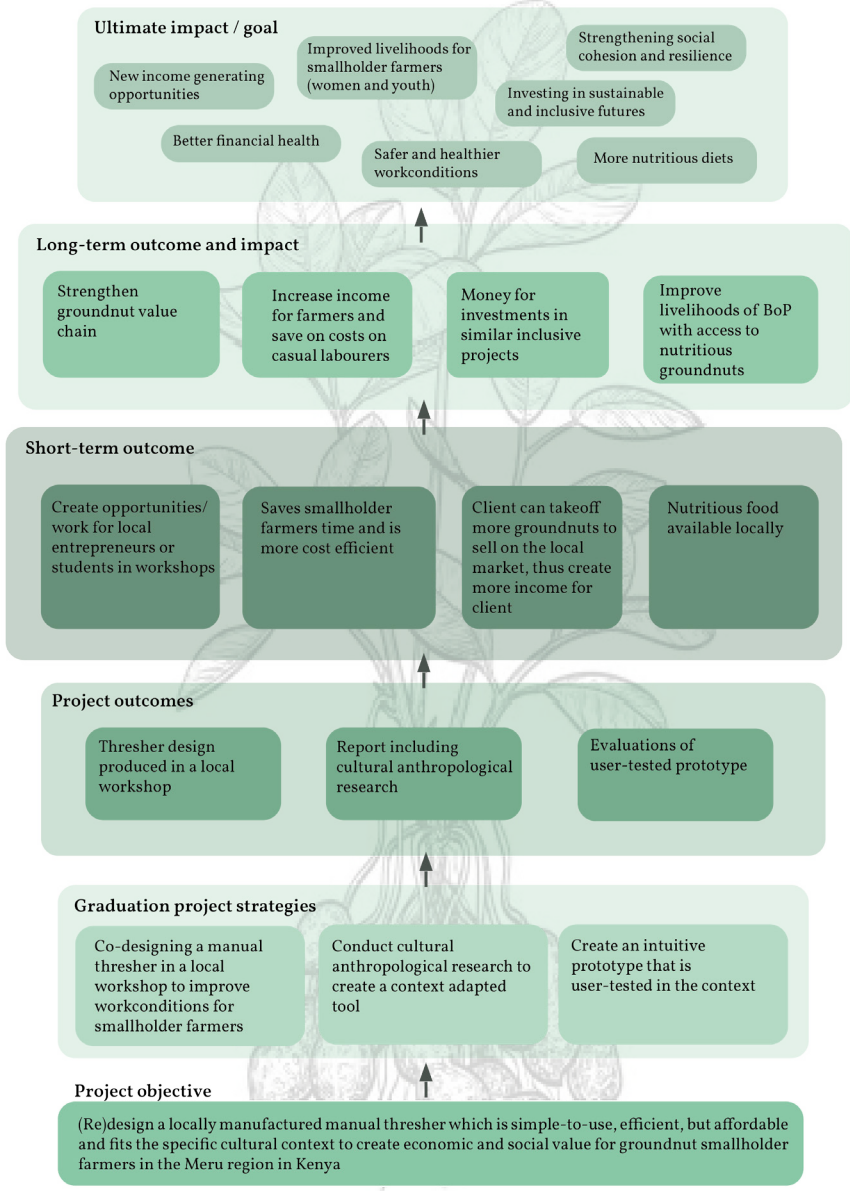


Image 12. Theory of Change overview from the "Empowering Meru Farmers" project.

Human-centred and technical level

Challenges

Following the exploration of the broader ecosystem in the research phase, the focus shifts to the human-centered and technical dimensions. At this level, the focal point is the first sub-question of the project:

01. What are the specific challenges faced by smallholder farmers in Meru related to groundnut farming?

Learning from research into the context of smallholder farmers in Kenya (see appendix 2), exploring groundnuts and their farming practices (see appendix 3), conducting participant observation at groundnut farms in the Meru Region to design a persona (see appendix 4) and examining a benchmark of currently available tools (see appendix 5), give insight into challenges that are faced by groundnut farmers:

Image 13. Woman handpicking groundnuts.
Phototgraph by Marte Lanning.

Current challenges in groundnut farming

- **Harvesting is labour intensive**: The labour-intensive nature of manual groundnut threshing poses an obstacle for farmers. (See appendix 4)

- **Harvesting is costly**: Smallholder farmers often resort to hiring casual labourers, leading to increased harvesting costs. (See appendix 2)

- **Lack of access to affordable and efficient tools**: Smallholder farmers face challenges in accessing suitable equipment for groundnut farming. While motorised threshers are available, they are prohibitively expensive. Additionally, manual threshers specifically designed for groundnut farming are not available in the region. (See appendix 2 and 4)

- **Absence of affordable and efficient tools**: Using manual threshing tools currently available in Kenya poses a challenge, as they are not tailored for groundnut farming. (See appendix 5)

- **Absence of affordable and efficient tools**: Tools available in other parts of the world are either too expensive, motorised, labour-intensive, or unsafe, posing challenges for smallholder farmers. (See appendix 5)

- **Lack of alternative goods**: There is a scarcity of affordable and efficient options specifically designed for threshing groundnut. Self-made tools, while used, are of low quality, inefficient, and prone to frequent breakage. (See appendix 5)

Specific challenge regarding groundnut:

- **Aflatoxin**: Mitigating aflatoxin contamination in groundnut farming poses a critical health and safety challenge. (See appendix 3)

Context-specific challenges:

- **Budget constraints**: Farmers operate within limited budgets, challenging for cost-effective solutions. (See appendix 2)

- **Local adaptation**: Designing tools that are tailored to the local context and affordable presents a key challenge for viability and adoption. (See appendix 5)

To answer sub-question number one, it can be concluded that groundnut farming encounters various challenges that impede its efficiency and productivity. These challenges include the usage of labour-intensive threshing techniques, the costly hiring of casual labourers, and a lack of access to affordable and efficient tools. The current options available are either too expensive or unsuitable for groundnut farming, which aggravates the issue. Additionally, the presence of aflatoxin contamination further complicates the situation, necessitating customised solutions that cater to the local context and affordability constraints.

Image 14. Bicycle wheel used as a tool to thresh groundnuts. *Phototgraph by Marte Lanning.*

Image 15. Women handpicking groundnuts in a field. *Phototgraph by Marte Lanning.*

Product requirements

Before delving into the product level, it is crucial to discuss the product requirements. These product requirements are based on the research and information gathered from the previous levels. They serve as guidance for the product level. During this research phase, the challenges identified in the previous level are translated into product requirements. These product requirements are the first step towards answering sub-question number two:

> 02. How can a manual groundnut thresher be designed to address the identified challenges?

Subsequently, in the 'Co-creation' phase, I will delve deeper into this question through the development and refinement of the final prototype, elucidating the decisions that inform its design.
To structure the information from the previous chapters into product requirements, these are organised into three distinct categories:

Social Anthropological Context: This category encompasses the socio-cultural aspects that affect the design and usability of the groundnut thresher. It takes into account factors such as local traditions, community dynamics, and user preferences, to ensure that the design aligns with the social context of the target community.

Product Specifications: Here, specific technical specifications and performance criteria for the groundnut thresher are outlined. These specifications cover aspects such as efficiency, ease of use, and safety features, aiming to optimise the functionality and usability of the final prototype.

Workshop Capacities: This section covers the practical aspects of manufacturing and maintaining the groundnut thresher. It includes requirements for workshop infrastructure, equipment, and skills needed for assembly, fabrication, and repair of the thresher.

By delineating these product requirements, this chapter serves as a guidepost for the subsequent ideation process. It provides a framework within which design concepts can be developed and evaluated, ensuring that the resulting groundnut thresher not only addresses the identified challenges but also resonates with the socio-cultural context and practical realities of the target community. The product requirements list will be expanded upon in subsequent phases of the report as new requirements are identified.

Requirement category	Nr.	Product requirement	Derived from
Social Anthropological context	1	The thresher can be used in the field, to fit the context in which threshing is normally done.	Participant observation: Observing how groundnut threshing is currently done.
	2	The product is affordable for (a group of) farmers to buy.	Project objective client and participant observation: speaking to the intended users.
	3	The thresher can comfortably be operated by men, women and youth.	Participant observation: Asking who is harvesting the groundnuts
	4	The thresher is safe for when little children are around.	Participant observation: Observing the environment and context of groundnut harvesting.
	5	The thresher design is based on local knowledge and expertise to encourage local innovation.	Anthropological desk research on similar projects. See appendix 2.
Product specifications	1	The thresher has clear use cues, making it an intuitive machine, so it is easy to use by farmers with basic skills.	Benchmark tools and participant observation: observing what skills the farmers have.
	2	The threshing process is clean and dry, and contact of clean pods with moist/ soil is avoided.	Desk research on groundnut farming. See appendix 3.
	3	Groundnuts are collected easily after the threshing process.	Participant observation: observing the threshing and storing process.
	4	The thresher works for all groundnut varieties.	Desk research on groundnut farming in Kenya. See appendix 3.
	5	The thresher is significantly more efficient than handpicking.	Project objective from the client.
	6	The thresher does not require power or electricity in order to operate.	Project objective client and participant observation: observing that smallholder farmers do not always have access to electricity or the financial means to buy petrol.
	7	The thresher does not pose any damage to the product; the groundnut pods.	Project objective client.
	8	Thresher is cost-effective; providing value for money, and balancing the initial investment cost with long-term benefits and operational efficiency.	Project objective client.
	9	While using the thresher, there are no specific risks to safety.	Benchmark tools. See appendix 5.
Workshop capabilities	1	The thresher can be manufactured and repaired in workshops located in Meru. With skills and tools locally available.	Project objective client.
	2	The thresher can be made out of locally available materials (within a one-hour drive).	Project objective client.

Image 16. Product requirements of the research phase.

Product level

Ideation

Coming to the product level in the Research phase, the ideation process of the manual thresher project is discussed. The ideation process is guided by the product requirements and the second sub-question on "how to design a manual groundnut thresher to address the identified challenges". Furthermore, through the exploration of currently available tools and by evaluating various principles from existing tools (see appendix 5) 4 categories of criteria are identified, which inform the ideation phase and inspire the design of a potential prototype.

Safety

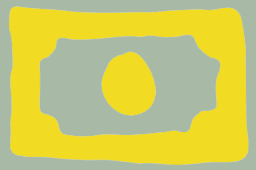
"The machine is without physical risks for people using or being around it"

Based on anthropological research and exploration of current available tools.

Power

"The machine is easily operated without much effort"

Based on product requirements from stakeholders.



Price

"The machine is realistically affordable for smallholder farmers"

Based on anthropological research and insights from the client.

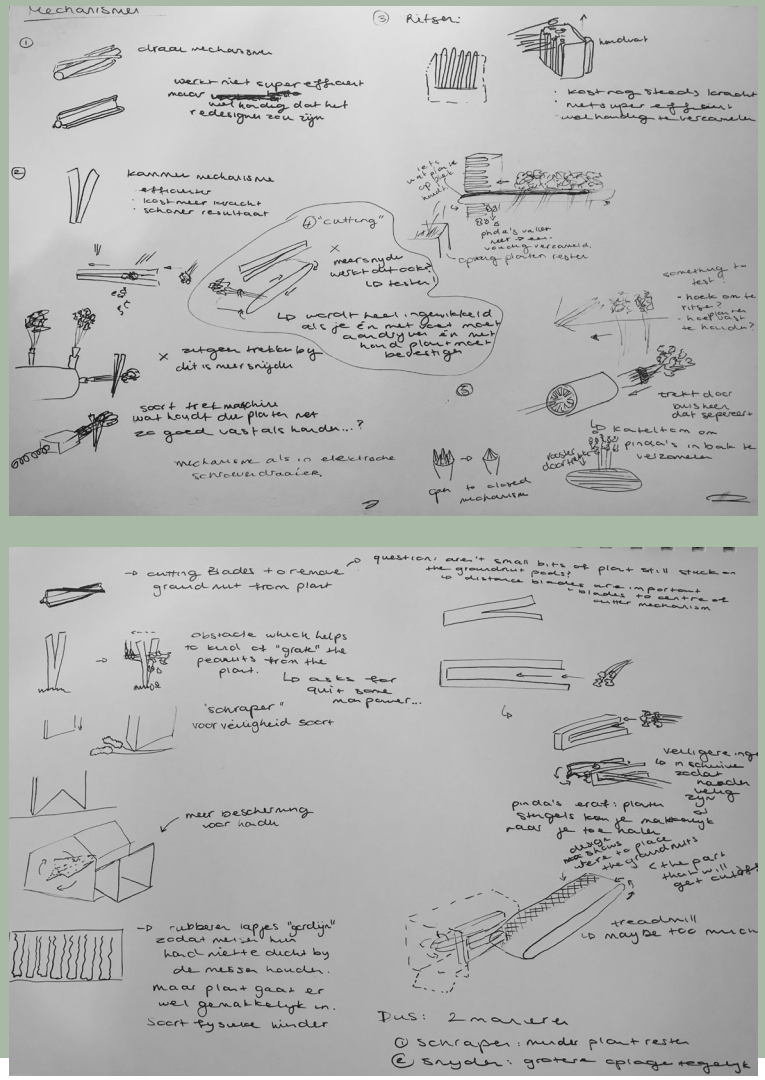
Efficiency

"The machine significantly increases the efficiency of threshing compared to doing it by hand"

Based on product requirements and research into groundnut farming.

Image 17. Criteria for ideation.

The criteria mentioned here aid in generating ideas for potential concepts for prototyping, as depicted in images 18, 19 and 20. Besides the predefined product requirements, these criteria also facilitate the evaluation of ideas before my involvement in the co-creation phase's conceptualisation and prototyping stage.



Images 18 & 19. First ideation drawings.

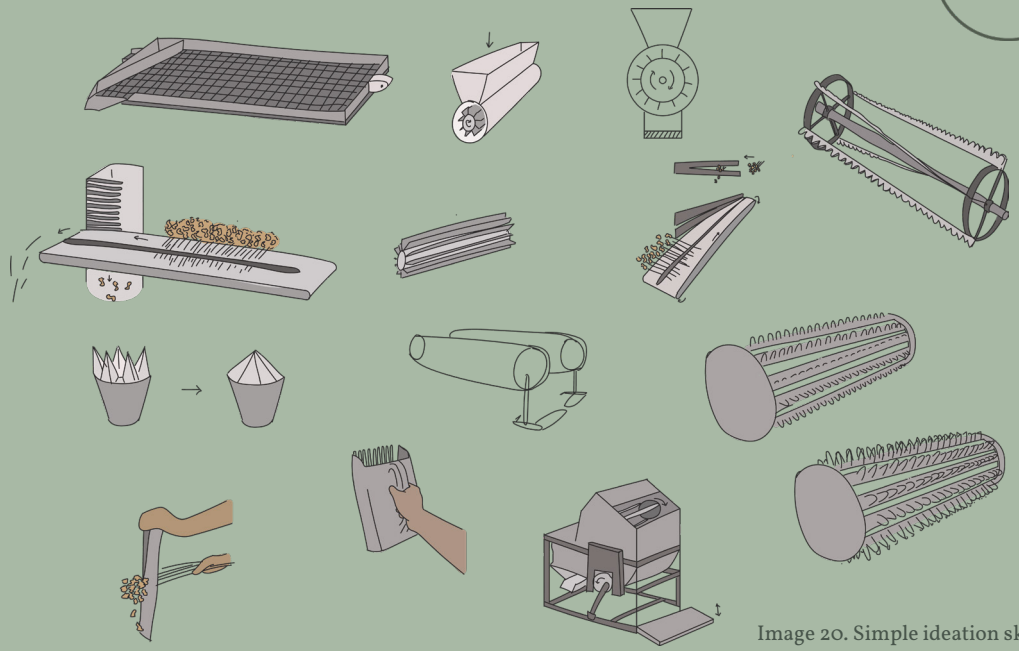


Image 20. Simple ideation sketches.

From the ideation and initial evaluation of ideas, the following conclusions follow, which will be taken into the Co-creation phase where the conceptualisation process will continue:

- I want to prototype and test a few different mechanisms for threshing and find out what technique is most effective.
- I want to discuss various transmission mechanisms with the prototyping team and discuss what they think would fit best in the context and for the intended users. Also, discuss this with groundnut farmers before prototyping.
- A mechanism based on the technique of rotating blades seems promising, more so if I can incorporate a so-called "strip" technique into it which is used when stripping berries or grapes.

04. Co-creation

In this chapter, I will discuss the fieldwork in Kenya, which was entirely devoted to the co-creation of the groundnut thresher prototype. All the different activities revolved around co-creation, hence the name of the phase. The image in question illustrates the topics that are discussed at each project level during this phase. In this phase, subquestion two is further addressed, as well as subquestion three:

02. How can a manual groundnut thresher be designed to address the identified challenges?

03. How effectively does the practice of co-creatiocontribute to the technical innovation and development of the manual groundnut thresher?

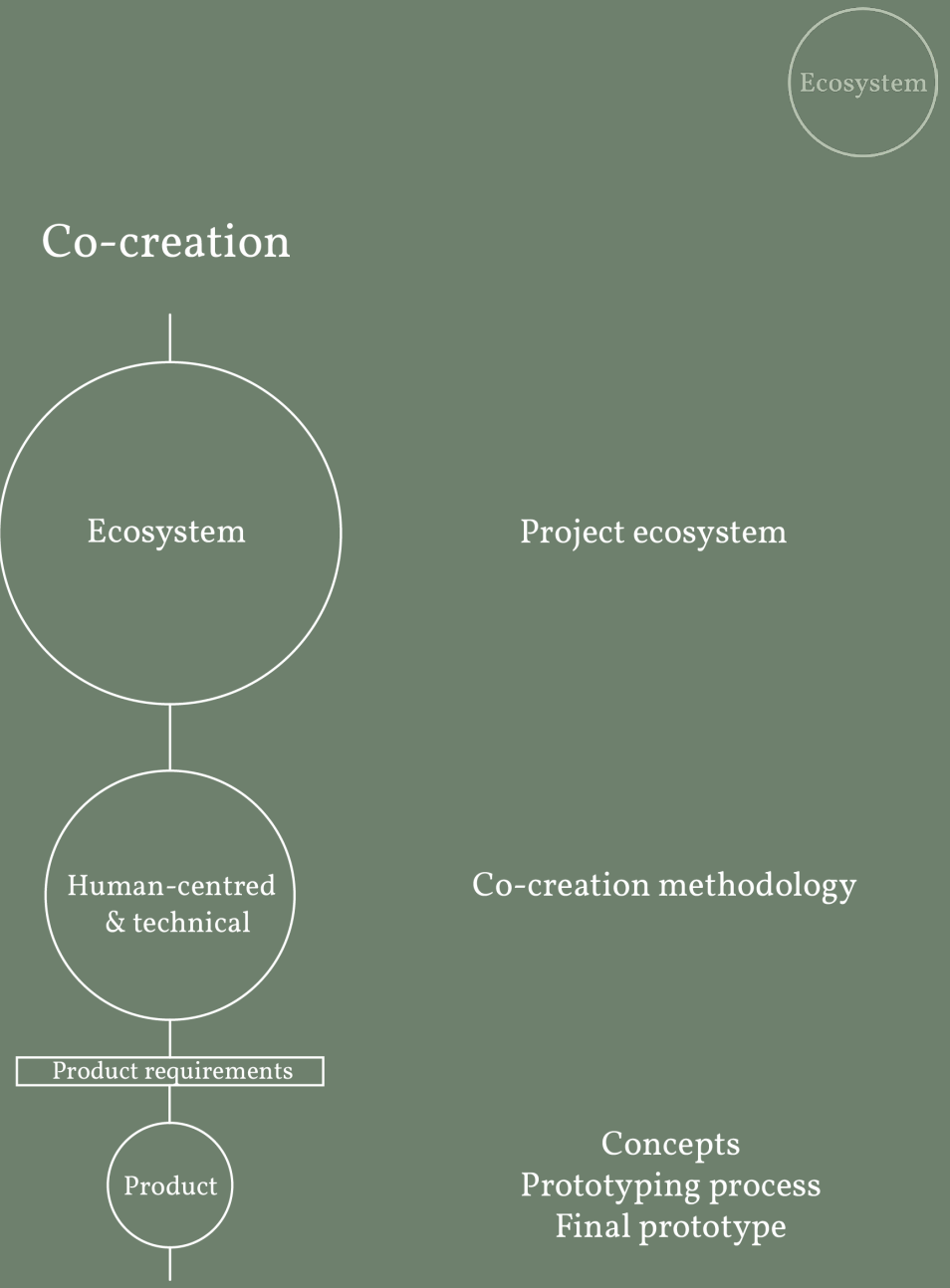


Image 21. Schematic overview of the co-creation phase.

