FACULTY OF ENGINEERING

DEPARTMENT OF AGRICULTURAL MECHANIZATION AND IRRIGATION ENGINEERING

DESIGN AND FABRICATION OF AN ENGINE POWERED WEEDER-SPRAYER MACHINE FOR MAIZE

By

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A final year project report submitted to the Department of Agricultural Mechanization and Irrigation Engineering as a partial fulfillment of the requirement for the award of a Bachelor of Science in Agricultural Mechanization and Irrigation Engineering

May 2026

ABSTRACT

Weeds are a major constraint to crop productivity, contributing to an estimated 25–26% yield losses in major crops annually and billions in financial losses worldwide. Traditional weed control methods, such as manual removal and conventional mechanical devices, often result in high labor costs, significant drudgery, and inconsistent efficacy, particularly in smallholder farming contexts. Engine-powered weeding machines have demonstrated substantially improved weeding efficiency up to 90% compared to manual methods, which typically achieve 65–82% efficiency.

This project focused on the design and fabrication of an engine-powered weeder-sprayer machine capable of mechanically removing weeds in crop inter-rows while simultaneously spraying herbicides within intra-row. The machine integrates dual implements, that is, the fixed tines for physical weed removal and cutting and a targeted spraying system for precise selective herbicide application. Performance benchmarks show that such machines can deliver a field efficiency of approximately 86%, maintain plant damage below 4%, and reduce weeding costs by over 60% when compared to traditional practices.

By leveraging mechanical automation and selective herbicide application, the proposed solution aims to address labor shortages and improve both the quality and quantity of crop production. The system is designed to be accessible, economical, and environmentally conscious, promising substantial benefits for small and medium-sized farms and aligning with the demand for sustainable agriculture.

DECLARATION

We MUDOOLA CORNERIOUS and KIKYO HELLEN declare that this final year project report was written by both of us and it has never been utilized for academic award by any individual in any learning institution.

MUDOOLA CORNERIOUS BU/UG/2022/1431

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APPROVAL

This final year project report has been prepared and compiled by **Mudoola Cornerious** and **Kikyo Hellen**. It is therefore submitted to be approved by;

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ACKNOWLEGEMENT

We gratefully thank God for provision, unity and cooperation during this period of final year project management.

We sincerely appreciate our academic supervisors, Mr. Ashabahebwa Ambrose and Mr. Muyingo Emmanuel for the guidance and commitment throughout the process.

We also acknowledge the faculty, staff of Agricultural Mechanization and irrigation engineering and the project's coordinator Mr. Igga Huzairu for providing the guidance and advice.

We are deeply appreciative of our families and friends for their funds provided, motivation and emotional support throughout this journey. Their belief in our abilities has been a constant source of strength.

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ABBREVIATIONS

m-Meters

mm-Millimeters

Mr.-Mister

SDGs-Sustainable Development Goals

l-liters

hr.-hour

hp -Hose power

PTO-Power Take Off

GDP-Gross Domestic Product

UBOS-Uganda Bureau of Statistics

e.g.- For example

HDPE-High density polyethylene

PVC- Polyvinyl Chloride

BOQ-Bill of Quantity

1.0 CHAPTER ONE: INTRODUCTION

1.1 INTRODUCTION

Weeds are any plants that grow where they are not wanted, such as in a garden or farm field. Weeds are one of the most significant impediments to optimal crop growth. They compete with cultivated plants for sunlight, water, nutrients, and space, leading to reductions in yield, sometimes exceeding 50%. (Chauhan & Johnson, 2010).

Weeds can be managed manually, mechanically, biologically and chemically. The efficient and timely weeding is paramount for fostering robust crop growth, enhancing nutrient uptake, and safeguarding against outbreak of pests and diseases (Kaur *et al*., 2018).

Weeding remains a labor-intensive and time-consuming agricultural task significantly impacting crop yields and farm profitability globally (Dash & Chowdhury, 2023).

1.2 BACKGROUND

Globally, the agricultural sector faces immense pressure to feed a growing population while contending with climate change, decreasing arable land, and a reducing rural workforce (Vos & Bellù, 2019). With the world's population projected to reach nearly 10 billion by 2050, agricultural output must increase by an estimated 70% to meet future food demand (Godfray *et al.*, 2010; *FAO*, 2017). In numerous agricultural systems worldwide, especially in developing regions, weed control predominantly relies on traditional manual methods. While effective at a micro-scale, manual weeding is inherently labor-intensive, time-consuming, physically demanding, and often contributes significantly to increased production costs and pervasive farmer drudgery. (Krishna *et al.*, 2017; Pretty *et al.*, 2006). The weeding required for even modest farm sizes renders manual approaches inefficient and often leads to delayed operations, missing critical periods for intervention and exacerbating yield losses (Li *et al.*, 2023).

Africa's agricultural sector is pivotal to its economic development and food security, employing a significant portion of the continent's population (Daramola *et al.*, 2020). However, agricultural productivity in many African countries remains low compared to other regions, largely due to limited mechanization, reliance on rudimentary tools, and inadequate access to modern farming technologies (Jayne *et al.*, 2019). Weeds are a major constraint to crop production in Africa, causing substantial yield losses if not effectively managed

(Akobundu, 2018). Weeding is predominantly done manually, a laborious task often carried out by women and children, exacerbating gender inequalities and hindering access to education (Christie *et al.*, 2025).

Uganda's economy is heavily reliant on agriculture, which accounts for approximately 24% of the GDP and employs over 70% of the population (UBOS, 2023). Smallholder farmers dominate the agricultural landscape, cultivating diverse crops such as maize, beans, coffee, and bananas. Weeds are a major constraint to agricultural productivity in Uganda, leading to significant yield losses and increased labour demands. The average Ugandan farmer spends considerable time on weeding, often at the expense of other essential farm activities or educational opportunities for their children (Andersson & Isgren, 2021). There is a clear need for a robust, and multi-functional agricultural machinery tailored to the specific needs and operational environments of farmers (Daum & Birner, 2020).
However, the adoption of advanced machinery often bypasses smallholder farmers due to high costs, lack of appropriate technology, and limited access to financing. The integration of weeding capabilities into a single, engine-powered weeder-sprayer machine addresses the dual challenges of weed management, offering a cost-effective and versatile solution.

1.3 PROBLEM STATEMENT

Medium-scale maize farmers say 2-5 acres (Nyirenda *et al.*, 2020) face significant productivity challenges due to persistent reliance on inefficient methods for weed management experiencing yield loses of up to 50%. The commonly used manual weeding practice is labor-intensive, time-consuming, and physically tiring, leading to delayed operations, high production costs, and substantial crop yield losses as weeds compete for the vital resources. The existing mechanical inter-row weeding machines leave weeds in the intra-rows and those close to the plant. This makes it costly to remove the left behind weeds in the intra-rows and in the plant. The use of basic knapsack sprayers for applying herbicides pose considerable health risks to operators since they have to be carried at the back.

Existing advanced machinery is often too costly, complex, and inaccessible. This gap necessitates the design and fabrication of an engine powered weeder-sprayer machine that can provide an efficient, safer, and economically viable solution, thereby transforming critical farm operations, enhancing farmer livelihoods, and contributing to sustainable agricultural development.

1.4 OBJECTIVES

1.4.1 MAIN OBJECTIVE

To design and fabricate an engine powered weeder-sprayer machine for maize.

1.4.2 SPECIFIC OBJECTIVES

1. To design the components of the machine.
2. To fabricate and assemble the different components of the machine.
3. To test the performance of the machine.
4. To determine the cost effectiveness of the machine.

1.5 RESEARCH QUESTIONS

1. What is the optimal design and operational parameter of the weeds blade for the mechanical weeding mechanism to maximize weed removal efficiency and minimize crop damage in diverse intra-row conditions?
2. How can the intra-row spraying system be designed and calibrated to achieve a uniform application rate and minimize spray drift, ensuring targeted weed control with optimal chemical usage?
3. What is the overall area covered per unit time, operating cost of the fabricated weeder-sprayer machine?
4. How do its ergonomic features impact operator comfort and safety?

1.6 JUSTIFICATION

Maize traditional weeding methods like pulling using hands, hoeing require much significant manpower and are time consuming. The advanced weeding machinery are too expensive, inaccessible, cannot weed in the intra-rows and at the maize plant post areas. The design and fabrication of an engine powered weeder-sprayer machine will ensure efficient weed removal in both the inter-rows and intra-rows. This will result into proper crop growth, high maize production, reduced manual labor hence allowing farmers to allocate their workforce to other activities.

1.7 SIGNIFICANCE

This project for the design and fabrication of an engine-powered weeder-sprayer machine directly contributions to Sustainable Development Goals (SDGs). By significantly enhancing farm productivity and reducing labor costs, the machine directly supports SDG 1 (No Poverty) and SDG 2 (Zero Hunger), enabling farmers to achieve higher yields, improve food security, and generate greater income. Reducing farmer drudgery, it promotes safer and more dignified working conditions, thereby contributing to SDG 8 (Decent Work and Economic Growth).

1.8 SCOPE OF THE STUDY

This study focuses on the design, fabrication, and evaluation of an engine powered weeder-sprayer machine with an integrated weeding and spraying mechanisms specifically for inter-row crops. The project will encompass the comprehensive engineering process, from initial design concepts, selection of appropriate materials and physical fabrication of a functional prototype and performance evaluation of the machine.

The project will include the integration of essential safety features to protect operators and minimize operational risks during weeding. Initial performance testing and evaluation of the prototype will investigate its effectiveness in weed removal, the uniformity and efficiency of herbicides spray coverage, operational speed, and overall fuel consumption. The geographical area of study is Iganga district, and the project duration is set for 6 months.

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

Brief Description of an Engine-Powered Weeder-sprayer machine

An engine-powered weeder-sprayer machine is an agricultural implement designed to efficiently perform two critical farm operations: mechanical weeding in the inter-rows and the precise application of liquid herbicides in the intra-rows. It integrates these functions into a single mobile chassis, typically powered by a small internal combustion engine, making it suitable for small to medium-scale farms, particularly those in developing regions.

The machine generally consists of a robust frame supporting a small petrol engine, which drives both the weeding mechanism and spray pump. The weeding component often comprises blades positioned to effectively remove weeds between crop rows. The spraying system utilizes a horizontally mounted boom fitted with two nozzles to ensure uniform distribution of herbicides in the intra-rows. A tank of appropriate capacity is also mounted on the frame. The entire unit is designed for walk-behind operation, guided by an operator using handles and controls, allowing for maneuverability in various field conditions. Key features include adjustable controllable spray pressure, and integrated safety guards for moving parts, aiming to significantly reduce labor, improve efficiency, and enhance farmer safety compared to traditional manual methods.

2.2 EVOLUTION AND TECHNOLOGIES IN WEED MANAGEMENT

Weeds are major biological constraints on crop production, competing for vital resources and causing significant yield losses globally, often exceeding 30-50% in many crops if not managed effectively (Chauhan *et al.,* 2012). Strategies for weed control have evolved from manual methods to a combination of mechanical, chemical and biological.

2.2.1 Manual Weeding

Manual weeding remains the most prevalent method in many developing countries, including Uganda. It offers precision, minimizes chemical use, and does not require capital investment in machinery.

Figure 1. Showing manual weeding by hand pulling

Advantages

1. Zero direct fuel cost.
2. No chemical residue.
3. Suitable for closely spaced crops or complex infestations.
4. No machinery breakdown.

Disadvantage

1. Extremely labor-intensive and time-consuming.
2. Highly susceptible to labor availability and cost fluctuations.
3. Physically demanding leading to farmer drudgery and fatigue.
4. Often results in delayed operations missing critical control windows.
5. Its scalability is severely limited making it impractical for even modest farm sizes.

2.2.2 Hoe weeding

This is a common method of weed control that involves using a hoe to cut or dislodge weeds from the soil. It is a traditional and widely practiced technique, particularly in small-scale farming and gardening.

Figure 2. Showing manual weeding by hand hoe

Advantages

1. Hoes are relatively simple to use and cheap tools.
2. No chemicals.

Disadvantages

1. Hoe weeding can be a very labor-intensive and time-consuming task, especially in larger areas or when dealing with a heavy weed infestation.
2. Prolonged hoeing can lead to physical fatigue, back pain, and other musculoskeletal issues, particularly for individuals who are not accustomed to manual labor.
3. Some deep-rooted or perennial weeds may not be effectively controlled by hoeing.
4. Careless hoeing can damage the roots or stems of desirable crops.

2.2.3 Mechanical Weeding

Mechanical weeding machines utilize physical force to remove or damage weeds. These range from simple hand tools to sophisticated tractor-mounted implements. For smallholder farmers, push/pull type rotary weeding machines or power tillers with weeding attachments are common.

2.2.3.1 Rotary Weeding Mechanisms

These typically consist of rotating blades or tines that uproot or cut weeds between crop rows.

Figure 3. Showing PTO Driven Rotavator

Advantages

1. Environmentally friendly. (reduces herbicide reliance)
2. Effective for inter-row weeding, breaks soil crust improving aeration.
3. Relatively low operating cost once purchased. ("Performance Evaluation of an Engine-Operated Weeding Machine," 2023)

Disadvantages

1. Less effective for intra-row weeds. (Within the crop line).
2. Requires specific row spacing.
3. Less effective in dense or deep-rooted weed infestations.
1. Initial high cost.
2. High maintenance costs.

2.2.3.2 Engine-Powered Walk-Behind Weeding machines

Kumar and Singh (2019), developed an engine-operated walk-behind weeding machines for maize cultivation, demonstrating significant time savings and higher weeding efficiency compared to manual methods. Their design incorporated adjustable rotary blades powered by a small petrol engine, making them less physically demanding than manual or push-type mechanical weeding machines. However, it lacked spraying components.

Bhullar *et al.* (2018) , highlighted the potential of multi-crop power weeding machines in enhancing farmer incomes by reducing weeding costs. While these machines perform mechanical weeding and sometimes light tillage, the integration of a precise spraying system is less common.

2.2.3.3 Solar Operated Walking Type Power Weeding machines

Solar-operated walking-type power weeding machines offer an eco-friendly and cost-effective solution for weed control by utilizing solar energy to power their weeding mechanisms. These operator-guided machines reduce reliance on fossil fuels, cut operational costs, and minimize environmental impact, representing a sustainable advancement in agricultural technology for efficient weed management.

Figure 4. Showing solar powered walk behind weeding machine

Disadvantages

1. Performance is reduced on cloudy days or in shaded areas, often requiring heavy and costly battery backups.
2. Less powerful than gasoline alternatives, struggling with very dense or tough weeds.
3. Requires specific technical knowledge.
4. Batteries have a limited life and replacement costs add to long-term expenses.

2.2.4 Chemical control Technologies of weeds

Chemical control, primarily through herbicides, forms a vital component of modern crop management. The efficiency of chemical control is highly dependent on the precision and uniformity of application.

2.2.4.1 Bucket method application of herbicides

A concentrated herbicide solution is mixed in a bucket, and then manually applied directly to the target weeds. This can be done by dipping a sponge or brush into the solution and wiping it onto the leaves, or by carefully pouring a small amount onto the base of the plant. It's particularly effective for selective weeding in gardens, nurseries, or around sensitive crops where precision is crucial.

Figure 5. Showing manual Spraying

Advantages

1. Precision control, minimal drift and protects desirable plants.
2. Lower consumption, cost-effective and environmentally friendlier.
3. Less applicator exposure to chemicals.

Disadvantages

1. Slow and impractical for large farms.
2. Requires bending/squatting.
3. Manual process can lead to inconsistencies.

2.2.4.2 Knapsack Sprayer

These are the most common spraying devices in developing countries, including Uganda, due to their low cost and portability (Vigo-Morancho *et al.,* 2024). They consist of a tank, pump (manual or motorized), and a lance with a nozzle, carried on the operator's back.

Figure 6. Showing Knapsack Spraying

Mode of operation of a knapsack sprayer

Preparation. The operator fills the sprayer's tank with the desired herbicide solution.

Pressurization (Manual). The operator wears the knapsack on their back and manually pumps a lever (usually located to the side) to build pressure within the sprayer's chamber. This action forces the liquid into a pressurized state.

Application. Once sufficient pressure is built, the operator uses a handheld lance with a nozzle at the end. A trigger or valve on the lance is activated, releasing the pressurized liquid as a fine spray onto the target area (weeds).

Continuous Pumping. For continuous spraying, the operator must maintain regular pumping with one hand while directing the spray with the other.

Advantages

1. Low initial cost.
2. Highly portable.
3. Suitable for small and irregularly shaped plots.
4. Flexible for spot spraying.

Disadvantages

1. Highly dependent on operator skill for uniform coverage.
2. Prone to uneven application leading to chemical wastage or inadequate control.
3. Slow operation rate for larger areas.
4. Significant operator fatigue.

5. Direct exposure to chemicals posing serious health risks. (Damalas & Eleftherohorinos, 2011)

2.2.4.3 Boom Sprayers

Boom sprayers utilize a horizontal boom fitted with multiple nozzles to achieve wide and uniform coverage of chemicals over an area. They typically comprise a tank, pump, boom, and nozzles, and can be mounted on tractors, towed, or designed as self-propelled units.

(Singh *et al.* 2021) explored the design parameters for a power tiller operated boom sprayer, emphasizing coverage efficiency. While effective for spraying, this approach often necessitates separate passes for weeding or requires complex interchanging of implements.

Tractor Mounted Boom Sprayers

The developed mini tractor operated sprayer cum weeding machines is an efficient machine that can complete both spraying and weeding tasks in a single pass, saving time, cost and increasing weeding efficiency (V. Jalu *et al., 2024).*

Nalavade *et al.* (2008). Developed a tractor mounted wide spray boom for increased efficiency. A 15-m tractor mounted spray boom was developed considering the stresses acting on the boom structure. The developed spray boom's performance was compared with existing 9-m spray boom developed by a local manufacturer. Further, both spray booms were evaluated from the economic point of view. Statistical analysis showed that there was no significant variation in spray uniformity within a field for all the test trials (Quan *et al., 2025).*

Figure 7. Showing PTO Boom Sprayer

Mode of operation of a tractor mounted boom sprayer

A boom sprayer cum weeding machines operates by a small engine powering a pump that draws liquid from a tank. This liquid is then pushed through a series of nozzles mounted on a horizontal boom, creating a wide, even spray pattern over the field. For weeding, the boom sprayer cum-weeding machines can either deliver herbicides or be fitted with light mechanical weeding attachments to disturb young weeds. The operator drives the machine through the field, ensuring precise and consistent application.

Advantages

1. Highly uniform chemical application over wide areas.
2. Significant reduction in application time compared to knapsack sprayers.
3. Greater coverage efficiency.
4. Reduces operator exposure to chemicals (as the operator is often separated from the immediate spray zone).
5. Improved control over droplet size and spray pattern.

Disadvantages

1. Higher initial cost.
2. Requires larger clear areas for operation.
3. Can be challenging to maneuver in very small or irregularly shaped plots.
4. Potential for spray drift in windy conditions.
5. Requires access to water and proper mixing equipment.
6. Engine-powered versions require fuel and maintenance.

Engine-Powered Walk-Behind Boom Sprayer

Integrating a small engine to power the pump and potentially propulsion for a walk-behind boom sprayer offers a step up from manual knapsack sprayers.

Advantages

1. Consistent pressure for uniform spray.
2. Reduced operator fatigue compared to manual pumping.
3. Faster application rate,
4. Better coverage for medium-sized plots.

Disadvantages

1. High initial cost of the engine and components.
2. Requires fuel and maintenance.
3. Still demands operator guidance and maneuvering.

4. Potential for uneven coverage if boom height or speed is not consistently maintained.

2.2.5 Biological weed control methods

Biological weed control is an environmentally friendly approach to managing weeds by using natural enemies to suppress their growth and reproduction. This method aims to reduce the weed population to an acceptable level rather than eradicating it completely. Here are some common biological weed control methods.

Many insect species feed on specific plants. Introducing host-specific insects that feed on a target weed can significantly reduce its spread. For example, the cinnabar moth has been used to control ragwort.

Livestock like goats, sheep, and even cattle can be effectively used to control weeds in certain areas. They browse on weeds preventing seed production. This is particularly useful in rangelands or areas where chemical control is not desired.

Advantages

1. Reduces reliance on synthetic herbicides, protecting ecosystems and non-target organisms.
2. Can reduce long-term weed control costs.

Disadvantages

1. Finding agents that are highly specific to the target weed and won't harm desirable plants can be challenging.
2. Effects may not be immediate, it often takes time for the biological agent population to build up and exert significant control.
3. Requires thorough research and testing to ensure the introduced agent does not become a pest itself.

2.2.6 Design Considerations for an engine powered weeder-sprayer machine

Studies by Nkwabi *et al*.., (2021) and (Ageze *et al*.., 2024) consistently highlight the specific challenges faced by African farmers, including labor scarcity, low mechanization levels, and limited access to appropriate technology. This underscores the need for specific designs, such as the proposed engine-powered weeder-sprayer machine, that are robust, affordable, and easy to maintain within local conditions (Phadtare *et al.*, 2023).

The design of an engine-powered weeder-sprayer machine requires careful consideration of several factors to ensure its effectiveness, durability, and user-friendliness in real-world agricultural settings.

Power Source (Engine)

A small internal combustion engine (5-7 Hp petrol engine) is a suitable choice for a walk-behind implement, offering sufficient power for both weeding mechanisms and a high-pressure spray pump.

Advantages

1. Readily available and understood technology in many rural areas.
2. High power-to-weight ratio.
3. Can operate continuously as long as fuel is supplied.

Disadvantages

1. Requires fossil fuel.
2. Produces noise and exhaust emissions.
3. Requires regular maintenance (oil changes, spark plugs), can be challenging to start manually, vibration can affect operator comfort.

Chassis and Frame

The frame must be robust enough to withstand vibrations, carry the weight of the engine, tank, and weeding unit, and provide stability. It needs to be maneuverable in tight spaces and easily adjustable for different crop row spacing and heights.

Weeding Mechanism

Rotary tines or blades are common. The design should allow for easy adjustment of weeding depth.

Spraying System

A tank of appropriate capacity (e.g., 20-50 liters for a walk-behind unit), a diaphragm or piston pump powered by the engine, a pressure regulator, and a boom with multiple nozzles are essential. Nozzle selection (e.g., flat fan, cone) is crucial for optimal spray pattern and droplet size based on the chemical being applied.

Ergonomics and Safety

Operator comfort and safety are paramount. Handlebar design, vibration dampening, location of controls, and clear visibility are important ergonomic factors. Safety features must include guards for moving parts (weeding blades), a secure tank for chemicals, and easily accessible emergency stop switches.

Maneuverability and Transport

The machine should be lightweight enough for manual steering and propulsion, or designed with driven wheels for easier movement. Its dimensions should allow for easy transport within small farm roads and paths.