Ecosystem level

Project ecosystem

Co-creation is of great importance in this project as it ensures that the final prototype aligns with the needs, preferences, and contexts of the stakeholders involved. By actively involving these stakeholders in the design process, I not only gain valuable insights and expertise but also foster a sense of ownership and empowerment within the community. During my fieldwork in Meru, I have identified and organised the key players in the ecosystem related to the groundnut thresher. These diagrams, see image 22 and 23, illustrate the ecosystem of the current situation and that of the envisioned situation. This latter ecosystem shows the stakeholders' relations and serves to understand the co-creation strategies I will be using in the upcoming stages.

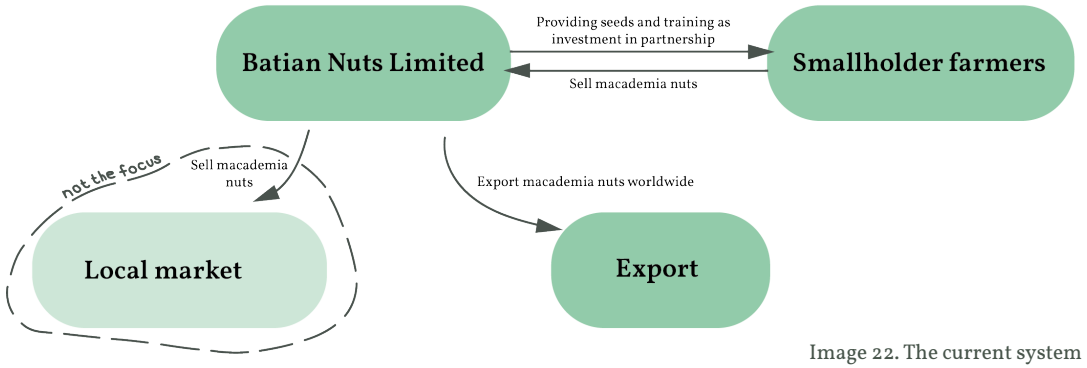


Image 22. The current system around macadamia nuts.

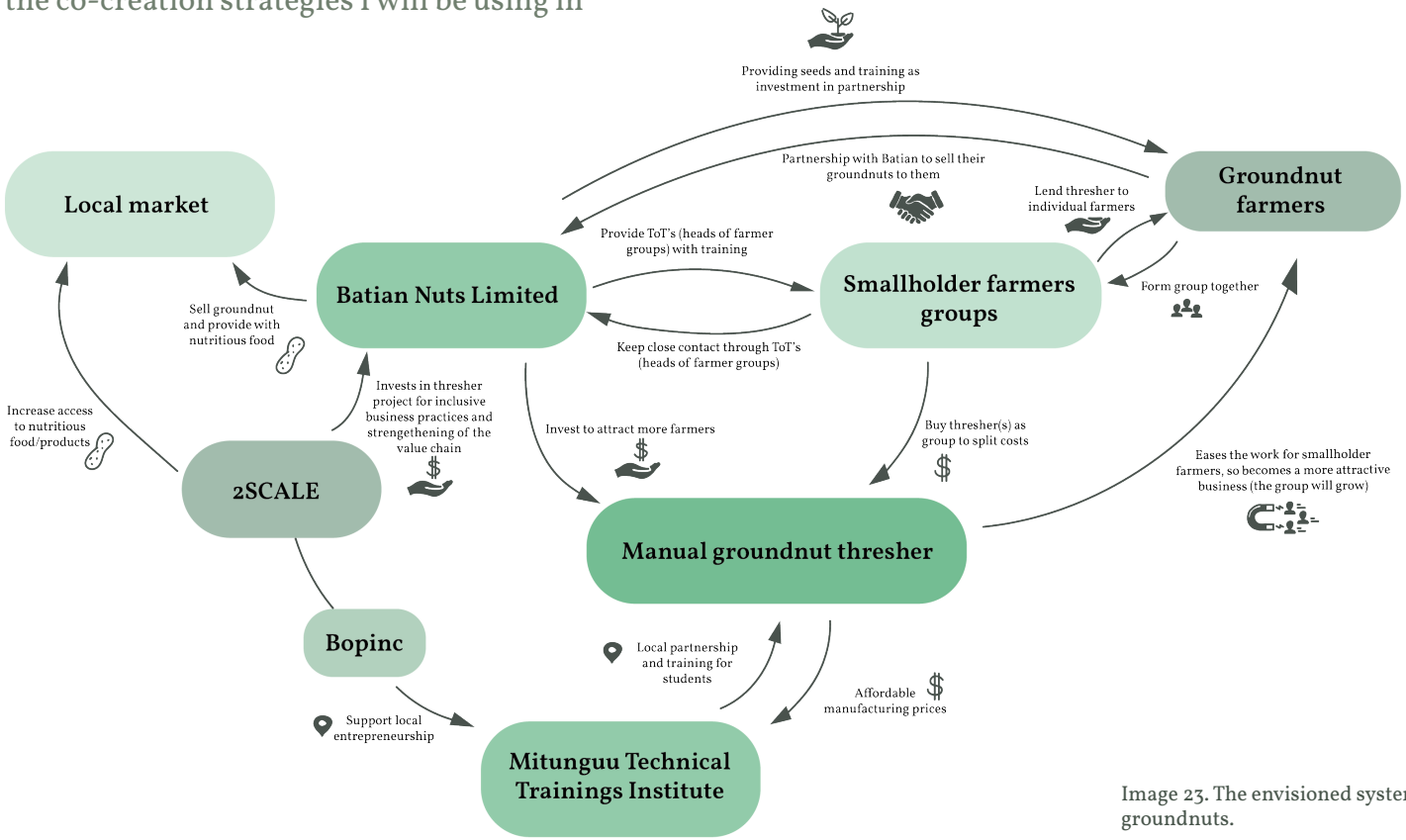


Image 23. The envisioned system around groundnuts.

Human-centred and technical level

Co-creation methodology

Throughout the project, I prioritised personalised communication strategies to engage effectively with stakeholders at all levels, including those within the system (see image 23). This included participant observation at some farms (see appendix 2 and 4) to establish direct contact and rapport. To facilitate open and comfortable communication, I ensured the presence of a familiar representative from Batian, someone known and trusted by the farmers, who could communicate fluently in their preferred language, whether Swahili or their mother tongue. This approach aimed to create a conducive environment where farmers felt comfortable sharing their insights and experiences.

Additionally, a workshop was organised (see appendix 8) that brought together most stakeholders, providing a platform for representatives of stakeholder groups to contribute their ideas and perspectives. As detailed in the appendix, the workshop brought together smallholder farmers, technicians, and Batian employees. This workshop encouraged open discussions in both larger group settings and smaller, more intimate groups where participants could converse comfortably in Swahili or their preferred language. In these groups, it was also made more comfortable for participants to make their contributions somewhat anonymously.

All information gathered during these activities has been integrated into the product requirements, detailed in the subsequent subchapter (see page 30).

The prototyping process also involved co-creation. Before creating the prototypes, I presented my concepts (refer to page 32) to a team of engineers from Batian. They then assisted me in bringing my ideas to life. During the prototyping process, co-creation was a constant factor. Batian's engineers and students from the Mitunguu Technical

Image 24. Testing the final prototype at a groundnut farm. *Photograph by Marte Lanning.*

Training Institute collaborated with me in an iterative process where ideas were discussed and choices were made. These ideas were then developed further until they were finalised.

After the initial interactions, we (the engineering team) maintained regular communication with the stakeholders to seek ongoing feedback and input. We regularly went to farmers to test the prototype (see image 24), creating feedback loops that facilitated ongoing input from the end-users during the design process. This continuous engagement allowed for the incorporation of diverse perspectives throughout the design process, ensuring that the final product addressed the varied needs and preferences of all the stakeholders involved.

To answer sub-question three "How effectively does the practice of co-creation contribute to the technical innovation and development of the manual groundnut thresher?", I can highlight the role of co-creation throughout the project. In implementing personalised communication strategies, I aimed to foster a collaborative environment where all stakeholders could actively participate and contribute their insights. Through a workshop and direct engagement with farmers, a co-creative process was facilitated that allowed for the integration of diverse perspectives into the design phase. Without co-creation, there's a risk of overlooking crucial user needs and preferences, resulting in a less effective and user-friendly product. In contrast, co-creation fosters an inclusive environment where stakeholders actively participate in the design process. This collaborative approach ensures that the final product is not only technically innovative but also aligns closely with the real-world needs of smallholder farmers. By incorporating continuous feedback loops and iterative improvements, co-creation maximised the likelihood of developing a successful and impactful solution for groundnut farming challenges.

Product requirements

The activities at the human-centred and technical level, like the co-creation workshop, generated fresh insights, resulting in added product requirements that steered the design process for the groundnut thresher prototype. Additionally, a thorough assessment of workshop capacities (refer to appendix 10) informed these new product requirements. This list of requirements serves as a blueprint for the design and prototyping phase, which is detailed in the following chapter on the product level. Moreover, these product requirements facilitate prototype evaluation and guide the iterative process. Through farmer testing, new requirements emerge or existing ones are reaffirmed, contributing to continuous refinement. The visual depicts the additional requirements incorporated into the initial list from the research phase.

Requirement category	Nr.
Social Anthropological context	1
	2
	3
	4
	5
	6
Product specifications	1
	2
	3
	4
	5
	6
	7
	8
	9
	10
	11
	12
	13
	14
Workshop capabilities	1
	2

Product requirement	Derived from
The thresher can be used in the field, to fit the context in which threshing is normally done.	Participant observation: Observing how groundnut threshing is currently done.
The product is affordable for (a group of) farmers to buy.	Project objective client and participant observation: speaking to the intended users.
The thresher can comfortably be operated by men, women and youth.	Participant observation: Asking who is harvesting the groundnuts
The thresher is safe for when little children are around.	Participant observation: Observing the environment and context of groundnut harvesting.
The thresher design is based on local knowledge and expertise to encourage local innovation.	Anthropological desk research on similar projects. See appendix 2.
The users (smallholder farmers) are included into the design process, so the design fits to their wishes.	Benchmark tools, expert meetings, and participant observation: observing what skills the farmers have. See appendix 4 and 5.
The thresher has clear use cues, making it an intuitive machine, so it is easy to use by farmers with basic skills.	Benchmark tools and participant observation: observing what skills the farmers have.
The threshing process is clean and dry, and contact of clean pods with moist/soil is avoided.	Desk research on groundnut farming. See appendix 3.
Groundnuts are collected easily after the threshing process.	Participant observation: observing the threshing and storing process.
The thresher works for all groundnut varieties.	Desk research on groundnut farming in Kenya. See appendix 3.
The thresher is significantly more efficient than handpicking.	Project objective from the client.
The thresher does not require power or electricity in order to operate.	Project objective client and participant observation: observing that smallholder farmers do not always have access to electricity or the financial means to buy petrol.
The thresher does not pose any damage to the product; the groundnut pods.	Project objective client.
Thresher is cost-effective; providing value for money, and balancing the initial investment cost with long-term benefits and operational efficiency.	Project objective client.
While using the thresher, there are no specific risks to safety.	Benchmark tools. See appendix 5.
The thresher can be operated by just one person.	Co-creation session: wish from smallholder farmers.
The thresher is movable on a motorcycle to transport from farm to farm.	Co-creation session: wish from smallholder farmers.
The thresher is comfortably movable over bumpy farm ground.	Co-creation session: wish from smallholder farmers.
The thresher is easily repairable.	Co-creation session: wish from smallholder farmers.
The machine requires minimum manpower when operating. No more labour is required than handpicking.	Co-creation session: wish from smallholder farmers.
The thresher can be manufactured and repaired in workshops located in Meru. With skills and tools locally available.	Project objective client.
The thresher can be made out of locally available materials (within a one-hour drive).	Project objective client.

Image 25. Product requirements of the co-creation phase.

Product level

In the previous subchapter (see 'product requirements'), it was discussed how the product requirements obtained from both the research and co-creation phase could help in the conceptualisation of ideas and the prototyping process. This section presents these processes and, next to that, the final prototype from the prototyping process at the workshop in Meru that has been tested and validated. With the presentation of the final prototype, this section answers sub-question two on "How can a manual groundnut thresher be designed to address the identified challenges?".

Concepts

Drawing from the ideation phase (see page 24), the refined product requirements, and discussions with the engineering team aiding in the prototyping process, I have selected concepts for prototyping. My main objective is to design an efficient groundnut threshing technique, which will be followed by focusing on other components of the thresher. Therefore, I have decided to initially focus on creating and testing the following techniques:

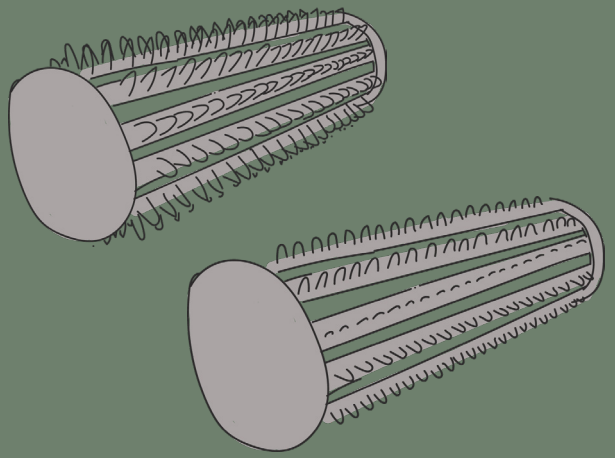


Image 26. Concepts 1a and b for the threshing technique.

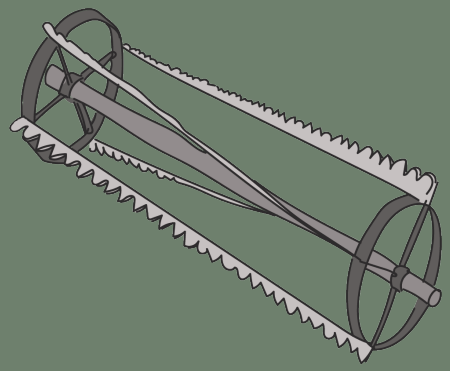


Image 27. Concept 2 for the threshing technique.

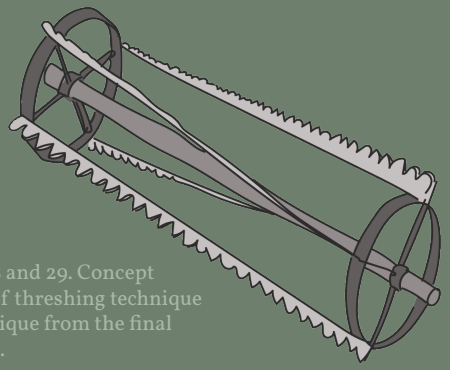
Both concepts incorporate rotating blades, yet they feature distinct patterns inspired by the berry stripping principle. Through these techniques, I aim to develop an efficient threshing method for groundnuts that delicately separates pods from the plant while not breaking them. The prototyping process will reveal whether and which technique proves effective, and whether it aligns with the requirements outlined in the product requirement list.

Prototyping process

To encourage co-creation during the prototyping process, I avoid detailing concepts extensively. Instead, I leave room for new ideas that may emerge during the prototyping phase. The concepts serve as a starting point for prototyping, while the ideas act as inspiration during the prototyping process. By consulting regularly with the engineering team, we gradually generate new options in the workshop that we subsequently test. During the prototyping process, we also seek feedback from farmers, which enables us to keep design options open and incorporate their input. As new plans emerge, I make sketches and develop them iteratively (see appendix II), with input from various stakeholders, including Batian engineers, students from a local technical institute, Batian agribusiness experts, and farmers. For a comprehensive look at the prototyping process, see appendix II.

The main conclusions from the prototyping process are listed here:

The efficiency of threshing techniques: Through testing different techniques, starting with an extensive exploration of bent nails, it was found that the technique like image 28 was the most efficient. Image 29 shows how this looks in real life.



Images 28 and 29. Concept drawing of threshing technique and technique from the final prototype.

Sizing: The prototype is designed to accommodate Kenyan people's heights, allowing for threshing to be done standing up. It is suitable for use by older children (teenagers) and adults, of both genders.

Single-user mechanism: Incorporating a foot pedal mechanism aimed at single-user operation faced challenges in achieving smooth and reliable functionality, requiring adjustments to make it work eventually.

Enhancing shaft rotation speed: Adjustments to the pivot axis, pedal mechanism, and pulley size improved shaft rotation speed.

Safety measures implementation: The incorporation of safety features, such as the addition of a safety bar and the adaptation of the threshing mechanism to minimise risk to users' hands, significantly enhanced user safety.

Adaptation to farm context: Adding extendable handles and a wheel to the thresher prototype facilitated ease of movement and operation within the farm context. Farmers were able to manoeuvre the machine easily over rough terrain, enhancing its practicality and usability in real-world farming environments.

Feedback from initial farmer testing: Farmer feedback highlighted the need for improvements in pedal mechanism usability, safety enhancements, and adjustments to the threshing technique.

Final farmer testing: Testing with dry groundnuts revealed that the adjusted threshing mechanism was safer and more comfortable for users, resulting in increased efficiency and ease of use.

Final prototype design of the Manual Groundnut Harvester

Design rationale and clarification

This section discusses the design of the final thresher prototype. Firstly, providing a general overview of how the machine operates and its intended user base. Then, delving into the prototype's design in detail, highlighting specific design choices made to address key considerations. Furthermore, evaluating the prototype against established criteria, including safety, power, efficiency, and price, to ensure its alignment with user needs and project objectives. Transitioning to the final prototype, the thresher is now also denoted as the Manual Groundnut Harvester. The term "harvester" aligns with the terminology familiar to local smallholder farmers, reflecting their customary naming convention for such machinery.

The thresher works by using a pedal mechanism to set the rotating blades with the specific pattern in motion. The speed of the foot pedal directly affects the rotation speed of the blades. To begin threshing, a three-day dried groundnut plant is inserted into the opening by the user of the thresher (see image 33), allowing the groundnuts to come into contact with the blades. These blades have small slots that provide a picking technique for the groundnut. Regardless of direction, the spinning motion effectively dislodges the groundnuts from the plant.

Image 30.
Testing the final prototype at a groundnut farm.
Photograph by Marte Lanning.

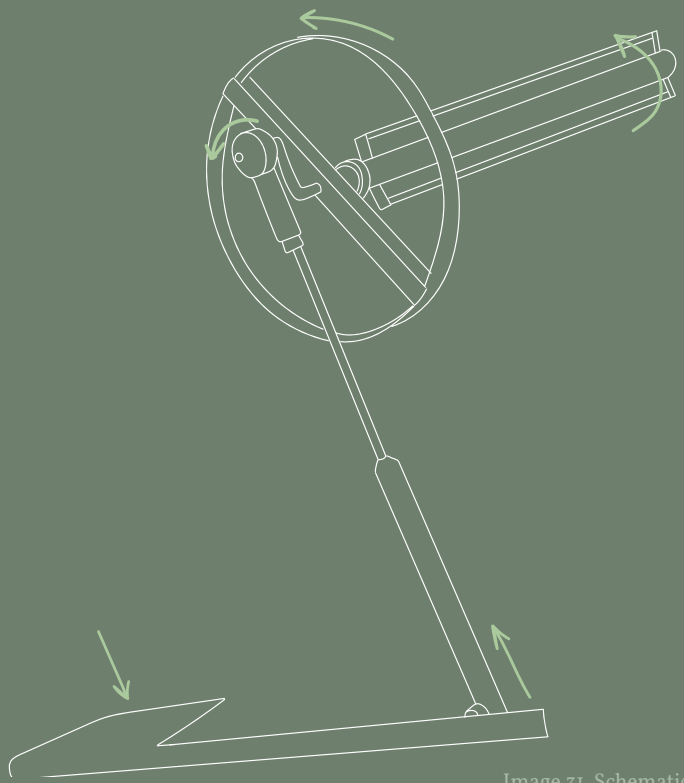


Image 31. Schematic drawing of the working of the foot pedal mechanism connected to the rotating blades with threshing technique.