2.2.7 Common weeds found in Uganda

Table 1. Showing different common weeds in Uganda

No.	Weed Name	Type	Key Features
1	Striga hermonthica (Witchweed)	Parasitic annual	Purple flowers; parasitic on maize, sorghum roots
2	Cynodon dactylon (Star grass/Bermuda grass)	Perennial grass	Creeping stems, forms dense mats
3	Imperata cylindrica (Spear grass)	Perennial grass	Tall (up to 1.5 m), sharp leaves, fluffy white seed heads
4	Bidens pilosa (Blackjack)	Annual broadleaf	Serrated leaves, barbed seeds
5	Ageratum conyzoides (Goat weed)	Annual broadleaf	Soft hairy leaves, purple/white flowers
7	Euphorbia heterophylla (Wild poinsettia)	Annual broadleaf	Milky sap, red/green bracts

8	Commelina benghalensis (Wandering Jew)	Perennial herb	Succulent stems, blue flowers, creeping habit
9	Galinsoga parviflora (Gallant soldier)	Annual broadleaf	Small white-yellow flowers, fast-growing
10	Cyperus rotundus (Purple nutsedge)	Perennial sedge	Triangular stems, tubers underground
11	Amaranthus spinosus (Spiny amaranth)	Annual broadleaf	Spiny stems, greenish flowers
12	Digitaria abyssinica (Finger grass)	Perennial grass	Creeping stolons, narrow leaves
13	Portulaca oleracea (Purslane)	Annual succulent	Thick fleshy leaves, yellow flowers

2.2.8 Research Design

This research adopted a mixed-methods approach, integrating both qualitative and quantitative data for comprehensive analysis. It involved conceptual design, detailed engineering design, fabrication, assembling, and testing and performance evaluation.

2.2.9 Research Instruments and Data Collection

This research utilized a combination of instruments and methods for data collection to ensure a holistic understanding of the problem and the effectiveness of the designed solution.

1. Open discussions

These were with farmers, particularly those involved in maize crops.

Discussions focused on current challenges and constraints related to spraying and weeding operations, existing methods and tools used for spraying and weeding, time and labor expenditure on these tasks, desired features and improvements in agricultural equipment.

2. Observation

Direct observation of existing spraying and weeding practices in the field provided empirical data on operational challenges and effectiveness of current tools.

3. Internet Sources and Library Research

Extensive literature review was conducted using academic databases, journals, and relevant publications to gather information on existing sprayer and weeding machines technologies, design principles, materials science, and safety standards.

3.0 CHAPTER THREE: METHODOLOGY

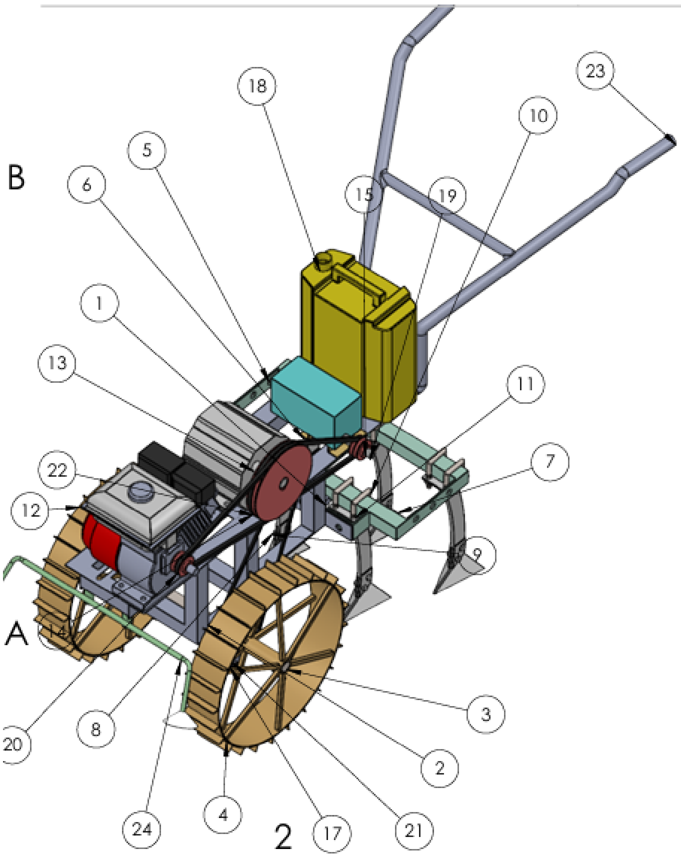
3.1 INTRODUCT ION

This chapter discusses the research methodology, design, and machine design concepts/features. The information from this chapter helped in data interpretation and analysis in the subsequent chapter.

This involved design of an engine powered weeder-sprayer machine for medium scale farmers.

3.2 SPECIFIC OBJECTIVE 1: TO DESIGN THE COMPONENTS OF THE MACHINE

3.2.1 Design drawing



ITEM NO.	PART NUMBER	QTY.
1	Main Frame 1	1
2	bearing1	2
3	shaft	1
4	fabricated wl	2
5	support	1
6	Detachable blade	5
7	Detachable shovel	5
8	m8 bolt	10
9	m8 nut	10
10	U-bolt stud	10
11	nut	20
12	engine	1
13	gear box	1
14	gearbox pulley	1
15	engine pulley	2
16	small sprocket	1
17	sproket	1
18	jerrican tnk	1
19	pump	1
20	Belt1-1^Final assembly	1
21	Belt2-2^Final assembly	1
22	Belt3-3^Final assembly	1
23	new handle	1
24	nozzle pipe	1

1

Figure 8. Showing conceptual drawing

3.2.2 Mode of operation

1. The engine powered weeder-sprayer machine was designed for weed control in both inter-rows and intra-rows simultaneously.
2. An engine serves as the primary power source.

3. The engine's power is evenly distributed, enabling the mechanical weeding mechanisms to operate in the inter-rows, physically removing weeds by cutting or uprooting. Concurrently, the engine also powers a pump system for the herbicide sprayer.
4. Upon engine activation, a clutching mechanism is engaged by the operator.
5. This mechanism allows the operator to determine precisely when to start the mechanical weeding and when to activate the herbicide sprayer using the tensioner, ensuring that they do not begin operation immediately upon engine start-up.
6. This provides essential control, allowing the operator to initiate weeding and spraying independently as needed for effective machine management.
7. This dual-action approach ensures comprehensive and efficient weed management, optimizing control in both critical areas of the field.

3.2.3 Process Flow Diagram

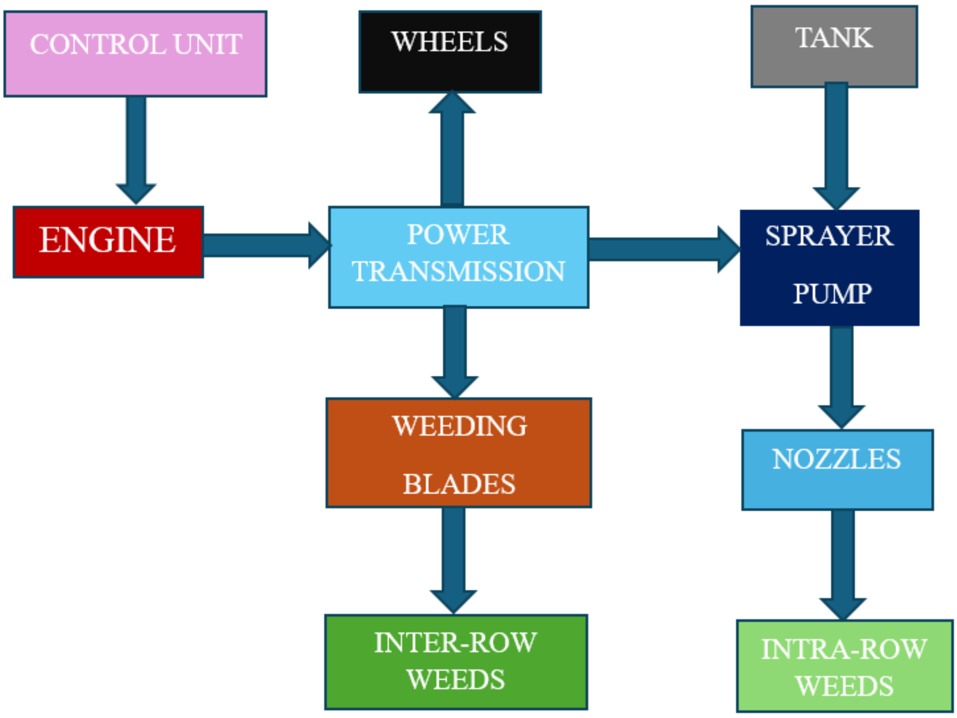


Figure 9. Process flow diagram

3.2.4 Design Considerations

The factors below were considered when designing an engine powered weeder-sprayer machine.

1. Availability of the raw materials.

2. Robust but portable and simple construction for easy operation, transportation and maintenance.
3. Maneuverability and steering in various garden profile conditions like in muddy conditions.
4. Safety guards on rotating components.
5. The spare parts availability in the market.
6. Affordability by majority of the small and medium scale farmers.

3.2.5 Component design

The engine-powered weeder-sprayer machine comprises of several key integrated components working unity for effective weed control.

Some components where designed using Solidworks and AutoCad while others were selected.

3.2.5.1 Design of the mechanical weeding unit

Distances between the maize rows range between 75 and 90cm. This guided on the width of the machine. Root depth and spread of maize at weeding stage helped to determine the permissible weeding depth. Soil properties that is, type, resistance, presence of obstacles guided on material selection of carbon steel for strength and corrosion resistance.

Types of forces acting on a weeding tool

1. Force of gravity acting upon then tool (vertical component).
2. Force acting between the tool and the machine.
3. Draft force between the tool and implement.

Number of tines

$$Number\ of\ tines, n = \frac{Width\ of\ the\ machine}{Width\ of\ tine} \quad \text{(3-1)}$$

Power required for mechanical weeding

$$Area, A_{weeding} = W_{weeding} \times D_{weeding} \quad \text{(3-2)}$$

$$P_{weeding} = {n(S.R \times A_{weeding} \times V_{machine})}\big/{746} \quad \text{(3-3)}$$

Where, $\mathrm{S.R}$ – soil resistance $(\frac{\mathrm{N}}{\mathrm{m}^2})$

$\mathrm{W_{weeding}}$ – Effective width of cut (m)

$\mathrm{D_{weeding}}$ – Depth of cut (m)

$\mathrm{V_{machine}}$ – Linear velocity of the tine or blade at the point of soil contact (m/s)

746 = conversion factor from W to Hp

3.2.5.2 Design of the wheel shaft

The shaft is subjected to both bending and twisting.

Equivalent Torque (Combined loading)

$$T_e = \frac{\pi}{16}\tau d^3 = \sqrt{(K_m M)^2 + (K_t T)^2} \text{..................(3-4)(Hooker, 1981).}$$

Where,

d - diameter of the shaft

M − Bending moment

T−Twisting moment

T_e − Equivalent twisting moment

k_m − Combined shock and fatigue factor for bending

k_t − Combined shock and fatigue factors for torsion

3.2.5.3 Wheels/Traction System

The machine has two self-propelled wheels

The rims are made from steel alloys.

Diameter of the rim, d

Taking linear velocity of the machine, v

Total power required to run the wheels

$$P = \omega T \text{................................(3-5)(Alam et al., 2016)}$$

$$since, \omega = \frac{2\pi N}{60}$$

Where, N = Number of revolution per minute

T = Torque

Load capacity, L_c

The wheels support the weight of the machine.

$$L_c = \frac{Total\ machine\ Weight}{Number\ of\ tires} \text{......................(3-5)(Vantsevich, 2008)}$$

Ground pressure, G_p

This determines how much the tire compacts the soil.

$$G_p = \frac{Load\ on\ wheel}{Wheel\ contact\ area} \text{...(3-6)}$$

3.2.5.4 Design of herbicide spraying unit

Required discharge

This is the flow rate. It is the total liquid volume needed per unit time.

$$Q = q_n N, \text{ .... (3-7)(J. Wang } et\ al.\text{, 2020)}$$

Where, q_n − Flow rate per nozzle

N − Number of nozzles

$$Distance = \frac{Area}{Width} \text{........................(3-8)(Privitera } et\ al.\text{, 2023)}$$

Time taken

$$Time = \frac{Distance}{Speed} \text{............................(3-9)(Privitera } et\ al.\text{, 2023)}$$

Total volume, V

$$V = Discharge \times Time$$

Design of the herbicides tank (Reservoir)

This is of HDPE.

Considering a safety margin of 10%, the reservoir volume is 30 liters.

The volume of the tank,

$$V = b \times w \times h \text{.............................. (3-10)(Paul } et\ al.\text{, 2024)}$$

Where, b − length of tank

H − Tank height

Taking height, length and width of a 10- liter jerrican as 280mm, 305mm and 350mm

Power required to run the pump

$$P_p = \frac{\rho h g Q}{\mu} \text{............................ (3-11) (Privitera } et\ al.\text{, 2023)}$$

Where, ρ − Density of the liquid

h − Discharge height

g − Acceleration due to gravity

Q − Discharge

μ − Engine efficiency

Hose pipes

Determining the hose pipe diameter using

$$Q = A \times v \text{................................ (3-9)(Privitera } et\ al.\text{, 2012)}$$

Were, Q − Volumetric flow rate $(\frac{m^3}{s})$

A − Cross − sectional area of the hose pipe (m^2)

v − Average fluid velocity (m/s)

3.2.5.5 Design of the main frame

This was made from angle lines and square hollow sections to provide a robust support, stability during operation and proper alignment for the engine, gearbox mechanical weeding unit, and the herbicide spraying unit.

Maximum bending stress

This helps to prevent yielding of fracture due to bending.

$$\delta_{max} = \frac{M_{max} c_{max}}{I} \qquad (3\text{-}13)$$ (Spanoudakis *et al*., 2020)

Maximum deflection

This helps to ensure rigidity, prevent misalignment.

$$y_{max} = \frac{WL^3}{48EI} \qquad (3\text{-}14)$$ (S. Wang *et al*., 2026)

Where, δ_{max} − Maximum bending stress

M_{max} − Maximum bending moment

c_{max} − Distance from the neutral axis to the outermost of the cross − section

I − Area moment of inertia of the cross − section

y_{max} − Maximum defelection

W − Concentrated load

L − Length of the cross − section

E − Modulus of elasticity of the material

3.2.5.6 Design of pulleys

For engine and gear box

Considering an engine with a pulley of diameter, d_1. And gearbox pulley d_2.

For a system with two pulleys,

$$n_1 d_1 = n_2 d_2 \qquad (3\text{-}15)$$ (Chung *et al*., 2026)

Where, d_1 −driving pulley diameter

n_1 − Number of revolutions of the driving pulley

$\mathrm{d_2}$ −Driven pulley diameter

$\mathrm{n_2}$ −Revolutions of the driven pulley

Belt length on the pulleys on engine and gear box.

$$L = 2c + \frac{\pi}{2} \times (d_1 + d_2) \frac{(d_1 - d_2)^2}{4c}$$ ……………………(3-16)(Chung *et al*., 2026)

Where, L − total belt length

c − center distance between pulleys

$\mathrm{d_1}$ − Diamenter of the driver pulley

$\mathrm{d_2}$ − Diameter of the driven pulley

Gearbox and pump

Gearbox pulley diameter, d_1 and Pump pulley diameter, d_2

$$n_1 d_1 = n_2 d_2$$ ……………………………………(3-17)(Chung *et al*., 2026)

Belt length on the pulleys on and the pump

$$L = 2c + \frac{\pi}{2} \times (d_1 + d_2) \frac{(d_1 - d_2)^2}{4c}$$ …………………(3-18)(Chung *et al*., 2026)

3.2.5.7 Sprockets and chain

For a system with 2 sprockets having

$$n_1 t_1 = n_2 t_2$$ ……………………………………(3-19)Woyessa & Olaniyan, 2023)

Number of chain links, k

$$k = \frac{2x}{p} + \frac{(t_1 + t_2)}{2} + \frac{(t_2 - t_1)^2 p}{4\pi^2 x}$$ ……………………(3-20)(Woyessa & Olaniyan, 2023)

Length of the chain,

$$L = kp$$ ……………………………………(3-21)(Woyessa & Olaniyan, 2023)

Where,

n_1 = Number of revolution of driver sprocket

n_2 = Number of revolution of driven sprocket

d_1 =Diameter of driver sprocket

d_2 =Diameter of driven sprocket

L= chain length

x = center distance between sprockets

3.2.5.7 Engine Unit

Serves as the prime mover. This internal combustion engine generates the power necessary to drive both the mechanical weeding and herbicide spraying systems and propel the machine.

3.2.5.8 Control unit and clutching mechanism

This housed all necessary controls for the operator, including engine start/stop, engagement/disengagement for the drive wheels, and activation/deactivation of the herbicide sprayer.

3.3 SPECIFIC OBJECTIVE TWO: TO FABRICATE AND ASSEMBLE THE COMPONENTS OF THE MACHINE.

3.3.1 Material selection and procurement

All the raw materials and components (steel plates, tubes, shafts, rubber, plastics, engine, pump, bearings, pulleys, belts, bolts, and nuts, wheels, tank and fasteners) according to the BOQ.
The selection of materials for fabricating and assembling the components was based on the following criteria.

Table 2. Showing components, selection criteria and possible material to be selected.

S/N	Machine component	Selection criteria	Material Selected
1	Frame	Strength and rigidity, weight, welding ability, cost, availability	MS 40×40×3mm hollow section, 50×50×2mm angle bars
2	Weeding blades	Hardness, toughness,	5×40mm High carbon steel flat bars
3	Shaft	Torsional strength, bending strength, machinability	32mm Solid carbon steel
4	Engine	Power output, fuel type, maintenance and spare parts, weight and size, reliability and durability	Small internal combustion engine
5	Wheels	Traction, load capacity, durability, size	Tire and rim

6	Pump	Flow rate, pressure, chemical compatibility, size	Pump body, internal components
7	Nozzle	Spray pattern, flow rate, chemical compatibility	Ceramic
8	Hose pipes	Pressure rating, chemical compatibility	PVC, HDPE
9	Belts	Power transmission capabilities, wear resistance, heat resistance, flexibility,	Fiber
10	Pulleys	Diameter, groove profile, material strength, weight	Cast iron
11	Handles	Ergonomics, strength	Hollow steel section, rubber/plastic tubing
12	Bearings	Load capacity, durability and life expectancy	High carbo chromium
13	Bolts and nuts	Strength, reliability	Mild steel
14	Tank	Strength, volume capacity, chemical compatibility	HDPE

3.3.2 The fabrication processes

Table 3. Showing Operations and their respective tools, equipment and machines for fabrication of components

S/N	Operations	Tools, equipment, and machines used
1.	Measuring	Measuring tape, tri-square, micrometer screw gauge, pressure gauge and Vernier caliper
2.	Marking out	Marker pen, scriber, center punch, tri-square, divider
3.	Cutting	Bench vice, hand hacksaw, angle grinder and cutting disc
4.	Welding	Arc welding machine, welding torch, welding mask
5.	Grinding	Angle grinder and grinding disc

6.	Machining	Lathe machine, turning, boring and chamfering tools, universal milling machine, universal shaping machine, and grinding machine
7.	Tightening	Spanners (open, fixed, combination and adjustable types)
8.	Drilling	Drill bits, power drilling machine, clamping table, and grinding machine
9	Bending	Hammer, bench vice
10	Painting	Tin, brushes

3.3.2.1 Frame, handles and blades fabrication

Cutting of steel sections to the specified dimensions for the main frame, handles and blades was done using hacksaws and angle grinder and then assembled and welded.

Grinding was done to clean-up the slags and remove sharp edges.

3.3.2.2 Blades heat treatment

This was a critical process to transform soft, shapeable steel into a hardened tool capable of resisting wear, shock, and abrasion while maintaining toughness to prevent snapping.

The blades were heated to 800^0C-900^0C for about 40 minutes.

Cooling was then done using oil.

3.3.2.3 Shaft machining

The solid steel wheel shaft was machined to achieve the calculated final diameter and length.

3.3.3 Assembling

3.3.3.1. Wheels and shaft

Bearings were fitted on the shaft.

The shaft was attached to the wheels using fabricated couplings and fasteners.

3.3.3.2. Weeder assembly

Bolted the weeder blades to the support/frame.

3.3.3.3. Frame, Engine Pump & Spraying System Assembly

Mounted the frame onto wheels and the weeder.

Mounted the engine, gearbox, pump, reservoir tank and other spraying accessories in their respective positions on the main frame.

The drive systems that are; pulley and belts, chains and sprockets were fitted.

3.3.3.4. Control system

Machine control levers for changing gears (wheel speeds) and belt tensioners for the pump speed were fitted in their ergonomic locations.

3.3.3.5. Final assembling and finishing

Torque fastening was done.

All the components were cleaned.

The frame and other susceptible metal parts were protectively coated with paint and adequate time for curing allowed.

3.4 SPECIFIC OBJECTIVE THREE: TO TEST THE PERFORMANCE OF THE MACHINE.

Trial of the Machine

Performance data was collected during field trials of the machine. This included;

3.4.1 Pre-functional checks & testing

1. Conducted visual inspections for completeness, quality, and proper assembly.
2. Carried out mechanical checks to ensure all moving parts operate freely.
3. The spraying system was for leakages.
4. Basic power-up tests (engine start, wheel drive and pump activation) without load before full operational testing.

3.4.2 Power requirement and fuel consumption

3.4.2.1 Engine power required

Calculated the engine’s output.

Total power,

$$P_t = P_{weeder} + P_{wheels} + P_{spraying} + Losses \ldots\ldots.. \text{(3-22)(Woyessa \& Olaniyan, 2023)}$$

3.4.2.2 Fuel consumption rate

Evaluated the cost and efficiency.

$$Fuel_{consumption} = \frac{Volume\ of\ fuel\ consumed}{Operating\ time}\ \text{(l/hr)} \ldots\ldots\ldots \text{(3-23)(Woyessa \& Olaniyan, 2023)}$$

3.4.3 Weeding mechanism performance

3.4.3.1 Weeding efficiency

Calculated the effectiveness of weed removal.

$$Weeding\ efficiency = \left(\frac{Weeded\ area}{Total\ area}\right) \times 100\%$$ .... (3-24)(Woyessa, 2023)

3.4.3.2 Crop damage rate

$$= \left(\frac{Number\ of\ damaged\ crops\ plants\ per\ unit\ area}{Total\ number\ of\ crop\ plants\ in\ weeded\ area}\right) \times 100$$ …… (3-25)(Woyessa, 2023)

3.4.3.3 Area weeded per hour

Determine productivity.

$$Effective\ field\ capacity = (Speed \times Effective\ working\ width \times Efficiency)$$

……………………………………………………………………. (3-26)(Woyessa, 2023)

3.4.4 Spraying system performance

3.4.4.1 Nozzle flow rate

Verified individual nozzle performance and total spray volume.

$$Flow\ rate = \left(\frac{Volume\ collected\ from\ nozzle}{Collection\ time}\right)$$ …………….……... (3-27)(Privitera *et al*., 2023)

3.4.4.2 Pump efficiency

Evaluated pump's energy conservation.

$$Pump\ efficiency = \frac{hydraulic\ power\ output}{mechanical\ power\ input}$$ ………………... (3-28)(Quan *et al*., 2025)

Where; $P_{hydraulic} = (Flow\ rate \times pressure)$ …….………..(3-26)(Quan *et al*., 2025)

$P_{mechanical}$ – Power from the prime mover

3.5 SPECIFIC OBJECTIVE FOUR: TO DETERMINE THE COST EFFECTIVENESS OF THE MACHINE

3.5.1 Cost-Benefit Analysis for the Weeding Machine

This project aimed at make weeding simpler and more effective for farmers. The machine's initial and operational cost to the farmer versus the financial gains it generates.

3.5.1.1 Net Present Value (NPV)

The Net Present Value was calculated using the equation below;

$$NPV = \left[\sum_{i}^{n} \frac{Cf}{(1+r)^n}\right] - i_0$$ ……………………….. (3-29)(Konyuhov *et al*., 2019)

Source:(Commonwealth of Australia, 2006)

Where; $\frac{1}{(1+r)^n}$ is the discount factor.

i_0 is the initial cost of investment

Cf is the net annual cash flow

r is the discount rate

n is the period

3.5.1.2 The Profitability Index, $P.I$

The profitability index was determined using the formula below;

$$P.I = \frac{Present\ Value\ of\ Net\ Annual\ Cashflows}{Initial\ Cost\ of\ Investment}$$ …………….. (3-30)(Konyuhov *et al.*, 2019)

If the$P.I > 1$, it indicates that the project should proceed whereas in the case of $P.I < 1$, this indicates that the project should be abandoned.