The separated groundnuts are then collected in a container positioned underneath the machine and guided to one side for easy retrieval. The thresher has been designed to be accessible to individuals of varying ages and physical abilities, including both men and women, as it requires minimal strength, relying primarily on foot movement and the ability to hold the plant. Moreover, the machine's design enables it to be moved easily around the farm using a wheelbarrow technique, ensuring flexibility in the location of harvesting. Its height allows for comfortable use by both teenagers and adults, enhancing its usability across different demographics within the farming community.

Image 32. The Manual Groundnut Harvester in use.
Photograph by Marte Lanning.

Image 33. Using the safety bar while threshing with the Manual Grounut Harvester.
Photograph by Marte Lanning.

Design details

Blades

The prototype has a threshing mechanism with three steel blades attached to a central shaft. These blades have notches of 2mm that allow for efficient plucking of groundnuts. The dimensions of the notches are crafted to ensure optimal performance. When dried groundnut plants (usually left to dry for three days) are processed, the notched blades gently suspend the groundnuts through their rotary motion, effectively separating them from the plant without causing any damage. It is important to note that the notches are small enough to dislodge groundnuts efficiently while being sized to prevent any entanglement of plant stems or roots during the threshing process. This design feature guarantees smooth and efficient operation, minimising machine jamming and damage, and enhancing longevity and reliability.

Image 34. The blades with the threshing mechanism. *Photograph by Marte Lanning.*

Image 35. Notches in the blades. *Photograph by Marte Lanning.*

Image 36. Attachment of the shaft and blades to a pully. *Photograph by Marte Lanning.*

Foot pedal mechanism

The design of the manual thresher is operated through a foot pedal mechanism that has been chosen for various reasons. Firstly, farms without access to electricity eliminate electric-powered options. Secondly, utilising a petrol engine for power would require a consistent supply of petrol, which may not always be accessible or financially feasible for farmers in these areas. In addition to addressing the limitations of electricity and petrol-powered options, the foot pedal design offers several advantages. Firstly, it is simple and intuitive to use, partly because it is similar to commonly used machines in the region such as sewing machines, and therefor requires minimal training for farmers to operate effectively. This simplicity not only reduces the need for complex maintenance but also ensures that the thresher can be used by farmers of varying ages and levels of experience. Moreover, the foot pedal design allows for consistent and controlled power input, enabling users to adjust the speed of rotation based on their preferences and the conditions of the groundnuts being threshed. This level of control enhances efficiency and ensures a thorough threshing process, ultimately maximising the yield of groundnuts while minimising the effort required from the user.

Overall, the foot pedal design offers a reliable, cost-effective, and user-friendly solution for groundnut threshing in environments where alternative power sources may be limited or inaccessible.

Image 37. Foot pedal.
Photograph by Marte Lanning.

Image 38. Foot pedal connection to pully and threshing mechanism.
Photograph by Marte Lanning.

Image 39. Pully connection.
Photograph by Marte Lanning.

Safety bar

Incorporating safety features is paramount in the design of the prototype, ensuring user protection and operational efficiency. One key safety element is the inclusion of a sturdy safety bar positioned around the threshing mechanism. This safety bar serves multiple purposes: it provides a secure grip for the user, offering stability and control during operation, while also acting as a protective barrier between the user's hands and the rotating blades. By placing their hands on the safety bar, users can exert the necessary pressure and control over the groundnut plant without directly exposing their hands to the moving components, reducing the risk of accidents or injuries. Additionally, the design of the safety bar is ergonomic, featuring a curved shape that comfortably accommodates the user's hands, promoting a natural and secure grip throughout the threshing process. This integration of safety measures underscores the commitment to prioritising user well-being and ensuring a safe and user-friendly experience with the prototype.

Image 40. Safety bar.
Photograph by Marte Lanning.

Image 41. Safety bar in use.
Photograph by Marte Lanning.

Image 42. Safety bar in use.
Photograph by Marte Lanning.

Form

The thresher was designed with stability and manoeuvrability in mind, ensuring efficient operation in various farm settings. Equipped with four legs for stability during threshing, the current design serves its purpose well. The force exerted by the foot pedal drive mechanism necessitates stability, which is ensured by the four-legged design. With its stability and portability, the thresher is a tool for farmers looking to streamline their operations. However, there is potential for further optimisation of the form to enhance portability. To meet product requirements, the thresher can move across uneven terrain within a farm and is also transportable by a motor between farms. This is made possible by the thresher's extendable handle and large wheel, which allow it to function as a wheelbarrow for easy manoeuvrability around the farm. During threshing, the handle can be retracted to avoid obstruction. The prototype's weight of 54 kg complies with the regulations outlined in The Occupational Safety And Health Act (The Republic of Kenya, 2007). According to the Act, employers are prohibited from subjecting employees to manual handling or transportation of loads that could cause bodily injury due to excessive weight. With a weight of 54 kg, tests with farmers showed that the prototype is within the permissible limit, ensuring that it can be safely transported and handled by farmers without risk of injury. Additionally, the manageable weight facilitates transportation, even for smaller or older farmers, as demonstrated during testing. However, to make transport easier, a redesign can be focused on reducing the weight.

Image 43. Form and transportation of the Manual Groundnut Harvester.
Photograph by Marte Lanning.

Image 44.Transportation of the Manual Groundnut Harvester.
Photograph by Marte Lanning.

The following paragraphs will assess the prototype against the criteria established during the research phase; efficiency, safety, power, and price.

Efficiency

The prototype demonstrates notable efficiency attributed to its innovative threshing mechanism that employs the "plucking" technique. Rather than cutting, the groundnuts are dislodged from the plant by the small notches in the rotating blades. These notches are designed to detach the groundnuts from the plant effectively, without getting stuck in the roots. The impact of this mechanism is significant. While it used to take an average of 1.5 minutes to handpick one plant, the prototype can thresh one plant in approximately 12 seconds when operated proficiently. This represents a remarkable increase in effectiveness by 750%. Additionally, the groundnuts are collected in a receptacle beneath the rotating mechanism, which makes it easy to retrieve them into a bag or container.

Safety

The safety of the prototype is paramount in its design. The plucking method with small notches exerts minimal force on the hands, ensuring user comfort and reducing the risk of strain. Additionally, the design incorporates a cover to partially enclose the mechanism, with the exception of the top entrance. To enhance safety further and provide ergonomic support, a safety bar has been incorporated where the user can place their hands for counterpressure and comfortable handling of the plant during threshing. The safety bar features a curved design, inviting the user to place one or both hands securely within it. Furthermore, for protection when children are nearby, the mechanism is shielded, and the entrance is positioned at a height inaccessible to small hands.

Price

The affordability of the prototype is a key consideration in its development. By utilizing locally available materials and simple tools, outsourcing costs are minimized. The primary material used was steel, chosen for its strength and relatively lightweight, contributing to a robust yet manageable construction. The total manufacturing cost of this prototype amounted to €322. (See page 48 for more information about the cost estimation.)

Power

The prototype operates manually, with a foot pedal providing comfortable manpower. Opting for a manual operation ensures simplicity and accessibility, as there are no additional costs involved. The foot pedal enhances both comfort and power transmission, allowing the thresher to be operated by a single person while keeping their hands free to hold the plant in the threshing mechanism.

05. Evaluation and recommendation

This chapter covers the evaluation and recommendation for the project. The evaluation of the project and prototype is mainly focused on the ecosystem level and human-centred and technical level. This evaluation continues in the recommendations of the project, which starts at the human-centred and technical level and continues in the product requirements and redesign at the product level. The chapter's discussed issues are visualised in the image (see image 42), illustrating the integration of evaluation and recommendations throughout this phase. This chapter highlights and answers sub questions four and five:

> 04. How can economic value creation be maximised for smallholder farmers through the introduction of the manual groundnut thresher?
>
> 05. In what ways does a culture-sensitive design approach contribute to the success and adoption of the manual groundnut thresher in Meru?

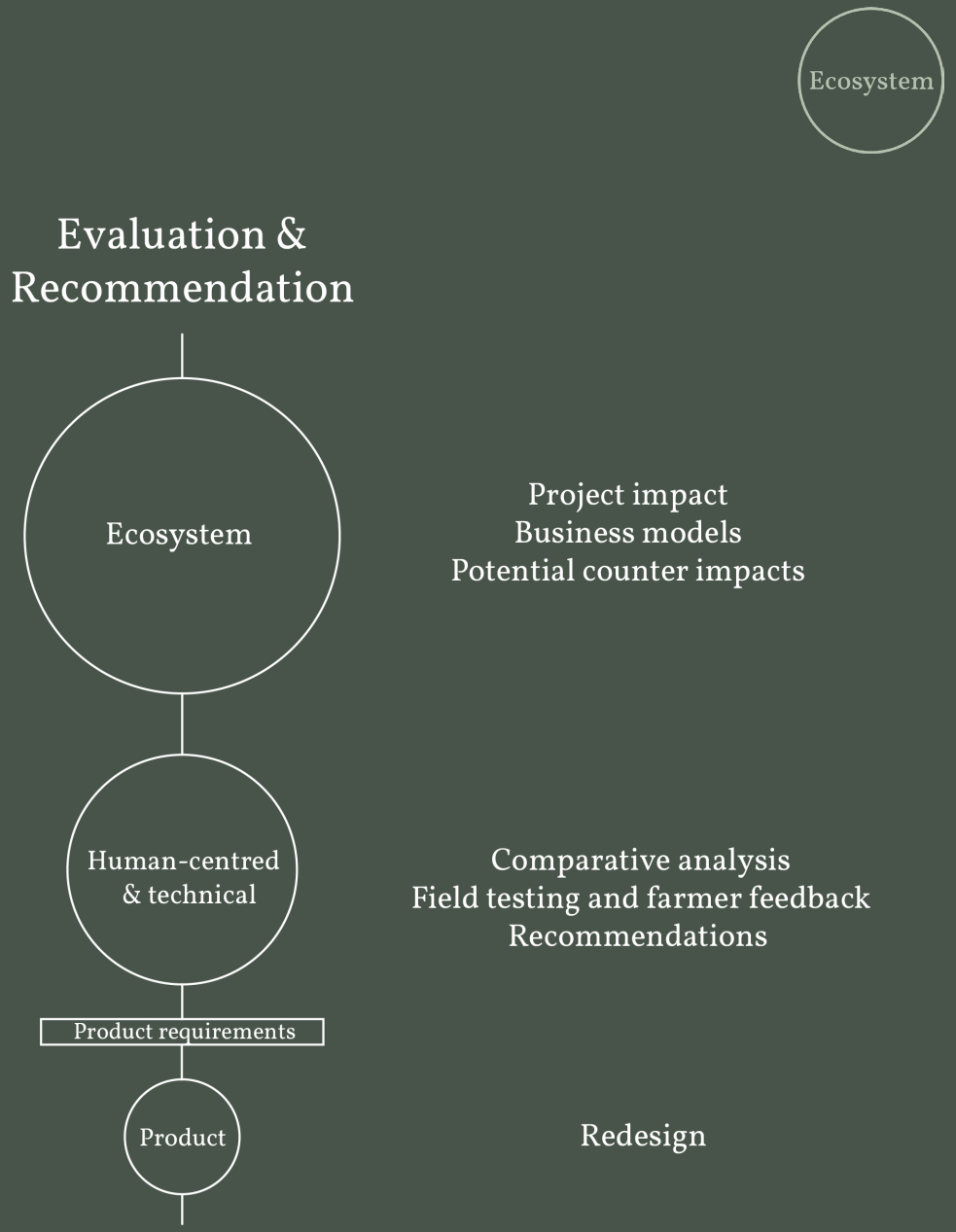


Image 45. Schematic overview of the evaluation and recommendation phase.

Ecosystem level

Project impact
(guided by the Theory of Change overview)

In evaluating the impact of the thresher prototype and the broader project, it is essential to consider not only the immediate effects but also the ripple effects on a larger scale, or so to say, ecosystemic level. Utilising the Theory of Change framework provides a structured approach to examine the project's impact at various levels, from direct outputs to long-term impacts and ultimate contributions. Here, I broadly discuss the impact on different levels of this project, however, in appendix 12 a more comprehensive overview of the impact per different points in the ToC overview can be found.

By creating transformative change within the community, rather than just providing functionality, this project can make a significant impact on the lives of smallholder farmers in Meru. By co-designing a manual thresher in local workshops and conducting thorough cultural anthropological research, a tool was developed that suited the needs and preferences of the farmers. This customisation has led to tangible benefits, such as time and cost savings, as farmers can now harvest groundnuts more efficiently without relying on costly casual labourers. Moreover, the project has the potential to spur economic growth by creating opportunities for local entrepreneurs and students, while also promoting self-reliance and entrepreneurship within the community. Beyond immediate outcomes, the project contributes to broader socio-economic development goals, including enhancing food security, increasing productivity, and improving financial health. Smallholder farmers experience enhanced livelihoods and greater economic empowerment with improved access to income and nutritious food. Additionally, by promoting safer and healthier work conditions and fostering a sense of community ownership and responsibility, the project strengthens social cohesion and resilience within the community. Ultimately, the project represents more than just a tool—it symbolises the collective efforts of a community striving for sustainable and inclusive futures, where locally driven solutions pave the way for lasting prosperity.

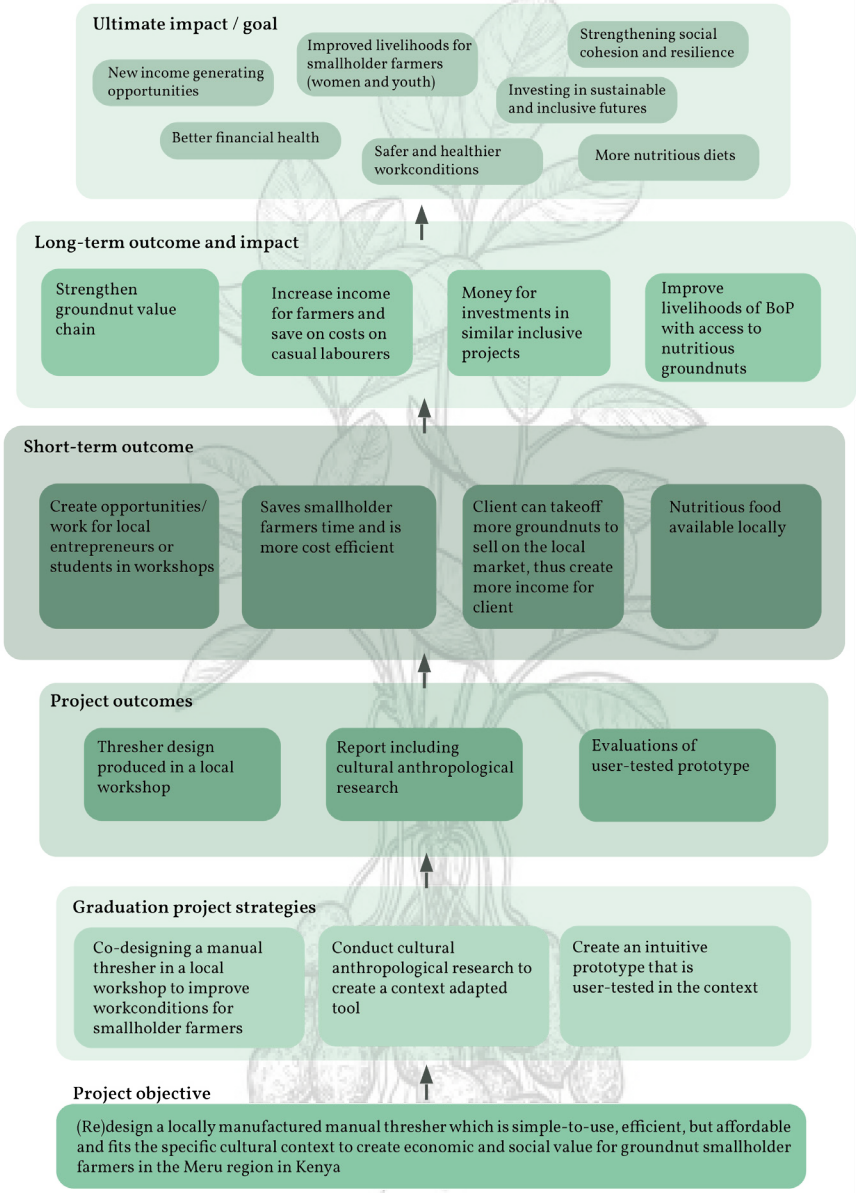


Image 46. Theory of Change overview from the "Empowering Meru Farmers" project.

To summarise the projects' impact briefly in terms of desirability, feasibility, and viability, please refer to the global overview provided below (see image 47).

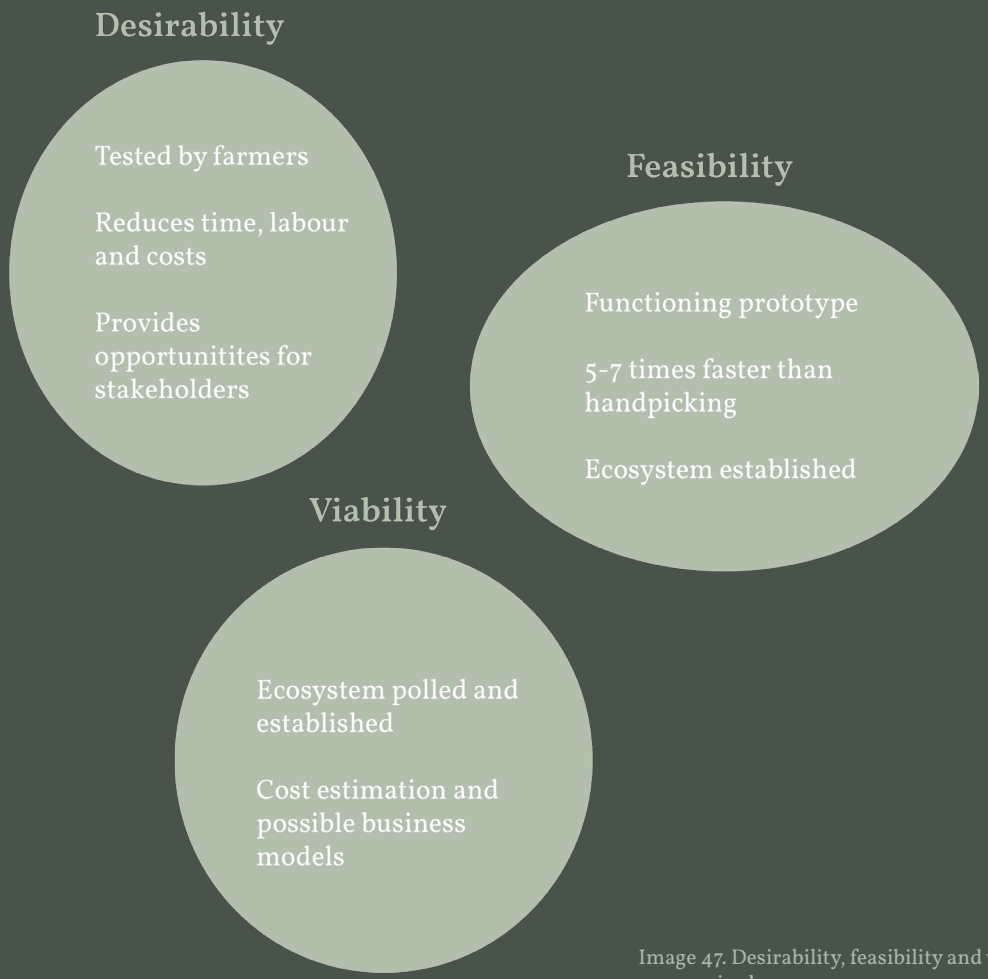


Image 47. Desirability, feasibility and viability summarised.