3.5.1.3 The payback period

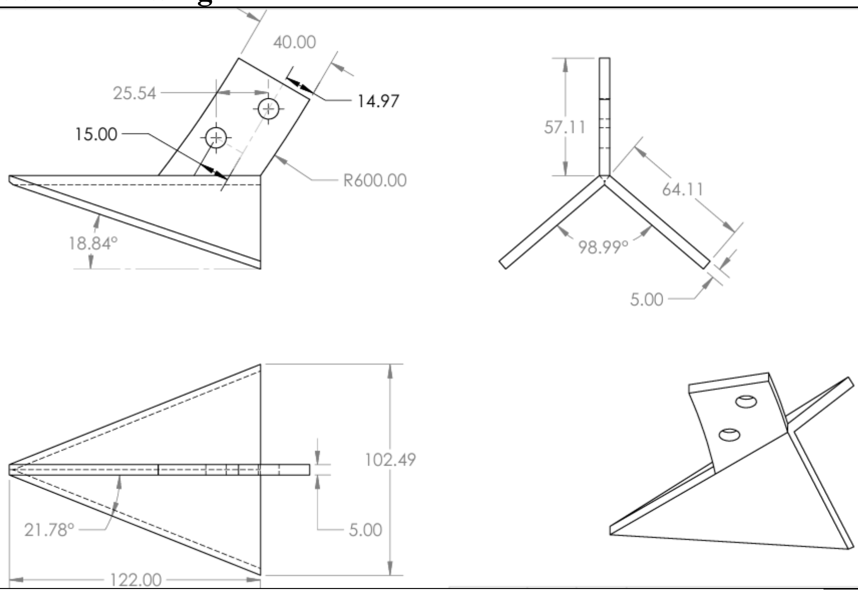
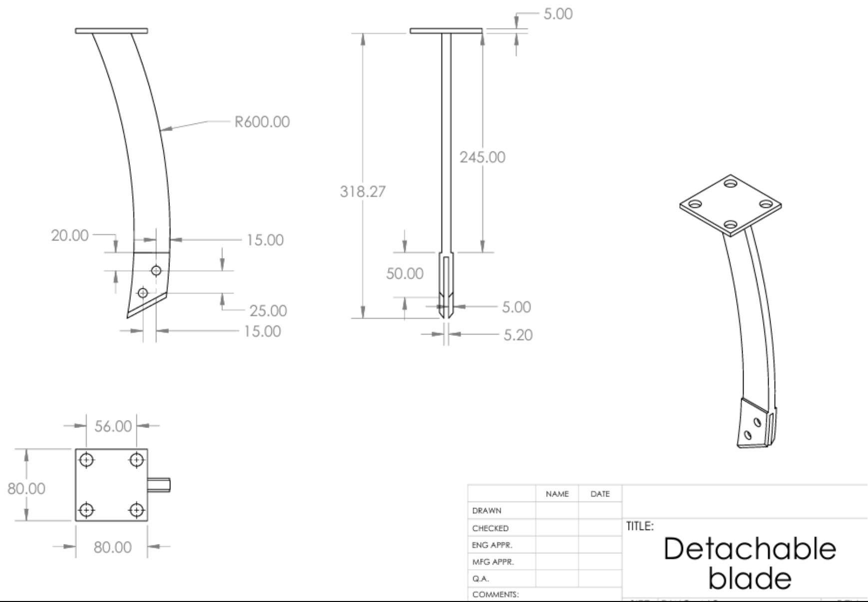
The payback period was calculated using the formula below;

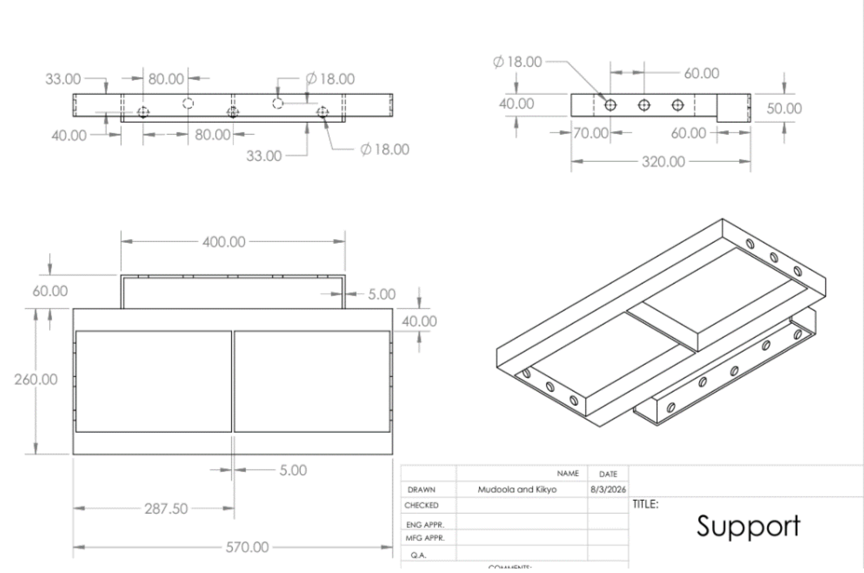
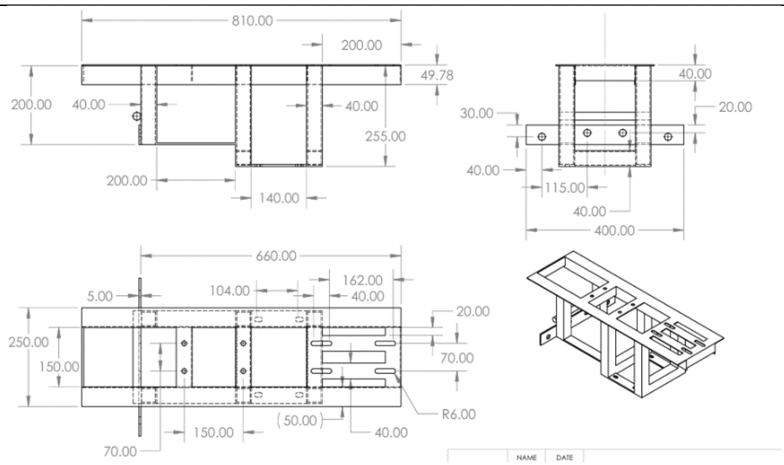
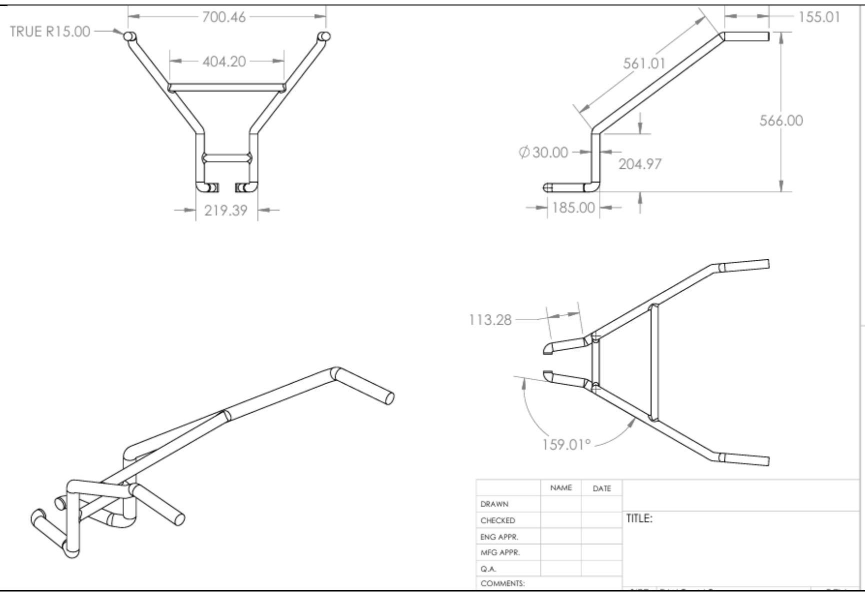
$$Payback\ period = \frac{Initial\ Cost\ of\ Investment}{Net\ Annual\ \ Cashflows}$$ ………….. (3-31)(Konyuhov *et al.*, 2019)

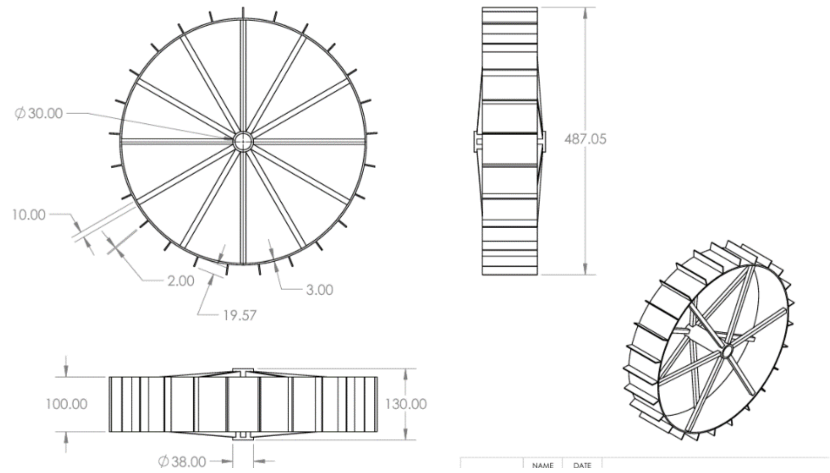
4.0 CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 To design the components

Table 4 Showing Dimensions of different components

No.	Components	Production Drawing
1	Detachable shovel	
2	Blade weeder	

3	Support for blades	
4	Main frame	
5	Main frame	

6	Wheels	

4.1.1 Weeding blades

Considering;

Travel speed $v = 0.5m/s$ or $= 1.8km/h$

Specific draft for clay loam soil, $= 5.0kg/cm^2$ (Angelopoulou *et al.*, 2023)

Cross-sectional area, $A = width \times depth$

$$= 10.2 \times 3$$
$$= 30.6cm^2$$

$$Draft\ of\ a\ single\ tine, d = A \times specific\ draft$$
$$= 30.6cm^2 \times 5.0kg/cm^2$$
$$= 153kg$$

$$Draft\ Power\ per\ tine, D = \frac{153 \times 9.81 \times 1.8}{3.6}$$
$$= 750.465W$$

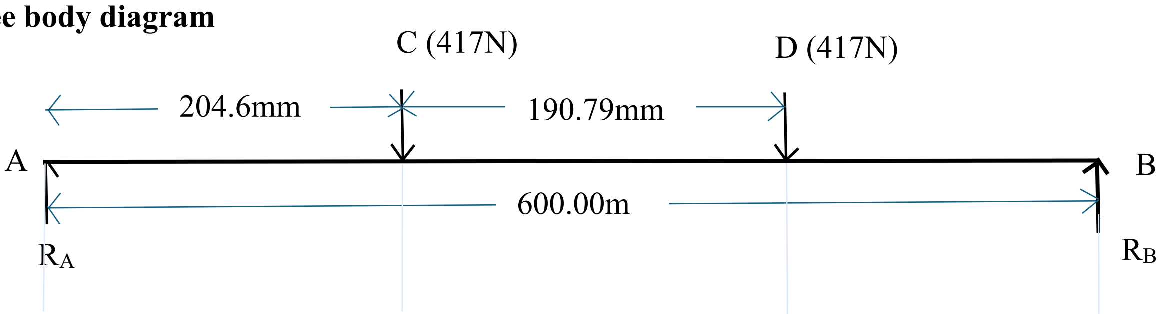
Number of tines, $n = 5$

$$Total\ Draft\ Power\ requirement, Drawbar\ = nD$$
$$= 5 \times 750.465$$
$$= 3752.325W$$
$$= 5.0hp$$

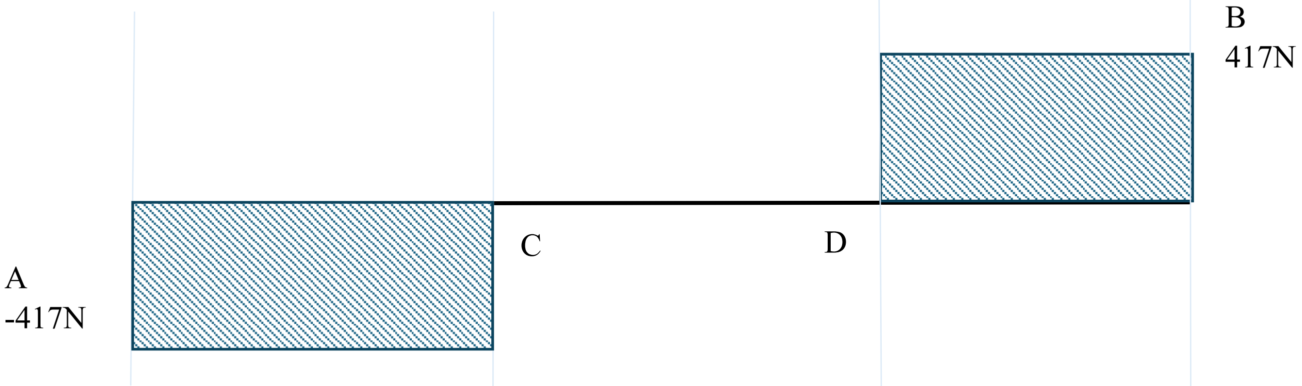
4.1.2 Wheel shaft

Total load on the shaft is 85kg=833.85N

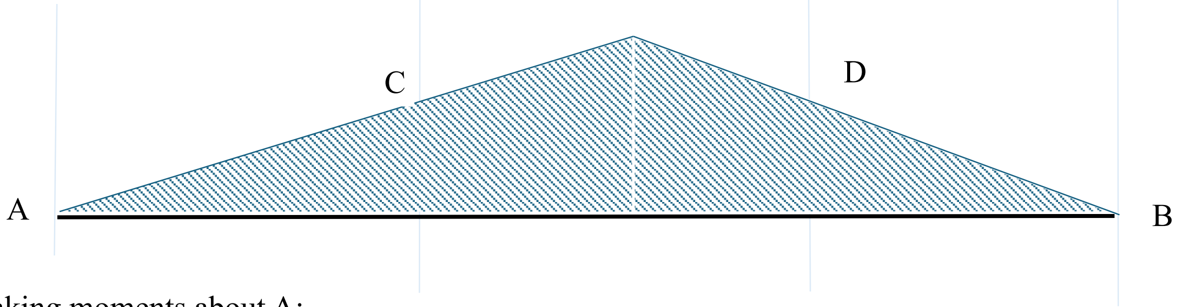
Free body diagram



Shear force diagram



Bending moment diagram



Taking moments about A;

$$R_B \times 600 - [(417 \times 204.6) + (417 \times 395.39)] = 0$$

$$R_B \approx 417N$$

Now; $R_A + R_B = 640N$

$$R_A = 417N$$

Calculating shear force

At B, $S.F_B = 417N$

At D, $S.F_D = (417 - 417) = 0N$

At C, $S.F_C = (417 - 417 - 417) = -417\text{N}$

At A, $S.F_A = (417 - 417 - 417 + 417) = 0N$

Maximum bending moment

At A, $BM_A = 0Nmm$

At B, $BM_B = 0Nmm$

At C, $BM_C = 417 \times 204.6 = 85318.2Nmm$

At D, $BM_D = [(417 \times 395.39) - (417 \times 190.79)] = 85318.2Nmm$

Total load on the shaft, $F = 833.85N$
Torque on the shaft, $T = F \times r$
Where, r is the radius of the rim.

$$= 833.85 \times 225$$
$$= 187{,}616.25Nmm$$

Equivalent Torque (Combined loading) and k_m and k_t values on various loading

$$T_e = \frac{\pi}{16}\tau d^3 = \sqrt{(K_m M)^2 + (K_t T)^2}$$

Taking $both\ K_m\ and K_t = 1.5$

$$\tau = 40MPa$$

$$\therefore \frac{\pi}{16} \times 40 \times d^3 = \sqrt{(1.5 \times 85318.2)^2 + (1.5 \times 187616.25)^2}$$

$$d = 34.01 \approx 35mm$$

4.1.3 Wheels

Diameter of the rim, $d = 450mm$

$$v = 0.5m/s$$

$$v = \omega r$$

$$0.5 = \omega \times 0.225$$

$$\boldsymbol{\omega = 2.22rad/s}$$

$$\omega = \frac{2\pi N}{60}$$

$$N = \frac{2.22 \times 60}{2\pi}$$

$$\boldsymbol{N = 21.20 \approx 21rpm}$$

Total power required to run the wheels

$$P = \omega T$$

$$= \frac{2\pi N}{60} T \qquad \text{But T=Fr}$$

$$= \frac{2\pi \times 21}{60} \times 833.85 \times 0.225$$

$$= 413W$$

$$= 0.55hp$$

Load capacity, L_c

$$L_c = \frac{Total\ machine\ Weight}{Number\ of\ tires}$$

$$= \frac{833.85}{2} = 417N/wheel$$

Ground pressure, G_p

$$G_p = \frac{Load\ on\ wheel}{Wheel\ contact\ area}$$

Wheel contact area $= 100 \times 120 = 12000mm^2$

$$G_p = \frac{833.85}{0.012} = 69.5kPa$$

This is less than the maximum threshold of 160kPa

4.1.4 Pump

Required discharge

$Q = q_n N$

Considering the 2 nozzles each having a flowrate of $1l/min$

$$Q = 1 \times 2$$
$$= 2l/min \approx 0.033l/s$$

The boom width is 0.9m. To cover an area of 1 acre of (4046m^2);

$$Distance = \frac{Area}{Width}$$

$$= \frac{4046}{0.9m}$$

$$= 4459.56m$$

Time taken

At a speed of 0.5m/s, the time required to spray the plot;

$$Time = \frac{Distance}{Speed} = \frac{4495.55}{0.5} = 8{,}991.11s = 149.85min = 2.5hours$$

Total volume

$$Discharge = 0.033l/s \times 8{,}991.11s$$
$$= 296.7liters$$

If a total distance of 4459.56m is travelled, 296.7liters are required.

Then if 400m distance is travelled, 26.61liters are required.

The volume of the tank,

$$V = b \times w \times h$$

Taking breadth, width and height of a tank to be, $280m, 305m, and\ 350m$ respectively.

$$V = 280 \times 305 \times 350$$

$$= 29{,}890{,}000mm^3$$

$$= 30liters$$

Power required to run the pump

$$P_p = \frac{\rho hgQ}{\mu}$$

Taking ρ =1000kg/m^3, h $= 1$, Q $= 0.033m^3$, g $= 9.81$, μ $= 0.70$

$$P_p = \frac{1000 \times 1 \times 9.81 \times 0.033}{0.70}$$

$$= 462.47W$$

$$0.62hp$$

Hose pipes

Determining the hose pipe diameter using

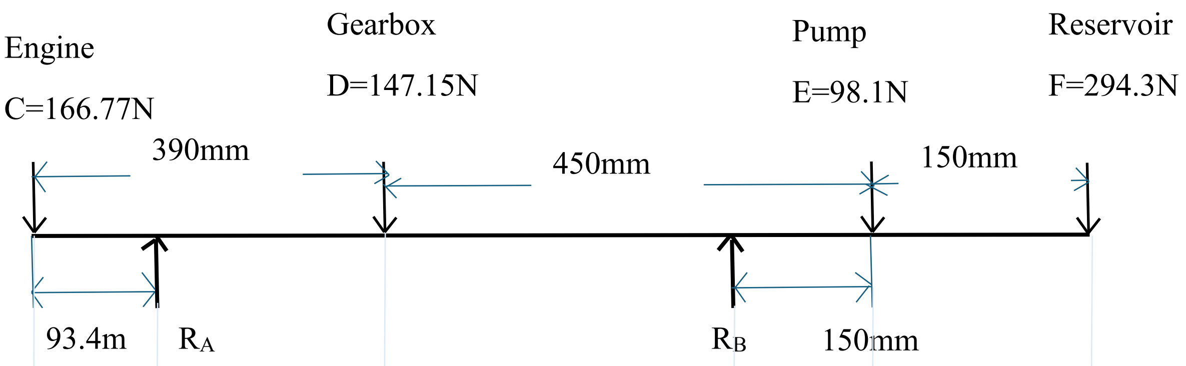
$Q = A \times v$

$= 0.000033m^2$

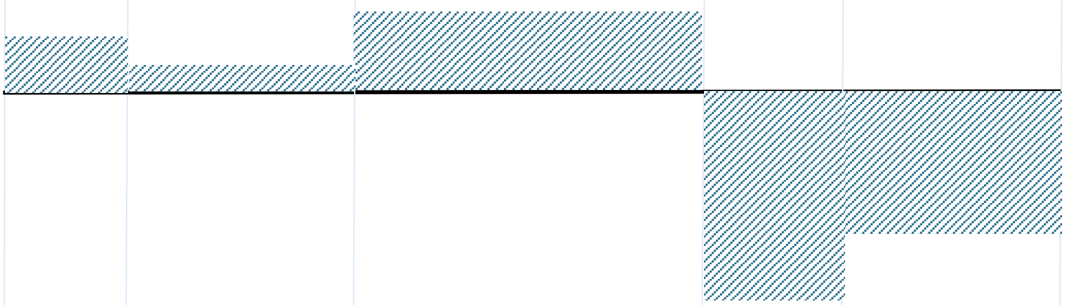
D= $\sqrt{\frac{4 \times 0.000033}{\pi}}$

$$= 0.0065m \approx 6.5$$

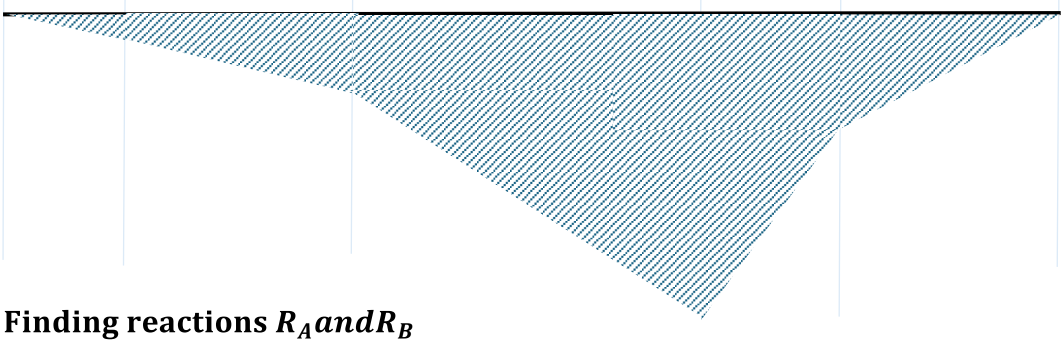
4.1.5 Main frame



Shear force Diagram



Bending moment diagram



Finding reactions $R_A and R_B$

$R_A + R_B = (10 \times 9.81) + (15 \times 9.81) + (17 \times 9.81) + (30 \times 9.81)$
$= (98.1) + (147.15) + (166.77) + (294.3)$
$R_A + R_B = 706.32$…………………………………………………….(i)

Taking moments at A
$(166.7 \times 93.41) + (596.59R_B) = (294.3 \times 896.59) + (98.1 \times 746.6) + (147.2 \times 296.6)$
$R_B = 612.23N$
From eqn (i), $R_A = 94.04N$