Business models

To improve agricultural practices and support smallholder farmers, the manual groundnut harvester is a promising solution. However, its successful integration depends not only on its technical effectiveness but also on the implementation of effective business models. This chapter explores various business models that are tailored to smallholder contexts and the envisioned ecosystem (see image 48). The aim is to ensure that the manual groundnut harvester is widely accessible and affordable. Through a cost analysis and examination of rental and ownership options, I seek to facilitate the sustainable adoption and impactful utilisation of this tool. Ultimately, it will be up to Batian which strategy(s) they want to adopt as business model(s).

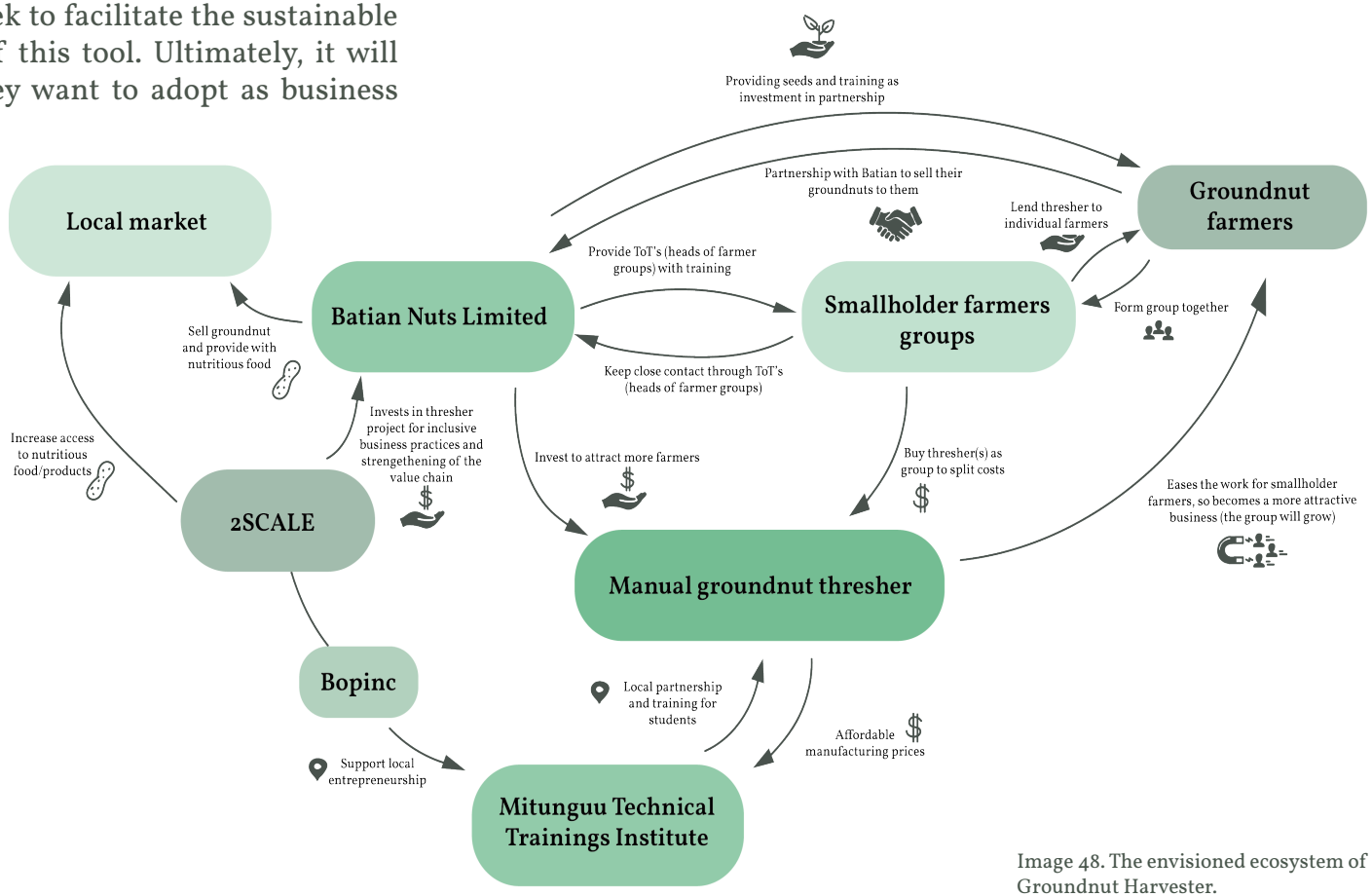


Image 48. The envisioned ecosystem of the Manual Groundnut Harvester.

Farm group purchase

Farm groups can collectively invest in multiple threshers, making them more financially feasible for individual smallholder farmers. By sharing the ownership and cost burden, farmers can benefit from the harvester's efficiency without shouldering the full expense. Given the variability in groundnut harvesting schedules among farmers, owning multiple threshers allows for alternating usage and efficient utilisation across the farming community.

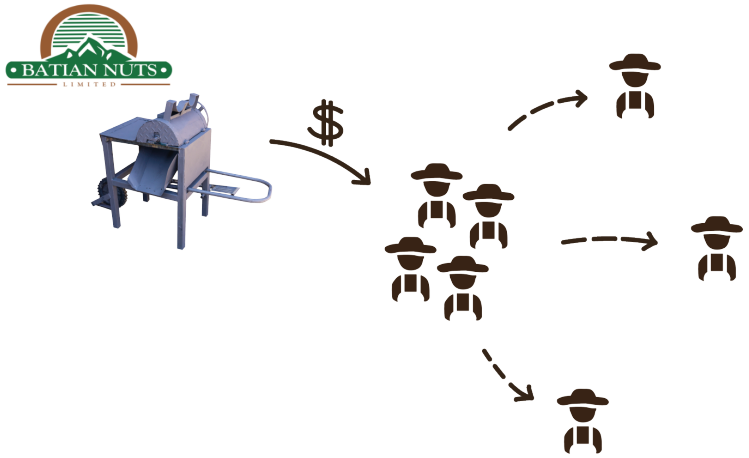


Image 49. Illustration of a farm group purchase business model.

Rental/lease by Batian

Batian may opt to lease the threshers to farmers at an affordable rate, particularly during the intensive groundnut harvesting periods, which typically occur twice a year. This rental arrangement offers flexibility and cost-effectiveness, allowing farmers to access the equipment when needed without the commitment of ownership.

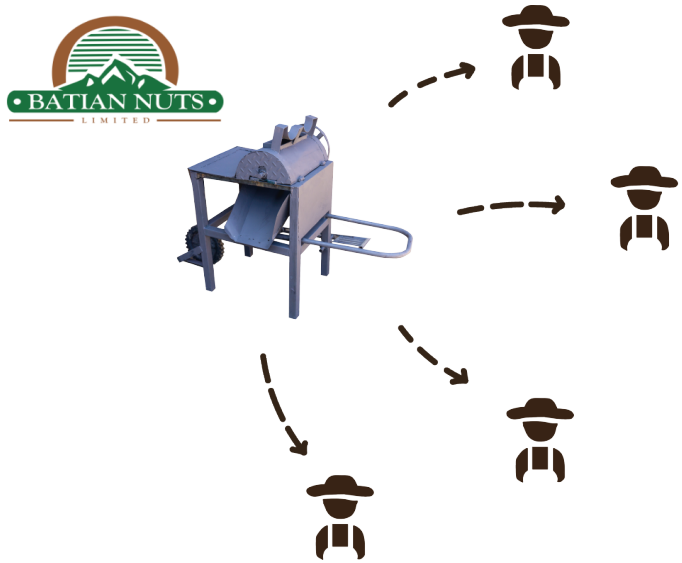


Image 50. Illustration of a rental/lease by Batian business model.

Trainers of Trainers (ToT's) lease

Another potential model involves the head of the farmer group, who is mostly a wealthier farmer, within a group purchasing the tool and leasing it out to other farmers within the group. This "Trainers of Trainers" approach also fosters collaboration and knowledge-sharing among farmers.

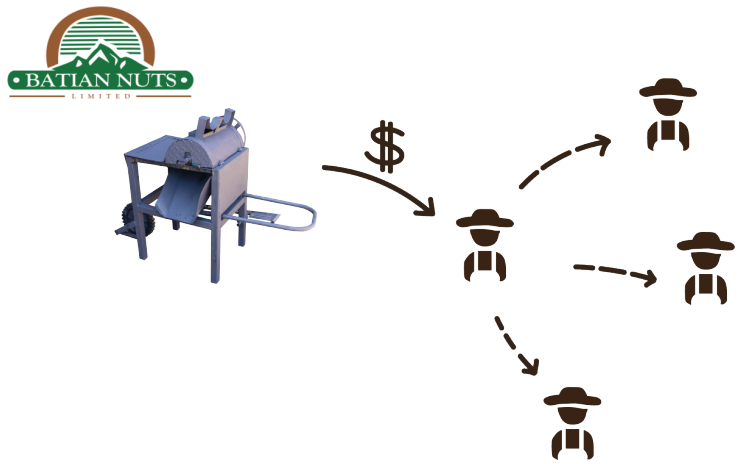


Image 51. Illustration of a Trainers of Trainers lease business model.

Independent production

Besides the previous business models, there is also the potential of independent production as a scenario to consider: Inspired by the success of the thresher, individuals or groups may choose to independently produce and sell similar tools. This decentralised approach promotes innovation and entrepreneurship within the community while expanding access to essential agricultural equipment.

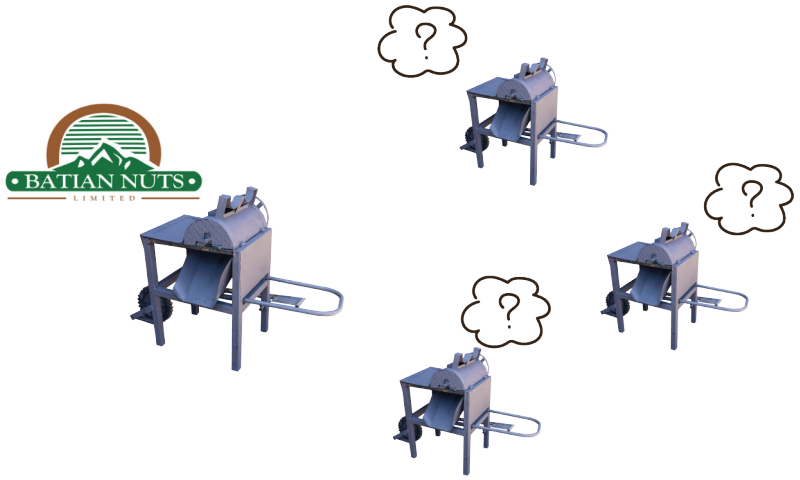


Image 52. Illustration of an independent production business model.

Each of these business models presents unique opportunities and challenges, and careful consideration must be given to factors such as affordability, accessibility, and long-term sustainability to ensure the successful adoption of the manual groundnut harvester.

Now, to answer subquestion four, "to maximise economic value creation for smallholder farmers through the introduction of the manual groundnut thresher", several factors must be considered, including cost-effectiveness, affordability, and income generation potential. The calculated cost overview (see image 53) and business models explored in this chapter offer avenues for achieving these objectives.

The manual groundnut thresher project is designed to not only address the affordability challenges faced by smallholder farmers but also unlock income generation potential while ensuring cost-effectiveness. With a total making cost estimation of 417.80 euros for one harvester, this price reflects the cost of producing a single unit. However, scaling up production to manufacture multiple units can significantly reduce material costs and expedite the building process, ultimately leading to lower prices per unit. To further increase affordability, collective purchasing presents an opportunity for farm groups of 50 to 200 farmers to distribute the financial burden among members, making the thresher more affordable to lease for individual farmers. Additionally, exploring business models such as rental schemes by Batian at affordable rates further enhances accessibility to the thresher. This approach ensures that farmers can access the necessary equipment without incurring the full financial burden of ownership, thereby reducing operational costs significantly. Consequently, by facilitating low-cost access to the groundnut thresher through collective purchasing and rental schemes, farmers can mitigate their expenses associated with manual labour such as the 144 euros required for two casual labourers to work on one acre of groundnut land for a month. Ultimately maximising economic value creation and promoting financial sustainability within the agricultural sector. Furthermore, the introduction of the thresher opens avenues for income generation, as it streamlines groundnut harvesting processes, enabling farmers to save both time and money.

Prototyping costs

Material cost	€322
Workshop	€0
Labour cost	€0
	€322 +

Estimated cost single thresher

Material cost €322-€75*=	€247
Labour cost	€170,40**
Total making cost	€417,80 +

(Add motor (+ 142,86) = 560,66)

Making more pieces means lower material price, and faster building process → lower prices

*-€75 for material when streamlined building process

** Average income mechanical engineer €17,08 p.d. X 5 days X 2 people = €170,80 (incl. Tools and workshop) (Paylab Kenya, n.d.)

General information

Income farmers = €270 p.m. (Paylab Kenya, n.d.)

Similar threshers for other crops = €350

Casual labourer = €3 p.d. (1 acre is 1 month 2 people = €144)

Image 53. Estimated cost overview.

Potential counter-impacts

During the design process of a product, it is crucial to consider not only its positive impact but also potential counter-impacts that may arise when the product is used. While these counter-impacts have not been empirically studied, it is essential to raise awareness of their possibility and prompt further investigation. Here are some potential counter-impacts that could emerge with the implementation of the manual groundnut harvester:

1. Displacement of casual labourers: The introduction of the Manual Groundnut Harvester may reduce the need for casual labourers in groundnut harvesting, potentially leading to a loss of income for individuals reliant on such employment opportunities.

2. Increased teenage usage: The user-friendly nature of the thresher may attract more teenage users. While this could empower younger individuals to engage in agricultural activities, there is a concern about the potential for increased child labour. However, the design complexity and safety features of the prototype may mitigate this risk to some extent, as it may not be easily operable by younger children.

3. Gender and financial impact: An important consideration is whether the improved efficiency of groundnut threshing primarily benefits the head of the family or also improves financial conditions for women and children within the household. Understanding the distribution of benefits among different household members can provide valuable insights into the socio-economic dynamics influenced by the use of the thresher prototype.

By acknowledging these potential counter-impacts, stakeholders can engage in informed discussions and implement measures to mitigate negative consequences while maximising the positive impact of the Manual Groundnut Harvester on agricultural practices and livelihoods.

Human-centred and technical level

Comparative Analysis

In this subchapter, a comparative analysis is conducted between the traditional method of handpicking groundnuts and the utilisation of the Manual Groundnut Harvester prototype using the product requirements list for reference (see page 56).

The conventional method of handpicking involves manual labour-intensive processes, where farmers gather groundnuts from the plants. This process is quite slow (as it can take up to 1 month for three workers to harvest 1 acre) and often requires casual labourers, leading to increased labour costs. On average, handpicking takes around 1.5 minutes per plant, which leads to prolonged harvesting periods and higher resource utilisation. In contrast, the introduction of the Manual Groundnut Harvester prototype offers a mechanised alternative to handpicking. The harvester employs innovative techniques to streamline the harvesting process, effectively reducing the reliance on manual labour. With its efficient design and user-friendly operation, the harvester aims to enhance productivity and minimize harvesting time. Using the harvester, the harvesting time per plant is significantly reduced to around 12 seconds, demonstrating its superior efficiency compared to handpicking.

Through field trials and farmer feedback, the performance of both methods was evaluated in real-world conditions. Key metrics such as time efficiency, labour costs, and overall effectiveness are compared between handpicking and harvester usage. Additionally, I assess the adaptability of the harvester to various field sizes and groundnut varieties.

Image 54. Woman handpicking groundnuts.
Phototgraph by Marte Lanning.

Image 55. The Manual Groundnut Harvester in use.
Phototgraph by Marte Lanning.

In conclusion, the comparative analysis provides insights into the advantages of transitioning from handpicking to mechanised harvesting with the Manual Groundnut Harvester. By highlighting the improvements in efficiency, cost-effectiveness, and ease of operation, the potential of embracing innovative agricultural technologies was demonstrated. This evaluation serves as an initial step towards promoting the widespread adoption of the harvester, with the understanding that further refinement and optimisation may be necessary to address any identified challenges. Nonetheless, the successful integration of the harvester has the potential to significantly enhance productivity and contribute to the long-term sustainability of livelihoods for smallholder farmers.

Field testing and farmer feedback

The final prototype of the groundnut thresher underwent rigorous testing by farmers to assess its effectiveness and usability in real-world conditions. Feedback from four farmers, one of whom used the machine extensively for a week to conduct full groundnut harvesting, provided valuable insights into the prototype's performance. Below the key findings are listed:

Ease of harvesting: Farmers reported that the prototype significantly eased the process of groundnut harvesting, notably reducing the time and labour required compared to traditional handpicking methods. The machine's efficiency in separating groundnuts from the plants was particularly praised, streamlining the harvesting process.

Long-term use experience: Despite its benefits, farmers noted that prolonged use of the machine could be tiresome, indicating potential challenges associated with extended operation. This feedback highlights the importance of considering ergonomic factors and user comfort in the design of the harvester for long-term usability.

Cost savings: Farmers expressed satisfaction with the cost-effectiveness of using the harvester, citing reduced labour costs and increased efficiency in harvesting. The prototype's ability to improve productivity while minimising expenses aligns with the project's goal of enhancing economic value for smallholder farmers.

Feedback on functionality: Farmer feedback also included suggestions for improving the functionality of the harvester, particularly regarding the manual components. One farmer proposed the development of a motorised version to address limitations in manual operation, emphasizing the need for further refinement to optimise performance.

Overall satisfaction: Despite some challenges, farmers generally expressed satisfaction with the prototype and its potential to transform groundnut harvesting practices. The positive feedback underscores the importance of ongoing collaboration between farmers and project stakeholders to fine-tune the harvester according to end-user needs.

To answer sub-question five, which is about the contribution of a culture-sensitive design approach to the success and adoption of the manual groundnut thresher in Meru, feedback from the farmers' tests shows that such an approach significantly enhances the success and adoption of the thresher in several ways. Firstly, incorporating local knowledge, traditions, and preferences into the design process makes the thresher more aligned with the cultural context of the community, which increases its acceptability and usability among farmers. Secondly, considering cultural factors makes sure that the design resonates with the values and practices of the target users, which fosters a sense of ownership and pride in the technology. Additionally, a culturally sensitive design approach promotes inclusivity by addressing the diverse needs and perspectives within the community, which ultimately enhances the relevance and effectiveness of the thresher. Overall, embracing cultural sensitivity not only facilitates the adoption of the technology but also promotes sustainable integration within the local farming practices of Meru.

Image 56. Testing the final prototype at a groundnut farm.
Photograph by Marte Lanning.

Recommendations

The feedback gathered from farmers during the testing phase informs future iterations of the groundnut harvester prototype. Incorporating suggestions for improvement, such as the development of a motorised version and enhancements to manual components, will be essential to enhance the machine's functionality and user experience. This subchapter outlines recommendations derived from the evaluation process, which will inform the refinement of product requirements (see page 56) for the redesign of the Manual Groundnut Harvester (see page 58).

To enhance long-term usability of the harvester, potential design adaptations include enabling operation while seated, aligning with the prevailing context of manual groundnut picking. Additionally, as farmers' financial capabilities increase, integrating a motor into the threshers could present an opportunity for heightened efficiency and productivity, particularly for larger-scale operations.

Moreover, optimisation of the safety bar design is essential to ensure intuitive usability and minimise the risk of accidents during operation. Iterative improvements to the shape and ergonomics of the safety bar will enhance user experience and compliance with safety standards.

Additionally, optimising the pedal mechanism to ensure smooth and intuitive operation is paramount for enhancing user experience and overall efficiency. By fine-tuning the design of the foot pedal, incorporating ergonomic features, and minimising friction points, the threshing process can be made even more seamless and effortless for operators. Intuitive controls and responsive feedback mechanisms will enable users to easily adjust the speed and rhythm of the rotating blades, enhancing their control over the threshing process and reducing the likelihood of errors or accidents. Furthermore, ergonomic enhancements, such as padded footrests and adjustable pedal positions, can minimise fatigue and discomfort during prolonged use, ensuring sustained productivity and user satisfaction. By prioritising the optimisation of the pedal mechanism, the thresher prototype can achieve a new level of user-friendliness and operational efficiency, further enhancing its appeal and usability among smallholder farmers.

Finally, exploring opportunities to further refine the form of the machine can lead to a more compact and lightweight design without compromising structural integrity. By reducing material usage and optimising dimensions, the machine becomes more portable, cost-effective, and environmentally sustainable, addressing the evolving needs and preferences of end-users.

In addition to refining the design, several recommendations can further enhance the project's impact and sustainability. Firstly, considering the multipurpose needs of smallholder farmers, the threshing mechanism can be modified to accommodate other crops, such as sorghum, thereby increasing its utility and relevance within diverse agricultural contexts. One way to achieve this can be by using interchangeable shafts with threshing techniques that are tailored to a particular crop.

Furthermore, expanding the project's ecosystem to include local metal artisans, known as "Jua Kali," can contribute to its inclusivity and sustainability (Adhiambo, 2021). Leveraging the skills and expertise of these artisans not only fosters economic empowerment within the community but also promotes cultural heritage preservation and innovation.

In conclusion, by implementing these recommendations, the project can not only enhance the functionality and usability of the

thresher prototype but also foster broader socio-economic impacts, promoting inclusivity, sustainability, and innovation within the agricultural sector. Some of the recommendations are used to revise the product requirements and guide the redesign of the Manual Groundnut Harvester that is discussed in the product level chapter on page 58.

Product requirements

In this subchapter, I introduce a new product requirement arising from the evaluation process and recommendations derived from farmer feedback. This addition helps with refining the design of the Manual Groundnut Harvester to better align with the needs of smallholder farmers. Additionally, existing product requirements that have been reaffirmed after thorough evaluation and testing of the prototype are highlighted. By emphasising these requirements anew, I ensure their continued centrality to the harvester's design objectives. The overview presented here provides a comprehensive insight into the evolving set of product requirements, underscoring the iterative nature of the design process and the dedication to delivering an effective and user-centric solution.

Requirement category	Nr.
Social Anthropological context	1
	2
	3
	4
	5
	6
Product specifications	1
	2
	3
	4
	5
	6
	7
	8
	9
	10
	11
	12
	13
	14
	15
Workshop capabilities	1
	2

Image 57. Product requirements of the evaluation and recommendation phase.

Product requirement	Derived from
The thresher can be used in the field, to fit the context in which threshing is normally done.	Participant observation: Observing how groundnut threshing is currently done.
The product is affordable for (a group of) farmers to buy.	Project objective client and participant observation: speaking to the intended users.
The thresher can comfortably be operated by men, women and youth.	Participant observation: Asking who is harvesting the groundnuts
The thresher is safe for when little children are around.	Participant observation: Observing the environment and context of groundnut harvesting.
The thresher design is based on local knowledge and expertise to encourage local innovation.	Anthropological desk research on similar projects. See appendix 2.
The users (smallholder farmers) are included into the design process, so the design fits to their wishes.	Benchmark tools, expert meetings, and participant observation: observing what skills the farmers have. See appendix 4 and 5.
The thresher has clear use cues, making it an intuitive machine, so it is easy to use by farmers with basic skills.	Benchmark tools and participant observation: observing what skills the farmers have.
The threshing process is clean and dry, and contact of clean pods with moist/soil is avoided.	Desk research on groundnut farming. See appendix 3.
Groundnuts are collected easily after the threshing process.	Participant observation: observing the threshing and storing process.
The thresher works for all groundnut varieties.	Desk research on groundnut farming in Kenya. See appendix 3.
The thresher is significantly more efficient than handpicking.	Project objective from the client.
The thresher does not require power or electricity in order to operate.	Project objective client and participant observation: observing that smallholder farmers do not always have access to electricity or the financial means to buy petrol.
The thresher does not pose any damage to the product; the groundnut pods.	Project objective client.
Thresher is cost-effective; providing value for money, and balancing the initial investment cost with long-term benefits and operational efficiency.	Project objective client.
While using the thresher, there are no specific risks to safety.	Benchmark tools. See appendix 5.
The thresher can be operated by just one person.	Co-creation session: wish from smallholder farmers.
The thresher is movable on a motorcycle to transport from farm to farm.	Co-creation session: wish from smallholder farmers.
The thresher is comfortably movable over bumpy farm ground.	Co-creation session: wish from smallholder farmers.
The thresher is easily repairable.	Co-creation session: wish from smallholder farmers.
The machine requires minimum manpower when operating. No more labour is required than handpicking.	Co-creation session: wish from smallholder farmers.
Ensure the harvester design allows for comfortable use over extended periods.	Prototype evaluation by farmer testing.
The thresher can be manufactured and repaired in workshops located in Meru. With skills and tools locally available.	Project objective client.
The thresher can be made out of locally available materials (within a one-hour drive).	Project objective client.

Product level

Redesign

At the product level of the evaluation and recommendation phase, the focus is on the redesign of the Manual Groundnut Harvester. Recommendations and product requirements that followed from the final prototype evaluation were used to redesign the thresher.

In the redesign phase, several new features have been introduced to enhance user comfort and efficiency. One notable addition is the incorporation of a seated threshing position. Incorporating a seated threshing position was driven by the recognition that while the Manual Groundnut Harvester proved efficient, prolonged use could lead to fatigue. Drawing inspiration from the ergonomic benefits of the manual handpicking method, the redesigned thresher now allows users to sit comfortably during operation. This modification not only enhances user comfort but also promotes sustained productivity during extended use. The foot pedal technique (highlighted in orange colour) has been refined to mimic sewing techniques, providing a familiar and intuitive user experience. Moreover, a resting area has been integrated atop the machine to guide the user's hands towards the entrance for plant placement. Additionally, a safety bar may be optionally added for enhanced safety measures.

To ensure ergonomic suitability, the machine has been lowered in height, aligning with ergonomic standards determined by anthropometric dimensions (see appendix 13). This adjustment allows for a more comfortable user experience. The positioning of the collection bin and threshing mechanism has been optimised to accommodate the user's legs, providing ample space for movement. Furthermore, the retractable handle has been removed to make room for the user's legs, while foldable handles have been added to facilitate transportation using a wheelbarrow technique.

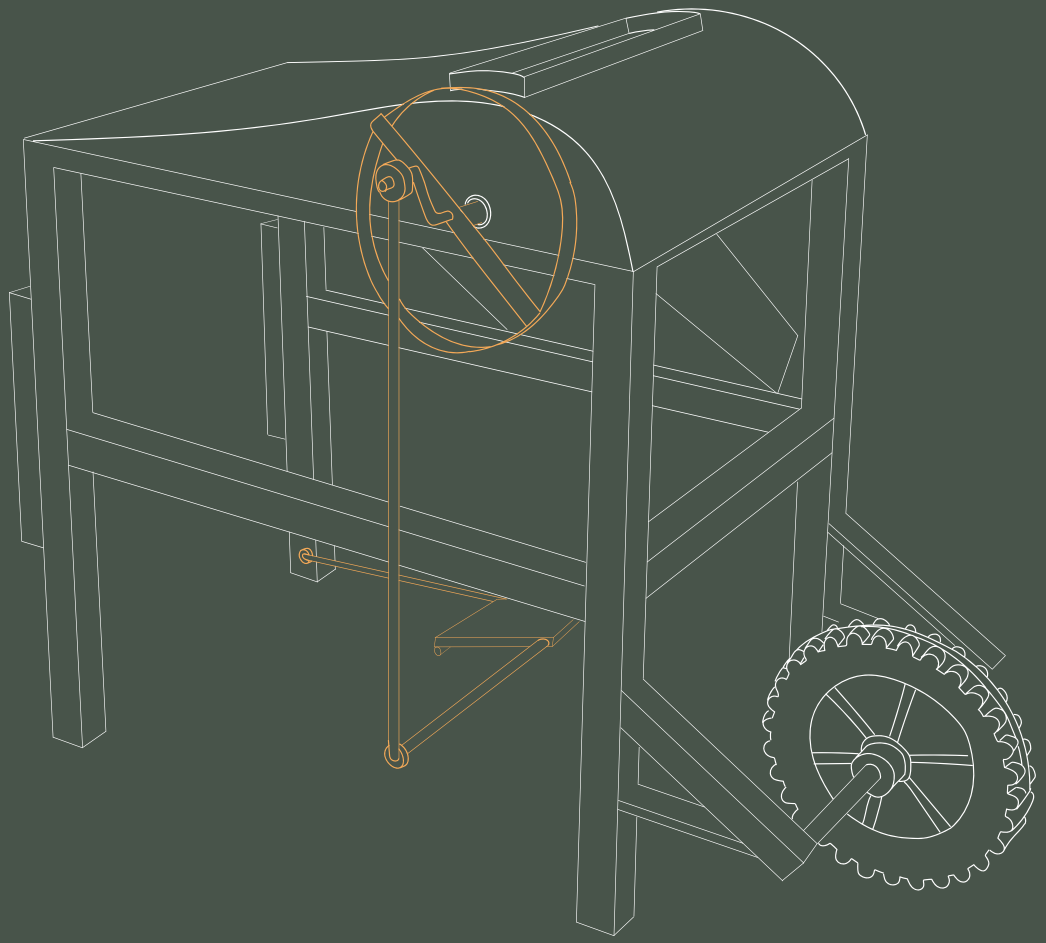


Image 58. Redesign drawing.

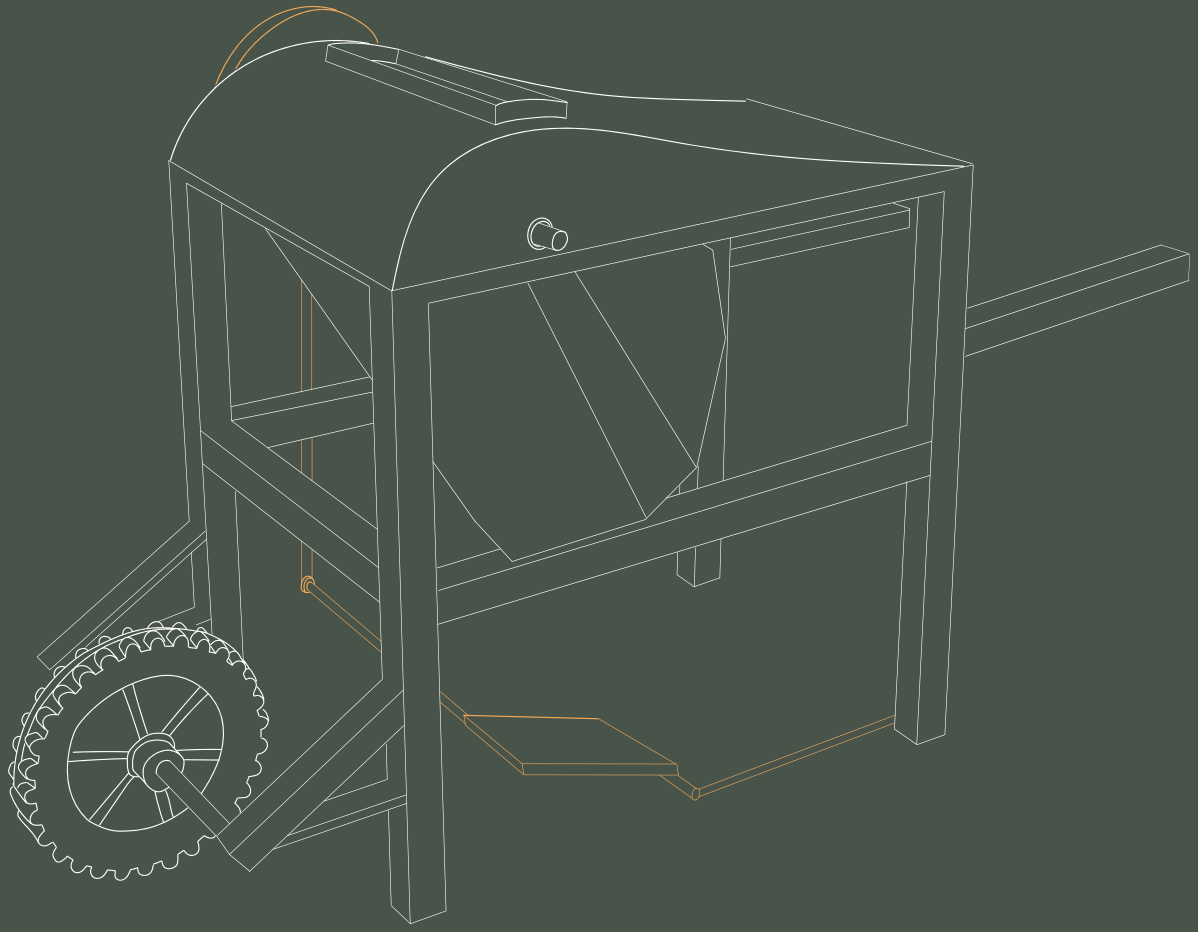


Image 59. Redesign drawing.

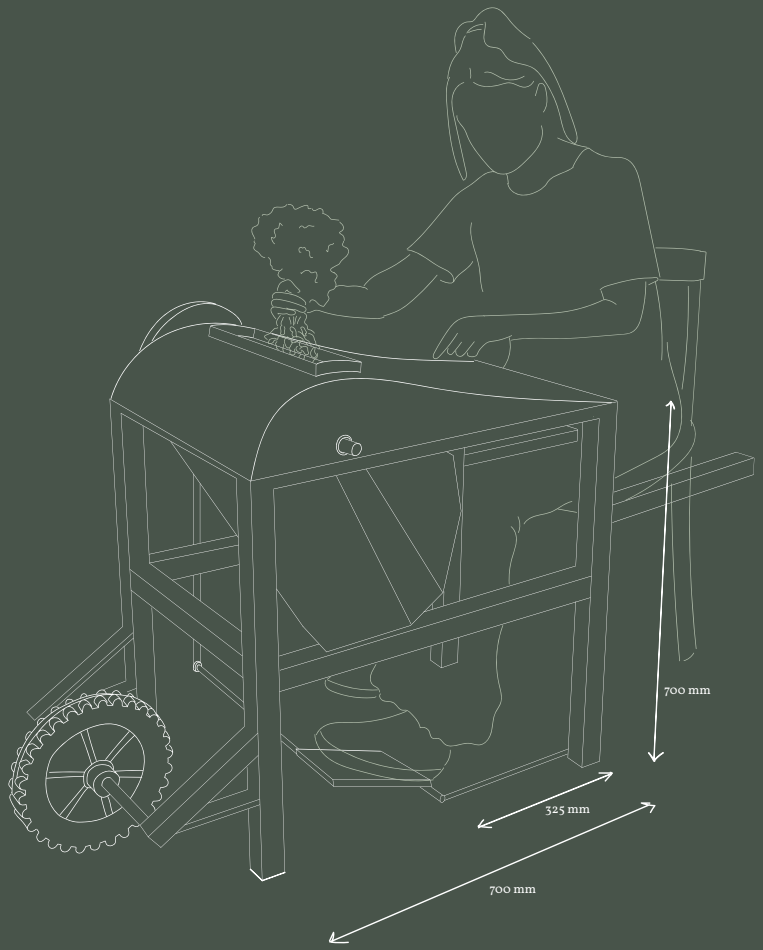


Image 60. Drawing of redesign in use.

Furthermore, the redesign also includes the transformation of the thresher into a multipurpose machine to better align with the farmers' diverse crop cultivation practices. By making the shaft interchangeable, the machine can accommodate various threshing techniques, allowing it to be used not only for groundnut but also for crops like sorghum (see image 62). This adaptation enhances the versatility of the machine, making it even more valuable for farmers in the region.

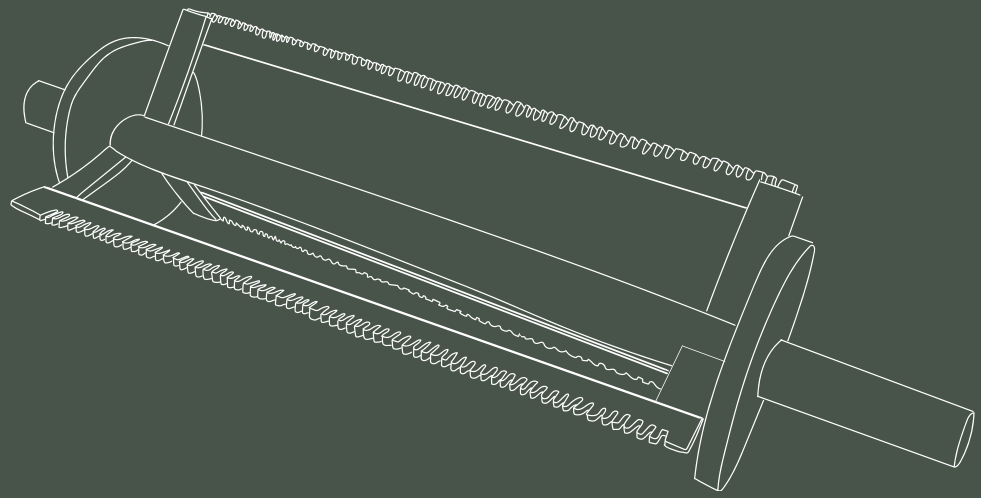


Image 61. Shaft with notches for groundnut threshing.

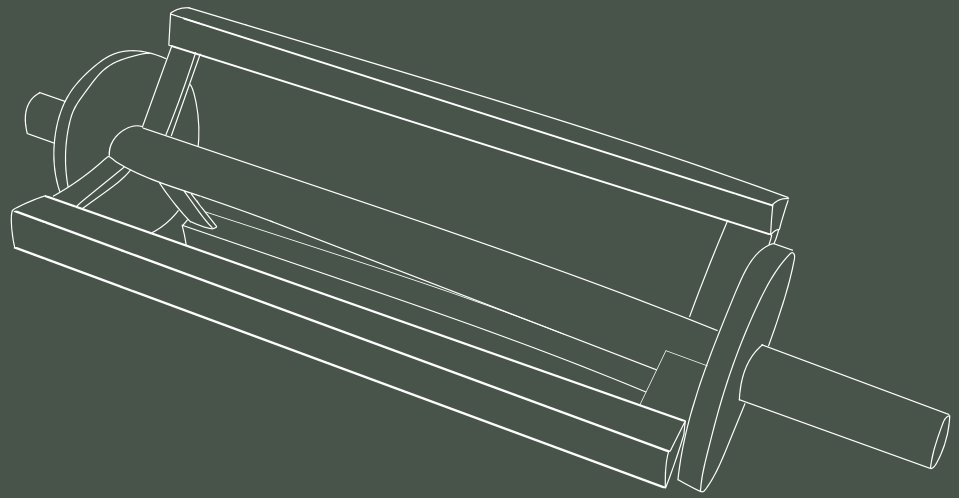


Image 62. Shaft with thick blades for sorghum threshing.

06. Conclusion

In conclusion, the journey of (re)designing a locally manufactured manual thresher for groundnut smallholder farmers in the Meru region of Kenya has been both enlightening and impactful. The main objective was to create a thresher that is simple to use, efficient, affordable, and culturally sensitive, aiming to enhance economic and social value for the farmers.

Throughout this endeavour, I encountered and addressed specific challenges faced by smallholder farmers in Meru related to groundnut farming, particularly in terms of socio-economic development. By embracing a culture-sensitive design approach and engaging in co-creation practices, I navigated these challenges, ensuring that the manual groundnut thresher we designed met the needs and preferences of the local community.