Calculating shear forces
At F, $S.F_F = -294.3N$

At E, $S.F_E = (-294.3 - 98.1) = -392.4N$

At B, $S.F_B = (-392.4 + 612.23) = 219.83\text{N}$

At D, $S.F_D = (219.83 - 147.15) = 72.68N$

At A, $S.F_A = (72.68 + 94.04) = 166.77N$

At C, $S.F_C = (166.77 - 166.77) = 0\text{N}$

Calculating bending moments

$BM_F = 0\text{Nm}$

$BM_E = (-294.3 \times 0.150) = -44.15Nm$

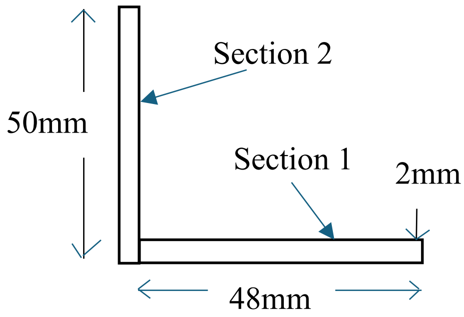
$BM_B = (-294.3 \times 0.3) + (-98.1 \times 0.15) = -103Nm$

$BM_D = (-294.3 \times 0.6) - (98.1 \times 0.45) + (612.23 \times 0.3) = -37.06\text{Nm}$

$BM_A = (-166.77 \times 0.0934) = -15.58\text{Nm}$

$BM_C = 0\text{Nm}$

Consider an angle line of $50 \times 50 \times 2m$



Area of section 1 $= 50 \times 2 = 100mm^2$

Area of section 2 $= 48 \times 2 = 96mm^2$

$$A_{total} = 196mm^2$$

Centroid of section 1 $y_1 = 25mm$

Centroid of section 2 $y_2 = 1mm$

$$\bar{y} = \frac{A_1.y_1 + A_2y_2}{A_{total}}$$

$$\bar{y} = \frac{100 \times 25 + 96 \times 1}{196}$$

$$= 13.24mm$$

Using parallel axis theorem

$$I = \frac{bh^3}{12} + Ad^2$$

For the rectangle 1 (vertical)

$$I_c = \frac{2 \times 50^3}{12} = 20{,}833.33mm^4$$

$$d = |25 - 13.25| = 11.75mm$$

$$Ad^2 = 100 \times 11.75^2 = 13{,}806.25mm^4$$

$$I_1 = 34{,}639.6mm^4$$

For the rectangle 2 (vertical)

$$I_c = \frac{48 \times 2^3}{12} = 32mm^4$$
$$d = |1 - 13.25| = 12.25mm$$
$$Ad^2 = 96 \times 12.25^2 = 14{,}406mm^4$$
$$I_2 = 14{,}438mm^4$$

Since it's an equal angle,

$$I_x = I_y = I = 34{,}639.6 + 14{,}438 = 49{,}077.6mm^4$$

Calculating the maximum stress $\delta_{max} = \frac{M_{max}\bar{y}}{I}$

$$= \frac{150 \times 13.24}{49{,}077.6} = 40.5MPa$$

Considering yield strength of mild steel to be 250MPa

Factor of safety, $F.O.S = \frac{250}{40.5} = 6$

Calculating the deflection using Macaulay's method

$$EI\frac{d^2y}{dx^2} = -166.77x + 94.22(x - 93.4) - 147.15(x - 390) + 612.1(x - 690) - 98.1(x - 840)$$

Integrating once gives

$$EI\frac{dy}{dx} = -83.39x^2 + 47.11(x - 93.4)^2 - 73.58(x - 390)^2 + 306.05(x - 690)^2 - 49.05(x - 840)^2 + C_1$$

$$EIy = -27.80x^3 + 15.7(x - 93.4)^3 - 24.53(x - 390)^3 + 102.02(x - 690)^3 - 16.35(x - 840)^3 + C_1x + C_2$$

Boundary conditions

At A(x=93.4), y = 0

At B(x=690), y = 0

Substituting in the equation gives

$C_1 = 10{,}785{,}000$

$C_2 = -984{,}670{,}000$

Simplification gives $y_{max} = \frac{8.56 \times 10^9}{EI} mm$

For mild steel, E=200GPa and I=49077mm^4

$$y_{max} = \frac{8.56 \times 10^9}{200 \times 1000 \times 49077} = 0.87mm$$

4.1.6 Pulleys and belts

For engine and gear box

Considering an engine with 1500rpm and a pulley of 54mm diameter, d_1. And gearbox pulley of 170mm diameter d_2.

For a system with two pulleys,

$$n_1 d_1 = n_2 d_2$$

$$1500 \times 54 = 170 \times n_2$$

$$n_2 = 476rpm$$

Belt length on the pulleys on engine and gear box.

$$L = 2c + \frac{\pi}{2} \times (d_1 + d_2) \frac{(d_1 - d_2)^2}{4c}$$

But c =0.39m

$$= 2 \times 0.39 + \frac{\pi}{2} \times (0.054 + 0.17) + \frac{(0.054 - 0.17)^2}{4 \times 0.39}$$

=1.14m

Gearbox and pump

Gearbox pulley diameter, d_1 is 170mm.

Pump pulley diameter, d_2 is 170mm

$$476 \times 170 = 170 \times n_2$$

$$n_2 = 476rpm$$

Belt length on the pulleys on gearbox and the pump

$$L = 2c + \frac{\pi}{2} \times (d_1 + d_2) + \frac{(d_1 - d_2)^2}{4c}$$

But c =0.46m

$$= 2 \times 0.46 + \frac{\pi}{2} \times (0.17 + 0.17) + \frac{(0.17 - 0.17)^2}{4 \times 0.35}$$

=1.45m

4.1.7 Sprockets and chain

For a system with 2 sprockets having

$$t_1 = 14, t_2 = 42, n_1 = \frac{440}{3} = 147rpm, x = 550mm, Pitch, p = 19mm$$

$$n_1 t_1 = n_2 t_2$$

$$n_2 = \frac{147 \times 14}{42} = 49\ teeth$$

Number of chain links, k

$$k = \frac{2x}{p} + \frac{(t_1 + t_2)}{2} + \frac{(t_2 - t_1)^2 p}{4\pi^2 x}$$

$$= \frac{2 \times 550}{19} + \frac{(14 + 42)}{2} + \frac{(42 - 14)^2 \times 19}{4\pi^2 \times 550}$$

$$k = 87\ links$$

Length of the chain, $L = kp$

$$L = 86.576 \times 19mm$$

$$L = 1.645m$$

4.2 To fabricate and assemble the components of the machine.

4.2.1 Fabrication

The fabrication of an engine powered weeder-sprayer machine was done according to the design specifications. To come up with the complete machine, various types of workshop machines and technology were used. Tools like hand hacksaw were used for cutting materials like the mild hollow sections. Drilling machines for drilling holes. More activities like measuring, marking out, welding and tightening were done using tools like tape measure, scriber, welding machine and spanners respectively.

4.2.2 Assembly

After fabrication, all the parts were assembled to form one unit. The various components were attached to the main frame in their respective positions using bolts and nuts.

Controls (gear lever and clutch pedal) were fitted in their ergonomic positions.

4.3 To test the performance of the machine.

4.3.1 Engine power required

Calculated the engine’s output.

Total power,

$$P_t = P_{weeder} + P_{wheels} + P_{spraying} + Losses$$

$$= 5.0 + 0.55 + 0.62 + 0.5$$

$$= 6.67hp$$

Hence a 7.5hp internal combustion petrol engine was selected.

4.3.2 Fuel consumption rate

Evaluated the cost and efficiency.

$$Fuel_{consumption} = \frac{Volume\ of\ fuel\ consumed}{Operating\ time}$$

Volume of fuel consumed =1liter

Operating time =1hour

$$= \frac{1}{1} = 1\ l/hr$$

4.3.3 Weeding efficiency

Calculated the effectiveness of weed removal.

$$Weeding\ efficiency = \left(\frac{Weeded\ area}{Total\ area}\right) \times 100\%$$

Considering a unit total area of 1m^2

$$Weeding\ efficiency = \left(\frac{0.75}{1}\right) \times 100$$

$$= 75\%$$

$$Crop\ damage\ rate = \left(\frac{Number\ of\ damaged\ crop\ plants\ per\ unit\ area}{Total\ number\ of\ crop\ plants\ in\ weeded\ area}\right) \times 100$$

$$= \left(\frac{2}{225}\right) \times 100$$

$$= 0.89\%$$

Considering weeded area of 100m^2 with average row width of 700mm-900mm.

Table 5: Showing time required to weed 10m distance in a single row

Rows (10m length)	Row width(mm)	Time(min)
1	800	2.7
2	810	2.3
3	790	2.0
4	820	2.1
5	780	2.0
6	850	2.5
7	800	2.2

8	910	2.5
9	880	2.1
10	800	2.3
11	850	2.2
12	900	2.0

$$Average\ time = 2.2 minutes\ per\ row$$

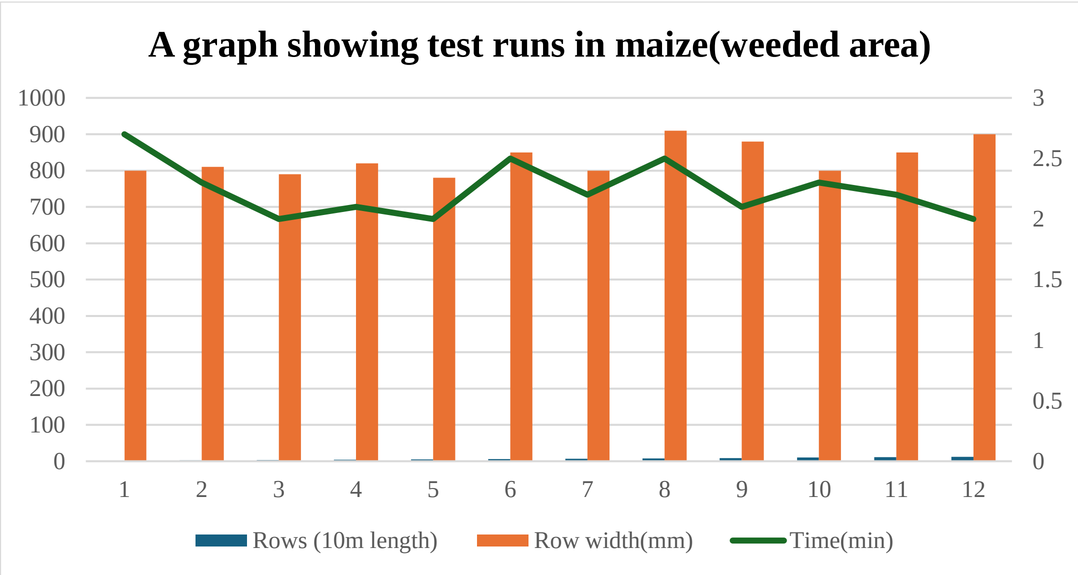


Figure 10: Showing test runs in maize (weeded area)

4.3.4 Area weeded per hour

Determine productivity.

$$Effective\ field\ capacity = (Speed \times Effective\ \ working\ width \times Efficiency)$$

$$= 0.5 \times 0.9 \times 0.75$$

$$= 0.3375\, m^2/s = 1215\, m^2/hr$$

Time required to weed an acre $= \frac{4046}{1215} = 3.3hrs$

The designed reservoir empties after 400m.

For an acre, it requires to be refilled $= \frac{4495.55}{400} = 11\ times$

Assuming time taken for refilling the reservoir= $5 minutes$.

Therefore, total time for refilling $= 11 \times 5 = 55 minutes \approx 1hr$

Hence total time required for weeding $= (Real\ time\ for\ weeding + Refilling + loss)$

$$= (3.5 + 1 + 0.5) = \mathbf{5}\boldsymbol{hrs}$$

4.3.5 Nozzle flow rate

Verified individual nozzle performance and total spray volume.