The process of co-creation played a pivotal role in the technical innovation and development of the thresher, allowing the incorporation of diverse perspectives and insights from stakeholders. This collaborative approach not only enhanced the functionality of the thresher but also fostered a sense of ownership and collective responsibility among the farmers.

Furthermore, the focus on maximising economic value creation for smallholder farmers led to the exploration of various business models and affordability options. By considering the financial constraints of the farmers and the potential for income generation, we aimed to ensure that the thresher would be accessible and beneficial to the community.

In light of these efforts, a culture-sensitive design approach has significantly contributed to the success and adoption of the manual groundnut thresher in Meru. By respecting and embracing the local culture, a thresher is designed that resonates with the farmers and integrates into their daily practices.

Looking ahead, the introduction of the redesigned manual groundnut thresher holds promise for driving socio-economic development in the Meru region. By empowering smallholder farmers with an efficient and affordable harvesting tool, I anticipate positive impacts on productivity, income generation, and overall livelihoods. This project showcases the impact of inclusive design practices and collaborative efforts in addressing tangible challenges faced by rural communities.

Image 63. Testing the Manual Groundnut Harvester with groundnut farmers
Photograph by Marte Lanning.

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Image 64. Agricultural lands in Meru.
Photograph by Marte Lanning.

08. Appendix

Appendix 1. Project Brief

DESIGN FOR our future

TU Delft

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME
Complete all fields and indicate which master(s) you are in

Family name	Lanning	6912	
Initials	M.W.J.		
Given name	Marte		
Student number	4560795		

IDE master(s) IPD ✔ Dfl ☐ SPD ☐

2nd non-IDE master: Cultural Anthropology-Sustainable Citizenship

Individual programme (date of approval):

Medisign ☐

HPM ☐

SUPERVISORY TEAM
Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	JC Diehl	dept./section	Design for Sustainability
mentor	Wim Schermer	dept./section	Design Aesthetics
2nd mentor	Johan van der Schaaf		
client:	Bopinc		
city:	Utrecht	country:	The Netherlands
optional comments			

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in **by the Chair** of the supervisory team

Sign for approval (Chair)

Jan-Carel Diehl

Digitally signed by Jan-Carel Diehl
Date: 2023.11.21 22:58:41 +01'00'

Name JC Diehl Date 21 Nov 2023 Signature

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Marte Lanning Student number 4,560,795

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Empowering Meru farmers: design and development of a context-adapted manual groundnut thresher for smallholder farmers in the Meru region, Kenya.

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

In Meru, Kenya, this project addresses the confluence of "design for sustainability," "emerging markets," and "cultural difference." Drawing from success witnessed in other African countries, this project's stakeholders recently introduced groundnut as a cash crop in Meru which now is gaining prominence among smallholder farmers. However, the novelty of groundnut farming in this region has exposed a notable gap: a lack of specialised tools which are both effective, affordable and safe, particularly for smallholder farmers who lack the financial means to invest in machinery.

At its core, this project focuses on creating economic value for smallholder farmers, who play a pivotal role in the Base of Pyramid. In the scope of this graduation project, the goal is to design a functional prototype of a manual groundnut thresher that not only empowers these farmers but also creates a market for their groundnut produce. In doing so, aiming to foster meaningful partnerships with stakeholders who all bring their own expertise and interests: Batian Nuts Lmt.'s interest in this project is to promote groundnut farming and help farmers thresh groundnuts so they can source from them en sell them, leading to business growth. 2SCALE is an agribusiness incubator that wants to support business champions (Batian) to strengthen the groundnut value chain, leading to higher incomes for farmers and more access to nutritious products. Lastly, Bopinc wants to make nutrition affordable and available to the Base of Pyramid through entrepreneurs.

Opportunities and challenges that enable or prevent from addressing these stakeholder interests:

1 Groundnuts present a new cash crop that allows farmers to increase their incomes.

2 The need for new tools creates employment opportunities in workshops around Meru and promotes local entrepreneurship.

3 The use of common materials and tools may allow for designs adaptable to broader (East) African regions.

4 Challenge: understanding the local context in phase 1 is challenging when done remotely. This challenge can be addressed by leveraging Batian and Bopinc staff to conduct research activities. Furthermore, past experiences in culturally similar regions and in the field of agriculture in East Africa will guide in creating designs that align with local realities, ultimately contributing to prosperity and empowerment.

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introduction (continued): space for images

image / figure 1 Current manual threshers worldwide (often expensive, unsafe or still labour intensive).

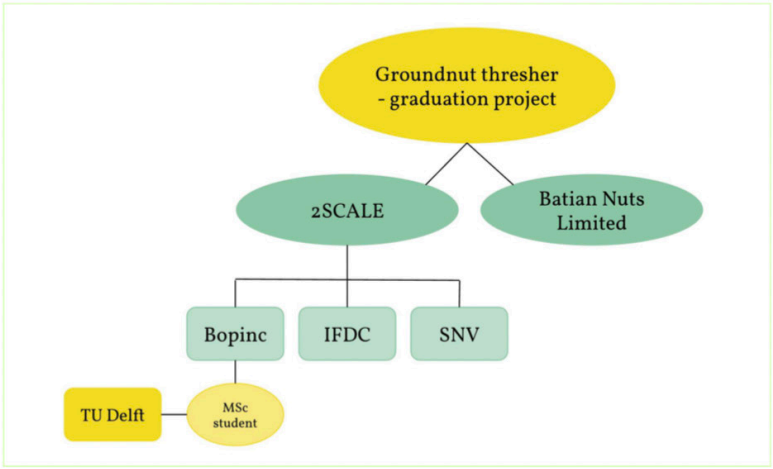


image / figure 2 Stakeholder construction graduation project (organisations and companies).

DESIGN FOR our future

TUDelft

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

Problem: The problem to be addressed in this project is the absence of affordable and effective tools for groundnut smallholder farmers. With groundnut farming being a relatively new and promising cash crop in Kenya, smallholder farmers lack access to specialised equipment that increases their productivity due to financial constraints. Furthermore, the tools available are often unsafe, motorized (needing electricity which is not available everywhere or consuming diesel which is environmentally unfriendly), and expensive.

Opportunities: By co-creating a physical prototype of a context-adapted manual groundnut thresher in collaboration with local communities, I hope to provide smallholder farmers with an effective tool that directly enhances their productivity. This would be the primary goal of this project. With the use of this thresher, secondary goals are to increase smallholder farmers' incomes, establish a market for their produce, promote local entrepreneurship, offer work opportunities in workshops, and ensure that the nutritious groundnut crop is readily available for local consumption.

This project not only fulfils a need but also aligns with the principles of sustainability by utilising available tools, skills and materials for local production and repair. Additionally, the design's adaptability to other regions, using common materials, presents opportunities for broader impact and value creation wherever this specific groundnut variety is grown.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design a locally manufactured prototype of a simple-to-use, effective, but affordable manual groundnut thresher to create economic value for smallholder farmers, primarily women and youth, in the Meru Region in Kenya.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

My project approach involves an initial exploration phase in the Netherlands, where I will conduct (remote) anthropological research to understand the groundnut farming culture in Meru and map the projects' context accurately. Simultaneously, I will explore the workshop's capabilities and research current thresher technologies worldwide. These insights will inform the ideation phase, where I'll create simplistic and rapid prototypes. These prototypes will be taken to Kenya, where I will spend 6-7 weeks, for collaborative discussion and further development with the workshop team, considering the requirements from all stakeholders' perspectives. The chosen prototype will be locally manufactured, tested with users, and iterated upon, with final design refinements made back in the Netherlands.

I will employ semi-structured interviews and focus group discussions to understand the cultural nuances and requirements of the local context. My design approach will prioritise co-creation, ensuring culture-sensitive solutions. The design methods will include Cultura, business modelling, product usability evaluation, product concept evaluation, and the development of 3D physical models to bring the concepts to life.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	26 okt 2023
Mid-term evaluation	20 dec 2023
Green light meeting	8 mrt 2023
Graduation ceremony	3 apr 2023

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

My motivation for starting this project is driven by the desire to blend my skills in industrial design engineering with the insights of cultural anthropology. It serves as a unique opportunity to validate whether this project's context aligns with my career aspirations. Through this project, I aim to demonstrate that the synergy between cultural anthropology and industrial design engineering is not just valuable but often essential, especially in complex cultural contexts like the one I am immersed in.

My personal motto "not design for, but together" encapsulates my belief that meaningful, context-appropriate design is best achieved through collaborative efforts. My learning ambitions are twofold: to craft a personal approach that integrates anthropological research into my design process, and to master the art of communicating ideas effectively, bridging the gap between technical and non-technical stakeholders.

Working within the constraints of context-specific materials, tools and skills, I am excited to explore the boundless creativity required to fashion a sustainable, efficient, and affordable product. While incorporating constraints into a design is always part of a design process, this project's context elevates the challenge, demanding innovative solutions that resonate with local communities and leave all stakeholders with a profound sense of pride.

Appendix 2. Smallholder farmers in the Meru Region

Smallholder farmers in the Meru region, exemplified by individuals working on projects with smallholder farmers like Rose Nduta who is an agri-business expert in Kenya (personal communication, November 14, 2023), typically have families with 3-5 children, some of whom are engaged in schooling or have completed their education but remain part of the family business. Working on 0.5 to a maximum of 1 hectare of land, these farmers primarily rely on manual labour. While smallholder farmers often take shortcuts, resulting in a loss of quality in the end products, efforts by various organisations aim to improve farming practices.

Income for smallholder farmers ranges between 10,000-15,000 Kenyan Shillings (about 57-85 euros) per month and is seasonal, dependent on harvest times. Many farmers also engage in livestock activities, selling eggs and milk for additional income. Education levels are generally basic, with limited digital literacy skills, though some own smartphones for social status.

Expenses are need-based, with a focus on necessities like cooking oil and sugar. Religious activities are significant, involving social gatherings. Different from farming in for example the Netherlands, Kenyan smallholder farmers do not specialise in one crop, but grow many different crops. This is both for personal supply and for sale. Images 65 and 66, show how Kenyan smallholder farmers arrange their land compared to farming practices in the Netherlands.

Smallholder farmers predominantly operate on ancestral land, organised in villages with each household having its own plot. Farmers practice crop diversification, often intercropping for consistent annual income. Traditional farming knowledge persists, but agribusiness organisations are introducing education on climate-adaptive crops and tree planting. The Meru Region, characterized by a dry and hilly climate, is primarily agrarian, with most people affiliated with the Methodist Church. Manual labour is predominant, utilising basic tools like machetes.

According to Rose (personal communication, November 14, 2023), smallholder farmers express interest in a new product, such as a manual groundnut thresher, if it offers time savings, preserves nut integrity, reduces labour, eliminates the need for casual labourers (saving costs), and allows for easy storage of the end product. However, farmers would need to see the product's impact before considering its adoption due to unfamiliarity with the potential benefits and costs.

In conclusion, the farming culture in the Meru region of Kenya is a complex tapestry of socio-cultural, economic, and environmental factors. Understanding these dynamics is critical for designing a manual groundnut thresher that aligns with the needs and realities of smallholder farmers, particularly women and youth, fostering economic value and sustainable agricultural practices.

Image 65 and 66, A Kenyan farm with multiple different crops and a Dutch farm specialised in one or two crops. (Apollo Agriculure, n.d.) and (Lekkerder bij de Boer, n.d.)

Appendix 3. Understanding groundnut farming

Groundnuts, commonly known as peanuts, stand out as a valuable source of plant-based protein, comprising 22–30% of their total calories (Arnarson, 2023). It is a legume crop and not related to other nuts (e.g. walnut, hazelnut or cashews) (Prasad et al., 2010). The richness in protein, coupled with a low carbohydrate content (13–16% of total weight), makes groundnuts a favourable dietary option, especially for individuals with diabetes (Arnarson, 2023).

Beyond their macronutrient profile, groundnuts boast an array of vitamins and minerals, including biotin, copper, niacin, folate, manganese, vitamin E, thiamine, phosphorus, and magnesium (Arnarson, 2023). Additionally, groundnuts contain bioactive plant compounds and antioxidants, with antioxidant richness comparable to many fruits. Notably, these antioxidants, concentrated in peanut skin, contribute to the overall nutritional value.

Despite these nutritional benefits, groundnuts are not without challenges. Aflatoxin contamination, caused by the mold Aspergillus flavus, poses a significant risk. Aflatoxins, particularly AFB1, are recognized as Group 1 Carcinogens, potentially leading to liver failure and cancer (Prasad et al., 2010). The risk of contamination is influenced by storage conditions, with warm and humid environments, especially in tropical regions, increasing susceptibility.

To address these challenges, proper post-harvest practices are crucial. Effective drying after harvesting, coupled with controlled temperature and humidity during storage, significantly reduces the risk of aflatoxin contamination (Arnarson, 2023). However, the farmers' lack of expertise during harvesting remains a primary concern, as aflatoxin production ideally begins in the soil (2SCALE, 2020). Ensuring soil-free groundnut pods during harvesting becomes imperative to mitigate aflatoxin risks.

Beyond their nutritional significance, groundnuts play a vital role in agriculture, particularly in Africa. Mainly grown in countries like Nigeria, Sudan, Senegal, Chad, Ghana, Congo, and Niger, groundnuts have been historically crucial for export, contributing significantly to the economies of nations like Senegal and Gambia (Prasad et al., 2010). Various forms of utilization, such as groundnut oil, roasted and salted groundnuts, boiled or raw groundnuts, and groundnut butter, underscore the crop's versatility.

In the agricultural context, proper field preparations, intercultural operations, and early-season weed control are vital for establishing robust groundnut crops (Prasad et al., 2010). Mechanical shellers aid in post-harvest processing, separating seeds for storage. However, challenges such as insect pests, diseases, and aflatoxin contamination necessitate integrated crop management practices and stringent post-harvest storage treatments (Arnarson, 2023).

Deborah

Age: 55 Occupation: Farmer Location: Meru County, Kenya

"Harvesting groundnuts takes us nearly a month, and we wish there was a tool that could make it faster. It's hard work, and we could use something to make it a bit easier."

User Story

Meet Deborah, a diligent smallholder farmer residing in the heart of Meru County alongside her husband. Their modest homestead thrives with a diverse array of crops, including peas, maize, sorghum, and the promising groundnut. Amidst their agricultural pursuits, they also tend to a small herd of cattle, comprising goats and a flock of chickens.

Deborah and her husband embody resilience in the face of financial constraints, preventing them from investing in motorized equipment that could potentially streamline their farming activities. Undeterred by their limited resources, they've attempted to fashion tools on their own, but these makeshift solutions have fallen short of delivering the efficiency they aspire to achieve.

In the pursuit of optimizing their farming practices, Deborah seeks a solution that aligns with their financial limitations while addressing the challenges they face in maintaining a thriving agricultural homestead. This user story delves into Deborah's quest for a practical, affordable, and effective tool that can enhance their productivity and contribute to the prosperity of their smallholding in Meru County.

Goals

- Increase income
- Increase yield
- Reduce costs on casual labourers

Frustrations

- Harvesting groundnut is labour intensive
- Harversting groudnut takes me about a month
- I need to pay for casual labourers for harvesting

Appendix 5. Exploration of available tools for groundnut threshing

In Kenya and across much of Africa, specialised machinery for groundnut threshing is scarce, with only basic, manual and improvised tools available for this purpose. However, a closer examination of agricultural practices in Asia revealed the existence of several (motorised) tools designed for groundnut threshing. To provide a comprehensive overview, an assessment of these tools was conducted, alongside an exploration of alternative techniques utilized in agriculture and farming practices worldwide. This chapter aims to illuminate the current landscape of (groundnut) threshing tools, drawing insights from both local contexts and global agricultural innovations.

What	Spin a bicycle wheel to thresh the groundnuts, which you try to get between the spokes.
Where	Kenya
Remarks	Does not work well, groundnuts get stuck in the wheel so it does not make the threshing process more efficient.

What	A motorised machine with a rotating mechanism that removes the pods from the plant by touching the plant with rotating blades.
Where	Asia
Remarks	Needs a motor and looks quite unsafe for users. Their hands can easily get into the mechanism. Pods do get removed from the plant quite quickly.

What	A motorised machine with an automated sieve system that separates the pods from the plant with a rotating blade mechanism. Users need to hold the plant into the opening.
Where	India
Remarks	It is quite expensive and motorised. The sieve system looks efficient. Hands can still get stuck into the machine, if not too careful.

What	Combs with a small opening between them. The user pulls the groundnut plant through the combs to separate the pods from the plant.
Where	Asia
Remarks	Quite efficient, since all pods fall off immediately. Labour-intensive since you have to pull with force. Cheap and simple to fabricate.

What	A motorised machine with an automated sieve system that separates the pods from the plant by a rotating blade mechanism. Users need to hold the plant into the opening.
Where	India
Remarks	It is quite expensive and motorised. The sieve system looks efficient. Hands can still get stuck into the machine, if not too careful.

Drawing upon extensive research, four criteria categories are drawn up to evaluate various principles from existing tools against these standards. This evaluation process aims to identify potential tools and principles that seem promising to align with the project's objectives and requirements. By systematically assessing available tools based on these criteria, valuable insights are gained to inform the ideation phase and inspire the design of a potential prototype. This exploration sets the stage for the subsequent phases of the project, facilitating the development of innovative solutions tailored to the specific needs of groundnut farmers in the Meru region of Kenya.

Safety

"The machine is without physical risks for people using or being around it."

Based on anthropological research and exploration of current machines

Power

"The machine is easily operated without much effort."

Based on product requirements from stakeholders

Price

"The machine is realistically affordable for smallholder farmers."

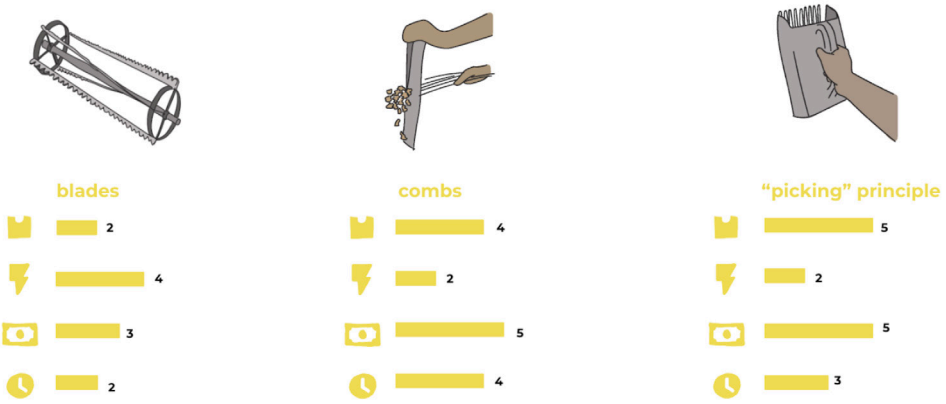
Based on anthropological research and insights from the client

Efficiency

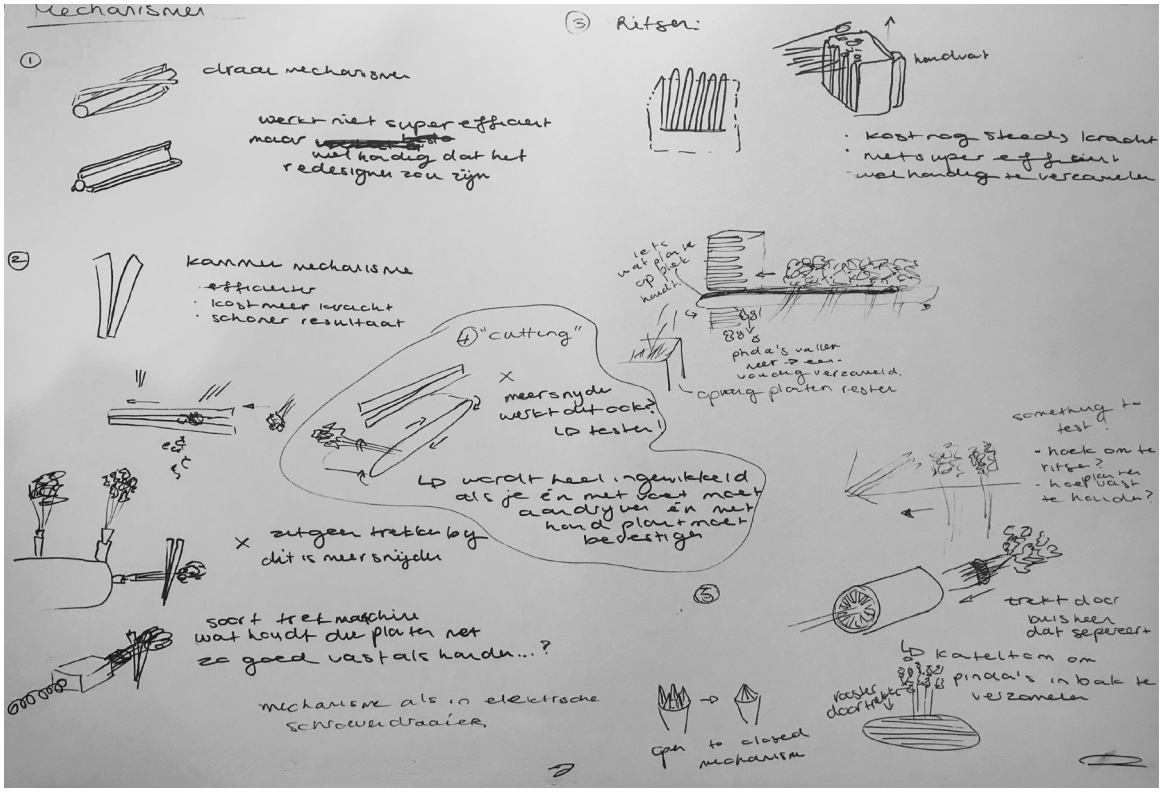
"The machine significantly increases the efficiency of thresholding compared to doing it by hand."

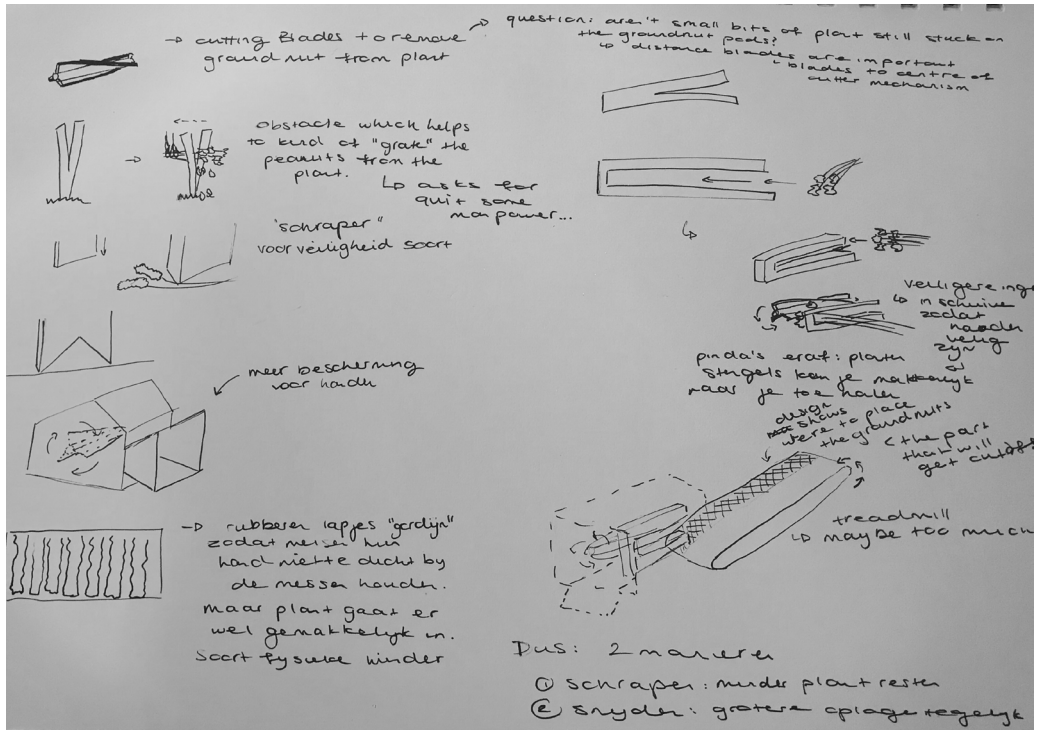
Based on product requirements from threshing and research into groundnut farming

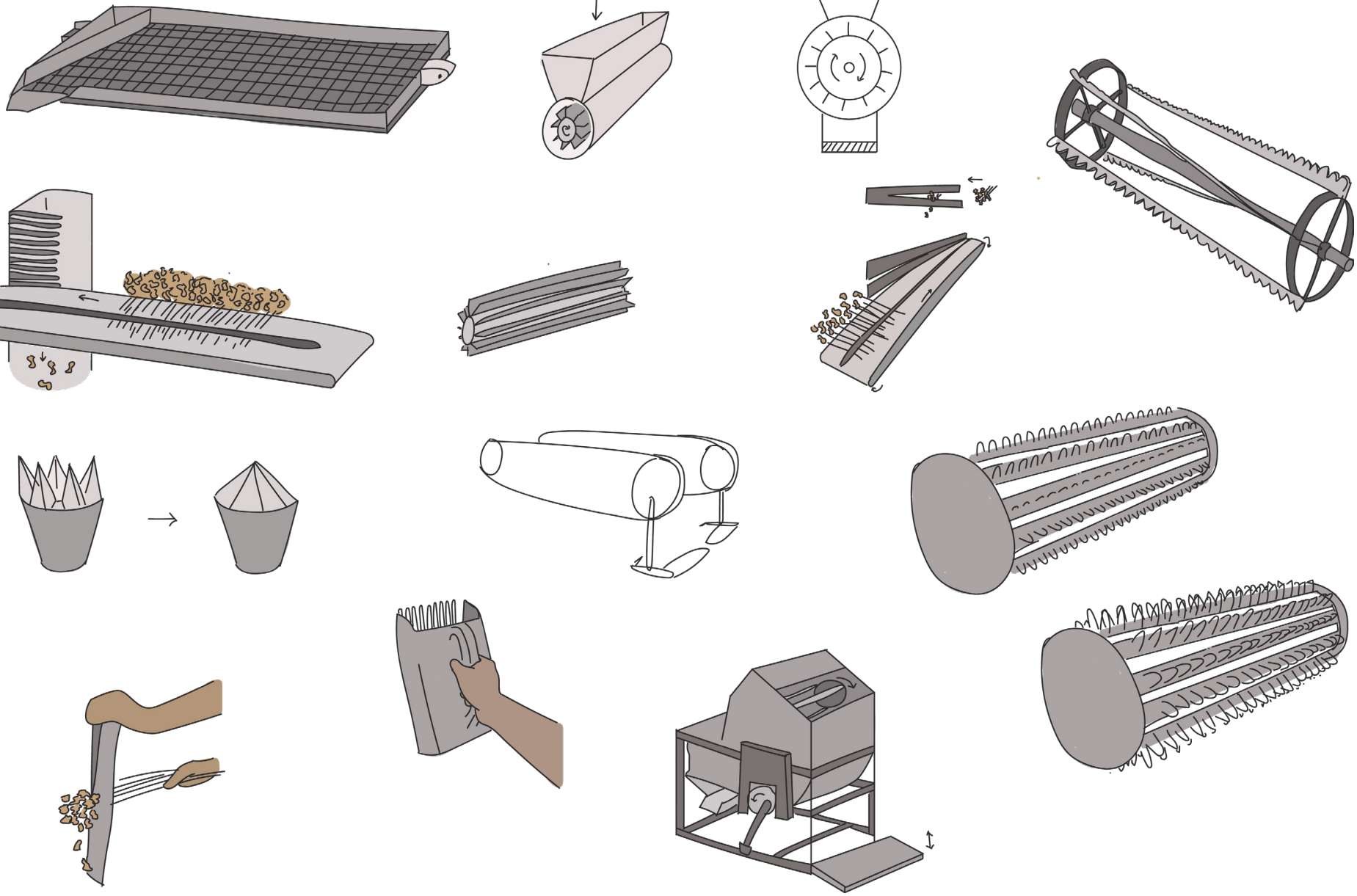
This image illustrates how different mechanisms perform on four specified criteria. Based on the criteria on which mechanisms score well, I can start exploring interesting constructions and aspects to incorporate into the design during the ideation process. For instance, even though this method consumes a lot of power, the efficiency of combs could be an example. During the ideation phase, I examine how a mechanism can possess the power intensity of blades, but then employ a combs technique that enhances the effectiveness.



Appendix 6. Ideation







Appendix 7. Exploration of transition mechanisms


24 Menzies Building
Faculty of Engineering
and the Built Environment

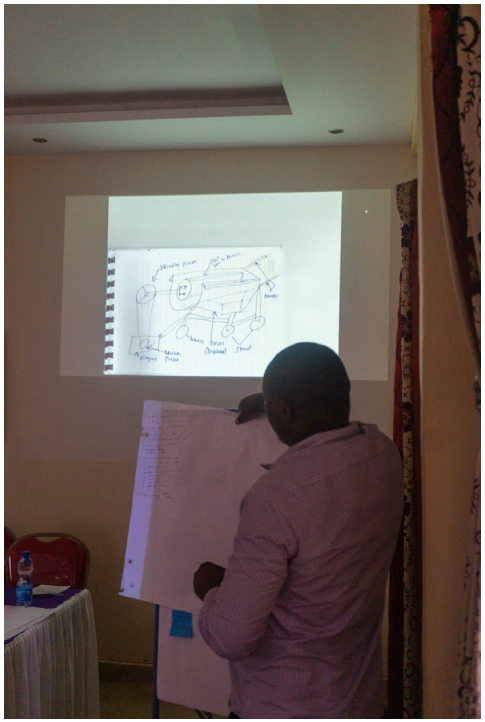
Appendix 8. Co-creation workshop

To facilitate co-creation, I organised a workshop that brought together representatives of all relevant stakeholders. Participants where smallholder farmers and representatives from farmer groups, technicians from Batian and the Mitunguu Technical Trainings institute, and other relevant employees from Batian from the financial and managing departments. During this workshop, the participants collectively brainstormed and defined the product requirements, ensuring that each stakeholder's input and contributions were duly considered. This collaborative approach generated a comprehensive list of requirements and ensured that all stakeholders had a say in shaping the project's direction.

The workshop also provided an opportunity for stakeholders to engage in focused group discussions and ideation sessions. Using "How do we" questions as prompts, participants delved into specific aspects of the prototype design, exploring various possibilities and considerations. Through group discussions and brainstorming exercises, participants were able to share their perspectives, exchange ideas, and contribute to the collective vision for the prototype.

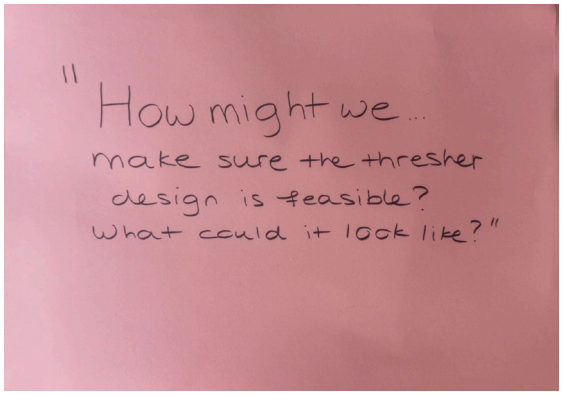
After the ideation sessions, each group presented their ideas, allowing for further collaboration and refinement. This iterative process of idea generation and feedback enabled stakeholders to actively participate in the design process, ensuring that the final prototype reflected a diverse range of perspectives and addressed the identified needs and challenges comprehensively.

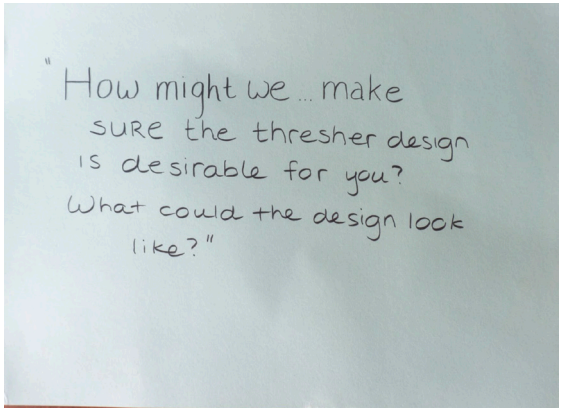
Overall, the workshop served as a catalyst for co-creation, providing a structured platform for stakeholders to collaborate, share insights, and collectively design a prototype that resonated with their aspirations and requirements. By fostering an inclusive and participatory design process, co-creation not only enhances the relevance and effectiveness of the prototype but also strengthens community engagement and ownership, paving the way for sustainable impact and success. (See appendix 9 for workshop materials).

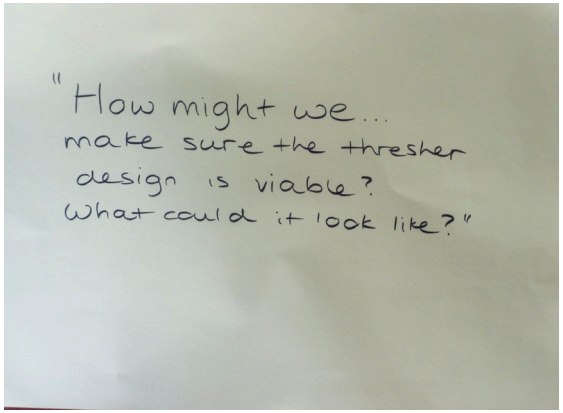


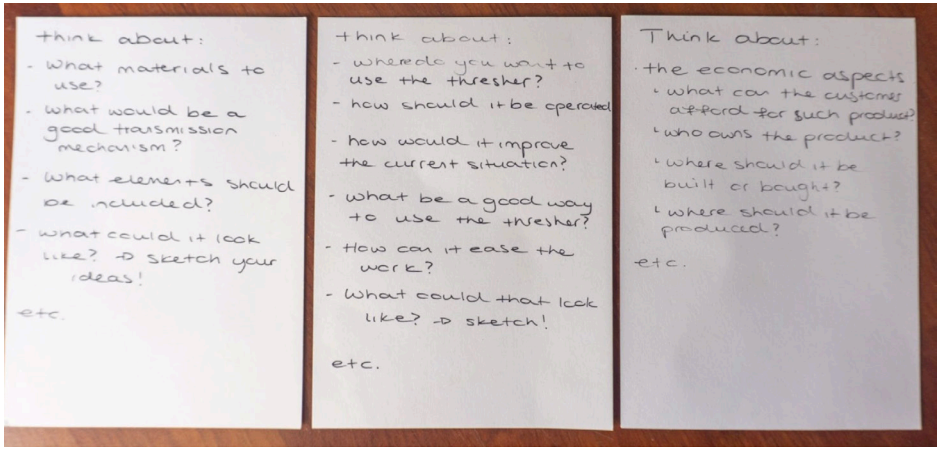
Following the co-creation workshop, results and insights gathered from the participants were collected and compiled. This additional information, along with the insights from desk research and participant observation, further enriched the understanding of user needs and challenges. These findings helped to refine and expand the list of product requirements, ensuring a comprehensive understanding of the project scope. Moreover, the results guided further ideation and concept development for the prototype. Concepts generated were carefully refined and discussed with technicians to ensure technical feasibility and alignment with the project goals. Detailed sketches and design ideas resulting from this collaborative process will be presented in the subsequent chapter, providing a comprehensive overview of the evolution of the thresher design concept. For a closer look at these concepts and idea sketches, readers are encouraged to refer to the dedicated chapter on thresher design.

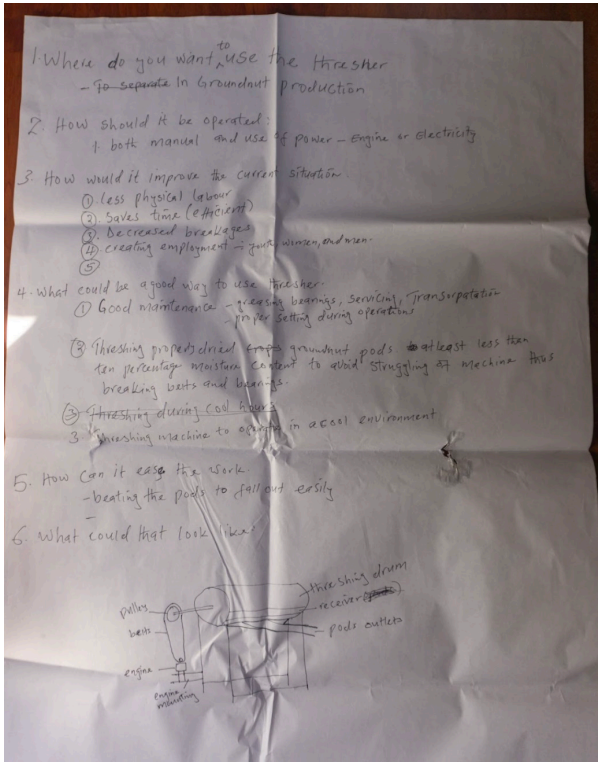
Appendix 9. Workshop materials

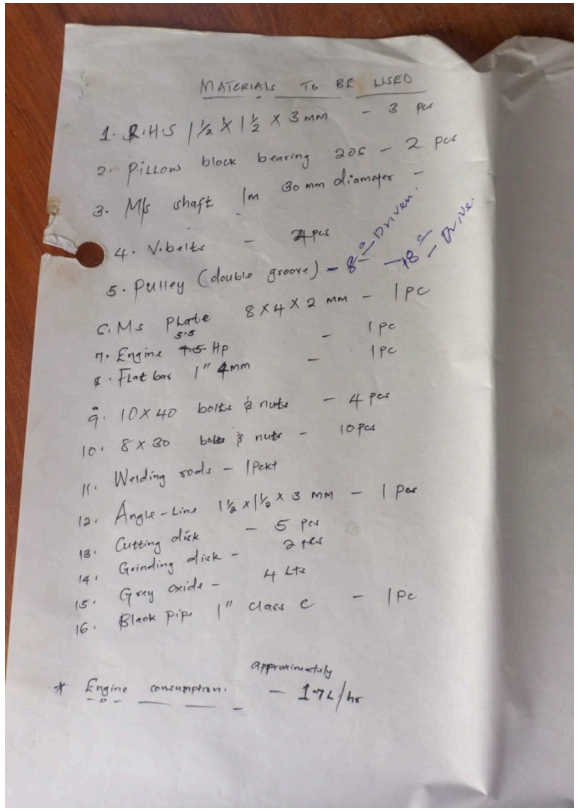








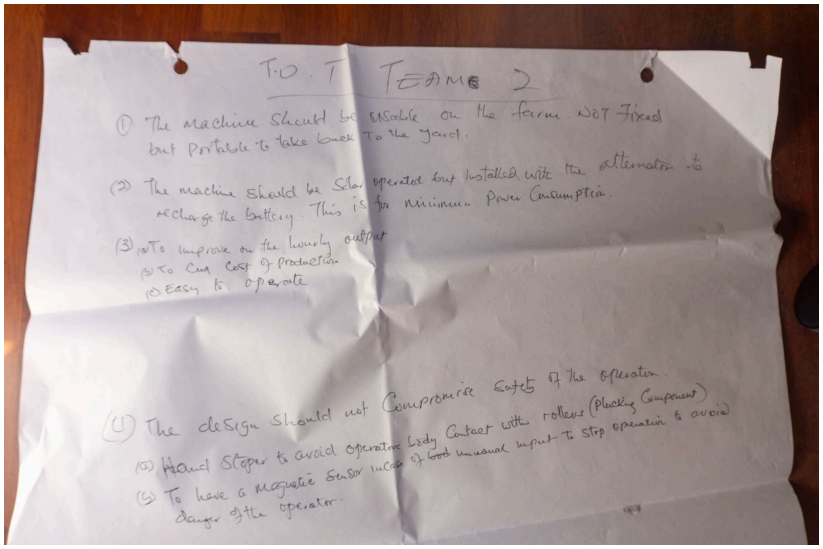




MATERIALS TO BE USED

1. RHS 1½ X 1½ X 3MM - 3 pcs
2. Pillow block bearing 205 - 2 pcs
3. MS shaft 1m 30 mm diameter -
4. V-belts - 2pcs
5. Pulley (double groove) - 8" Driver, 18" Driven
6. MS Plate 8X4X2 mm - 1pc
7. Engine 5.5 HP - 1pc
8. Flat bars 1" 4mm - 1pc
9. 10X40 bolts & nuts - 4 pcs
10. 8X30 bolts & nuts - 10pcs
11. Welding rods - 1pckt
12. Angle-Line 1½ x 1½ x 3 MM - 1 pcs
18. Cutting disk - 5 pcs
14. Grinding disk - 2 pcs
15. Grey oxide - 4 Ltr
16. Black pipe 1" class C - 1pc

* Engine consumption - Approximately 1-7L/hr



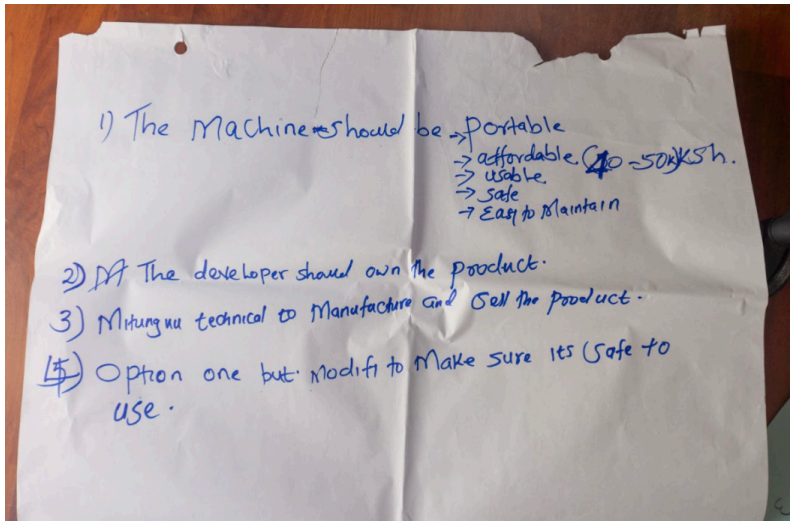
T.O.T TEAM 2

(1) The machine should be usable on the farm. Not fixed but portable to take back to the yard.

(2) The machine should be solar operated but installed with the alternator to recharge the battery. This is for minimum power consumption.

(3) a) To improve on the luxury output
b) To cut cost of production
c) Easy to operate

(4) The design should not compromise safety of the operator
a) Hand stoper to avoid operators body contact with rollers (Plucking Component)
b) To have a magnetic sensor incase of unusual input to stop operation & avoid danger of the operator.



1) The Machine should be → portable
→ affordable. (40-50K)sh.
→ usable.
→ safe
→ Easy to Maintain

2) The developer should own the product.

3) Mitungu technical to Manufacture and Sell the product.

4) Option one but modify to make sure its safe to use.

Appendix 10. Workshop capacities

The wish to fabricate the prototype locally, aligning with the project's goal of leveraging local resources, led to exploring workshop capabilities within the vicinity. Situated in the same small town as the Batian Nuts office, a technical training institute emerged as a promising location. Here, students undergo training in various trades, including mechanical engineering.

Recognizing the potential synergy, it was envisaged that the institute's workspace and available tools could support the prototype fabrication process. Moreover, involving students in the project not only offers them hands-on experience but also lays the groundwork for future replication of the prototype.

Before finalising the partnership, an assessment of the workshop's capacities was essential. Collaborating with the engineering team from Batian, discussions ensued regarding the requisite tools and materials for the prototyping phase, focusing on tasks such as cutting and welding. The workshop at the training institute was found to be well-equipped for these requirements, prompting the decision to establish a partnership for the project's execution.

An agreement was reached to borrow tools from the institute for the required duration. A student, knowledgeable about the workshop's resources, volunteered to assist the project, ensuring seamless access to tools and active participation in the design process. The prototyping process took place in a reserved space just outside the official workshop.

Image 67, Prototyping in process in the improvised workshop at the Mitunguu Technical Trainings Institute.
Photograph by Marte Lanning.

Appendix 11. Overview of the prototyping process

The basis	To create and test different techniques and design options for the thresher prototype, we start by creating a simple framework. This framework works as a basis for the further design process. Furthermore, in the worksho, we test with groundnuts that have been dried for at least 3 days. 

1.	
Research question	*What is an efficient design for threshing technique that is also quick and simple to make with local materials?*
Set-up	Test with cutting technique by blades and gripping technique made by bent nails. Operated with a hendle that is manually driven  
Outcomes	The cutting technique does not remove the pod from the plant. The grabbing technique with nails clears the whole plant quickly, without breaking or damaging the pods.
Conclusions	The grabbing technique with the bent nails has potential, we will continue with this technique.

2.	
Research question	*How can the grabbing technique be optimised to thresh as efficiently as possible?*
Set-up	At the shaft, test different spacing of the nails. Also, test whether a changing pattern makes a difference. Next, make the distance per blade just different so that the plant is hit at a different spot each time. (place nails by offset) 
Outcomes	The last technique (the offset placing), with a spacing of 1 inch between nails seems to thresh the most efficiently.
Conclusions	We make the whole shaft with that technique and then offset-placed

3.	
Research question	*How can gripping techniques be further improved?*
Set-up	To ensure that the groundnut plant can enter the grabbing mechanism at a good height, we make a structure with an elevation above which the plant can be inserted. 
Outcomes	This ensures that the plant is threshed more efficiently, and within a shorter time, the groundnuts are removed from the plant. In addition, it is also more comfortable to hold the plant in this way and the hand is also somewhat stopped from getting into the gripping mechanism by the construction.
Conclusions	This seems like a good step and perhaps interesting to think out this system further with a focus on safety, so that hands cannot get into the grabbing mechanism.

4.	
Research question	*How can we adjust the size of the machine so that this is comfortable for 1 farmer to use, but also with the context in mind of moving it around?*
Set-up	Halving the size of the machine. 
Outcomes	Easier to make subsequent adjustments (less material, money and time needed) and easier to move for testing with farmers.
Conclusions	We keep the prototype this size and test it with farmers.

5.	
Research question	*To increase efficient use, how can we use a mechanism that the machine can be driven and used by one person?*
Set-up	Make a mechanism with a foot pedal.  

	
Outcomes	It turns out to be quite a job to make a pedal that rotates in a winged motion. Regularly, the shaft oscillates back and forth instead of a continuous movement.
Conclusions	We need to look further into adjustments to the pedal mechanism as it does not yet work comfortably and reliably.

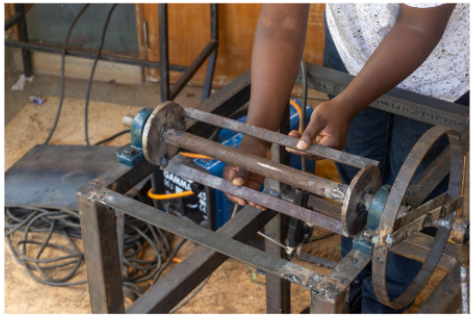
6.	
Research question	*How do we increase the speed of the shaft rotation with the grabbing mechanism?*
Set-up	Adjust the pivot axis and further adjust the pedal mechanism so that it makes a smooth movement. Enlarge the pulley and make sure it is straight to counter any wobbling. Also, straighten the shaft and reconnect at the sides so that this sits in the middle, this also to counter wobbling. 

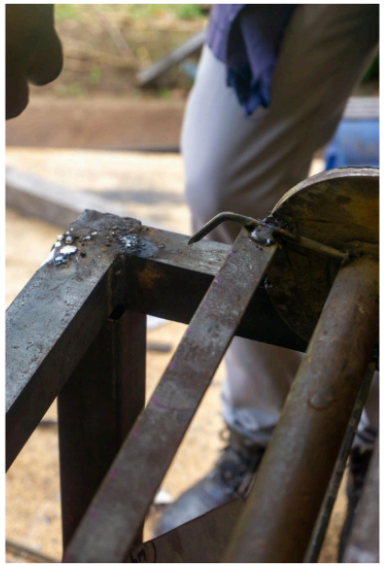
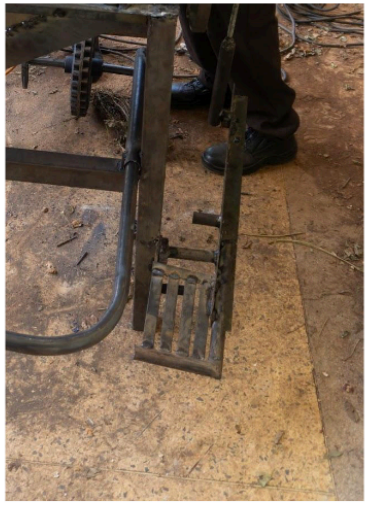
	 

	 
Outcomes	The shaft now rotates through and at a speed that seems desirable. The groundnut plant is threshed efficiently (well when they have dried, wet ones that have just been uprooted get stuck in the mechanism).
Conclusions	We will have to look at how to stop the plant from getting stuck in the mechanism. Trying to make the pedal mechanism even smoother and run faster.

7.	FIRST TEST FARMERS
Research question	*What do framers think of the current prototype and what suggestions do they have to improve the machine?*
Set-up	Test at the farm with their groundnuts, most groundnuts however were just uprooted so still quite wet which makes it harder the thresh. First show how to use the machine and then let them try to use it themselves.  

	
Outcomes	- Add bearing to make using the pedal-mechanism easier - Increase arm of foot pedal so less force is needed - Increase radius of the hooks to increase speed a bit more - Positive about the efficiency - Question of ensuring safety - Hooks are good, perhaps shorter to reduce chalking of the whole plant and make it safer. - Insertion of the plant is now horizontal but would be a lot more comfortable vertically with the movement of the hooks - The size of the machine is good and comfortable
Conclusions	We are going to tweak these things before we move on to finishing the machine.

8.	
Research question	*Can we improve the machine by making the adjustments that the farmers suggested during the tests?*
Set-up	Re-make shaft with hooks, increasing the radius of the height of hooks for this and making the hooks themselves shorter. Add bearing to pedal mechanism to make the movement smoother, requiring less force. Also, add a clear foot surface.  

	 
Outcomes	The Pedal mechanism goes smoother and more comfortably. Radius enlargement of the swivel hooks provides an even faster shaft rotation speed.
Conclusions	Satisfied with these adjustments so now we can continue to finish the machine in terms of safety and ease of use.

9.	
Research question	*How to improve the usability to fit the context of the smallholder farmers?*
Set-up	Make a cover to keep the groundnuts from flying everywhere. Add a catch basin to catch the groundnuts and be able to collect them. Add one wheel (after discussing going for 1 or 2) and extendable levers to be able to move the prototype around over the bumpy ground of a farm. This way threshing can simply be done in the field itself. Deciding that adding a sieve is not necessary and does not add to the prototype, since sieving is done extensively in the factory after collecting the groundnuts. 

	
Outcomes	Tested on bumpy ground, moving around is easy and the machine is not too heavy. The groundnuts are collected well through the catch basin.
Conclusions	We keep these adjustments.

10.	
Research question	*How can we make sure the prototype is entirely safe to use?*
Set-up	Add a safety bar on top of the cover to ensure safety and comfort when threshing. This prevents users' hands from slipping into the machine. 
Outcomes	The safety bar helps, however, there is still a lot of force on the hands due to the grabbing force of the threshing technique.
Conclusions	Bringing in the plants is not comfortable and safe enough yet.

11.	SECOND TEST FARMERS
Research question	*What do farmers think of the current prototype and what suggestions do they have to improve the machine?*
Set-up	Go to a new farmer to test at the farm. Use dry groundnuts to test. 
Outcomes	The grabbing mechanism is too dangerous, the women are scared to use it. The pedal mechanism is not easy for women. However, with some practice time, they are able to use the machine.
Conclusions	We have to change the threshing mechanism to make it more safe. Farmers should be given a bit of training on how to use the machine, especially the pedal mechanism. Once they know how to do it, it is very easy.

12.	
Research question	*How can we change the threshing technique so that it is still effective but also safe?*
Set-up	Remove the nails from the bars and make in these bars very tiny slots that ensure a grabbing force but one that is less intense.  

Outcomes	The threshing of groundnut is still efficient but the blades do not grab the whole plant, therefore the force on hands is gone and the users' hands are safe. Furthermore, with this mechanism, the shaft can turn in both directions for threshing which makes the pedal mechanism even easier to use.
Conclusions	Happy with this adjustment, and the threshing mechanism is more safe and comfortable while still being efficient.

13.	**THIRD TEST FARMERS**
Research question	*What do farmers think of the current prototype and what suggestions do they have to improve the machine?*
Set-up	Testing at the farm, in the groundnut field of one of the smallholder farmers. An elderly woman and her husband are testing. We tested with groundnuts that were still a bit wet since they were just uprooted before testing. We first showed them how to use it and then let them test themselves. 
Outcomes	The threshing mechanism feels safe and comfortable for the farmers. Using the pedal mechanism is easy for the woman, however, when the man tries it, he is using too much force on the pedal. One of the engineers gives tips and slowly explains that the mechanism does not need any force. After some practice, the man is also able to make the machine go and thresh himself. Also, he needed some explanation on how to hold the groundnuts in a way that they make use of the safety bar as a comfort point. We timed efficiency. Hand-picking takes on average 1,5 minutes per plant, while the machine can thresh one plant in 12 seconds. The elderly woman also tested if she was able to carry and move the machine around on her own.
Conclusions	The thresher is efficient and safe now. Users might need a bit of explanation and practice on how to comfortably use the thresher, however, when they get it threshing seems quite easy. Moving the machine around is doable even for an elderly (and quite small) woman. The prototype as it is now fits the context and works well.

Appendix 12. Project impact guided by the Theory of Change overview

In evaluating the impact of the thresher prototype and the broader project, I dive into the tangible outcomes and lasting effects it has had, using the Theory of Change framework as a guide. The overarching goal was to improve the work conditions for smallholder farmers in Meru by co-designing a manual thresher in a local workshop and conducting cultural anthropological research to ensure the tool is contextually adapted.

Graduation Project Strategies:

Co-designing in a local workshop: I facilitated workshops where local stakeholders, including farmers and engineers, collaborated to design the thresher, ensuring it meets the specific needs of the community.
Cultural anthropological research: By conducting in-depth research, I gained insights into the local context, informing the design process to create a tool that resonates with the cultural practices and preferences of the farmers.
Creating an intuitive prototype: Using the insights gathered, I developed a prototype that was intuitive and user-friendly, incorporating feedback from farmers at every stage of the process.

Project Outcomes:

Thresher design produced: Through collaborative efforts, we successfully produced a thresher in the local workshop, tailored to the needs of the farmers.
Report of cultural anthropological research: The research findings were compiled into the report, providing valuable insights into the cultural nuances that shaped the design process.
Evaluations of the user-tested prototype: The prototype underwent testing in the local context, with feedback from farmers helping refine its design and functionality.

Short-Term Outcomes:

Opportunities for local entrepreneurs: The project creates opportunities for local entrepreneurs and students to engage in meaningful work of producing the threshers, contributing to the community's economic growth.
Time and cost savings for farmers: The thresher proved to be a game-changer, saving farmers valuable time and reducing their reliance on costly casual labourers for groundnut harvesting.
Increased income for farmers: With the ability to harvest more groundnuts efficiently, farmers can take on larger groundnut harvests and sell more produce on the local market, boosting their income and financial stability.
Availability of nutritious food: By streamlining the harvesting process, the project ensures a more abundant supply of nutritious groundnuts in the local market, promoting food security.

Long-Term Outcomes and Impact:

Strengthening the groundnut value chain: The project contributes to the overall strengthening of the groundnut value chain, from production to market, benefiting farmers, Batian as processor and consumers alike.
Increased income and cost savings: Farmers will experience an increase in income while saving on harvesting costs, allowing for further investment in their agricultural endeavors.
Improved livelihoods: With improved access to income and nutritious food, smallholder farmers experience enhanced livelihoods and greater economic empowerment.
Safe and healthier work conditions: The introduction of the thresher not only makes the harvesting process more efficient but thereby also safer and healthier for farmers, reducing the risk of injuries due to repetitive uncomfortable posture.
Strengthening social cohesion: The collaborative approach fosters a sense of ownership and collective responsibility within the community, strengthening social cohesion and resilience in the face of challenges.
Investing in sustainable futures: By investing in locally driven solutions, the foundation was laid for sustainable and inclusive futures, where

communities have the agency to address their own needs and challenges.
Promoting nutritious diets: With increased access to nutritious groundnuts, community members could enjoy a balanced and healthy diet, contributing to overall well-being.

Ultimate Impact/Goal:

New income-generating opportunities: This project opened up new avenues for income generation, empowering local engineers (and students of Mitunguu Technical Trainings Institute).
Better financial health: With increased income and reduced expenses, farmers will experience improved financial health and stability, allowing for greater investments in their families and communities.
Improved livelihoods: Ultimately, the project aims to uplift the lives of smallholder farmers, providing them with the tools and resources they need to thrive in their agricultural pursuits.
Safe and healthier communities: By promoting safe and healthier work conditions, the project contributes to building stronger and more resilient communities, capable of withstanding future challenges.
Strengthening social fabric: Through collaborative efforts and community engagement, the social fabric of the community is strengthened, fostering a sense of solidarity and mutual support.
Investing in sustainable futures: This project was not just about addressing immediate needs but also about laying the groundwork for sustainable and inclusive futures, where communities are empowered to chart their own path to prosperity.

Appendix 13. DINED measures

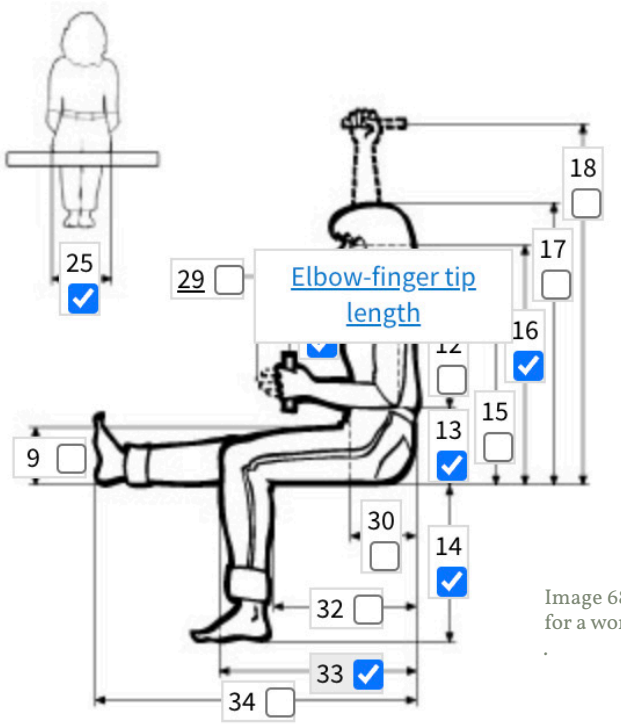


Image 68, DINED measures for a woman sitting.

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populations	International South East Africa, mixed		International South East Africa, female	
measures	mean	sd	mean	sd
Popliteal height, sitting (mm)	400	27	385	21
Eye height, sitting (mm)	740	30	730	30
Elbow-grip length (mm)	353	32	325	15
Hip breadth, sitting (mm)	330	22	340	21
Elbow height, sitting (mm)				
Buttock-knee depth, sitting (mm)	570	34	550	27

Image 69, DINED measures for a South East African woman sitting.

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