Table 6: Showing nozzle discharge tests

Run	**Nozzle discharge(l) in 1 minute**
1	1.0
2	0.8
3	0.7
4	0.8
5	0.8
6	0.9

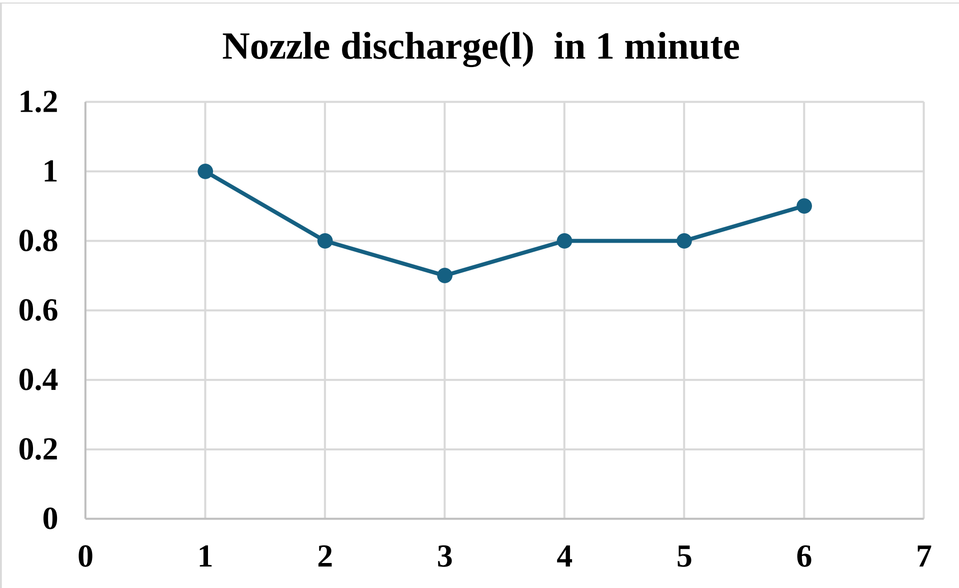


Figure 11: Showing discharge in 1 minute per nozzle

$$Flow\ rate = \left(\frac{Volume\ collected\ from\ nozzle}{Collection\ time}\right)$$

$$Average\ volume\ of\ water\ collected = 0.83liters$$

$$Time = 60seconds$$

$$Flow\ rate = \left(\frac{0.83}{60}\right) = 0.0138l/s$$

Efficiency of the nozzle

$$eff = \frac{determined\ flow\ rate}{calculated\ flow\ rate}$$

$$\frac{0.017}{0.0138}$$

$$= 0.81$$

4.3.6 Pump efficiency

Evaluated pump's energy conservation. $Pump\ efficiency = \frac{hydraulic\ power\ output}{mechanical\ power\ input}$

If required pressure is 2.6bars

Where; $P_{hydraulic} = (Flow\ rate \times pressure$

$$= 0.0276 \times 0.001 \times 2.6 \times 10^5 = 290.3W$$

$P_{mechanical}$ – Power from the prime mover

$$Pump\ efficiency = \frac{290.3}{462} = 0.62 = 62\%$$

4.4 To determine the cost effectiveness of the machine

4.4.1 Cost-Benefit Analysis for the Weeding Machine

Table 7: Showing costs

S/N	ITEM AND SPECIFICATION	QUANTITY	UNIT PRICE (UGX)	TOTAL PRICE (UGX)
WEEDING SYSTEM AND FRAME				
1	MS hollow section (40x40x2) mm	2pcs	50,000	100,000
2	MS angle line 50x50x2mm	¼ pc	35,000	35,000
3	MS hollow section ($\varphi 30mm$)	1pc	30,000	30,000
4	MS flat bar	2pc	50,000	100,000
5	Angle line	1 pc	45,000	45,000

6	Bolts and nuts	30pcs	1,500	45,000
7	MS plate	½ pc	40,000	40,000
SUBTOTAL				**395,000**
SPRAYING SYSTEM				
8	Pump and accessories	1pc	500,000	500,000
9	Nozzle (flat fan)	2pcs	5,000	10,000
10	Tank	1pc	10,000	10,000
11	Pipe ½ inch	¼ pc	5,000	5,000
SUBTOTAL				**525,000**
POWER SYSTEM				
12	Engine(7.5hp)	1	650,000	650,000
13	Gearbox	1	700,000	700,000
14	Pulleys	2	15,000	30,000
15	Pillow block bearings	2pcs	25,000	50,000
16	V-Belts	2pc	10,000	20,000
17	Rear /Land wheel	1pc	30,000	30,000
18	MS Shafts ($\varphi 40mm$)	2ft	25,000	50,000
19	Chain and Sprocket kit	1 kit	60,000	60,000
20	Clutch kit	1 kit	8,000	8,000
21	Wheels	2pcs	90,000	90,000
SUBTOTAL				**1,688,000**
TOOLS				
22	Hacksaw Cutting blade	2pcs	5,000	10,000
23	Grinding disc (6”)	1pc	15,000	30,000
24	Cutting disc (9”)	2pcs	11,000	22,000
25	Welding Rods (2.5mm)	2 pkt	30,000	60,000
SUBTOTAL				**122,000**
OTHERS				
26	Paint	1 liter	20,000	20,000

27	Painting brush	2	5,000	10,000
28	Thinner	1 liter	20,000	20,000
29	Fuel	5 liters	7,000	35,000
30	Petrol engine oil (Shell Advance)	2 liters	16,000	32,000
31	Airtime and internet		100,000	100,000
32	Transport		50,000	50,000
33	Labor		400,000	400,000
34	Test ground preparation		10,000	10,000
35	Printing		150,000	150,000
SUBTOTAL				**827,000**
Grande total				**3,557,000**

$$\text{Investment cost} = \text{material cost} + \text{labor}$$
$$= \text{UGX } 3{,}557{,}000$$

Assumptions made

Assume the initial cost of the machine for a farmer is UGX 4,000,000

Number of workers employed =2 people

Amount paid per day to each worker=UGX 10,000

$\text{Total amount paid to workers per day} = 2 \times 10{,}000$

$$= \text{UGX } 20{,}000$$

$\text{Total amount paid to workers for 6 days of working} = 6 \times 20{,}000$

$$= \text{UGX } 120{,}000$$

Machine operating costs

Assuming a manual worker weeding $100m^2$ in 1 hour, at a wage of UGX 2,000

The engine powered weeder-sprayer machine takes 10minutes in 1 hour equivalent saving 50 minutes of labor per $100m^2$.

Assuming 1 acre ($4046m^{2)}$ is weeded per day, the result in daily labor saving is;

$$= \frac{40}{60} \times 15{,}00 \times 2 \times 40$$
$$= UGX\ 80{,}000$$

Assuming 15 days per month $= 15 \times 80{,}000$

$$= UGX\ 1{,}200{,}000$$

Other sources of cash

Assuming cost of hiring is UGX 150,000 per day

Assuming the machine is hired for 6 days in a period of 3 months per season.

Considering 2 seasons per year $= 150{,}000 \times 6 \times 3 \times 2$

$$= UGX\ 5{,}400{,}000$$

Expenses incurred throughout the year

Labor during hiring per year= $10{,}000\ per\ person \times 75\ days \times 2\ people \times 2\ seasons$

$$= UGX\ 3{,}000{,}000$$

Labor during operation at owner's farm per year $= 2\ seasons \times 20{,}000 \times 3 times$

$$= UGX\ 120{,}000$$

For an acre field of maize, 296.7 liters of herbicides are required. (1.6 liters of Lumax 537.5SE)

Cost of herbicides = UGX 112,000

Cost of fuel per acre = $1\text{liter/acre} \times 5hrs \times 6500 = UGX\ 32{,}500$

Machine maintenance costs $= 10{,}000 \times 3\ months \times 2\ seasons$

$$= UGX\ 60{,}000$$

Net cash inflow $= 1{,}200{,}000 \times 12$

$$= UGX\ 14{,}400{,}000$$

4.4.1.1 Net Present Value (NPV)

$$NPV = \left[\sum_i^n \frac{Cf}{(1+r)^n}\right] - i_0$$

Discount factor $= \frac{1}{(1+r)^n}$

Assuming a project life span of 5 years, n=5

Assuming a standard discount rate of 10%, $r = 0.1$

The Net Present Value (NPV) was calculated as shown in the table

Table 8 Showing calculated Net Present Value (NPV)

Year	Cash inflows(UGX)	Discount factor	NPV(UGX)
0	(3,557,000)	1	(3,557,000)
1	14,400,000	0.9091	13,091,040

2	14,400,000	0.8264	11,900,160
3	14,400,000	0.7513	10,818,720
4	14,400,000	0.6830	9,834,200
5	14,400,000	0.6209	8,940,960
Total			**51,028,080**

Net Present Value =UGX **51,028,080**

4.4.1.2 The Profitability Index, $\boldsymbol{P.I}$

$$P.I = \frac{Present\ Value\ of\ Net\ Annual\ Cashflows}{Initial\ Cost\ of\ Investment}$$

$$\frac{14{,}400{,}000}{4{,}000{,}000}$$

$$= 3.6$$

4.4.1.3 The payback period

$$Payback\ period = \frac{Initial\ Cost\ of\ Investment}{Net\ Annual\ \ Cashflows}$$

$$= \frac{4{,}000{,}000}{14{,}400{,}000}$$

$$= 4\ months$$

$$\boldsymbol{Depreciation} = \frac{Initial\ cost - salvage}{number\ of\ year}$$

$$= \frac{4{,}000{,}000}{5}$$

$$= UGX\ 800{,}000$$

5.0 CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The design of the integrated weeder-sprayer was successfully executed, achieving a balance between mechanical weeding and chemical application. The choice of materials primarily high-strength mild steel for the chassis and weeder blades and chemical resistant polymers for the spraying system ensures the machine can withstand the stresses of soil penetration while resisting the corrosive nature of herbicides. The ergonomic height and position of the controls confirm that the machine is adaptable to various operator statures minimizing physical strain during prolonged use in maize fields.

The integration of a mechanical weeding unit for inter-rows and a precision spraying system for intra-rows proved highly effective. By utilizing a shielded nozzle system, the machine successfully applied selective herbicides to the intra-row weeds without causing drift or accidental damage to the maize stalks. The mechanical tines or blades demonstrated sufficient soil turnover to uproot inter-row weeds, significantly reducing the overall weed seed bank. This dual action approach effectively addresses the weed-free requirement of the critical early growth stages of maize.

Testing and performance evaluation revealed a mechanical weeding efficiency of 75% and spraying efficiency of 62.3% indicate that the weeder-sprayer drastically reduces the time and labor required for weed management. Compared to the traditional two-step process of manual hoeing followed by separate knapsack spraying, this machine offers a significant reduction in man hours per acre. The synchronized operation ensures that weeding and spraying are completed in a single pass, allowing farmers to optimize their field schedule and reduce labor costs. The tests showed that the machine does not work well in muddy soils.

From an environmental perspective, the precision application of herbicides in the intra-rows reduces the total volume of chemicals used compared to blanket spraying promoting more sustainable agricultural practices. Economically, the machine presents a high value-to-cost ratio. With a relatively low fabrication cost using locally available components and a favorable payback period, the weeder-sprayer is a viable investment for small and medium-scale maize farmers. It provides a technical solution that enhances crop yields by reducing weed competition while remaining affordable and easy to maintain.

The financial analysis demonstrated that the engine powered weeder sprayer machine is economically viable, with a positive Net Present Value (NPV) of UGX 51,028,080 over five years, a favorable Profitability Index (PI > 1), and a relatively short payback period. The use of petrol fuel energy reduces operational costs and is readily available. The cost-benefit outcomes indicate that the machine can increase farmers' income by reducing the losses due to poor weed management. This economic feasibility, combined with low maintenance requirements and use of standardized, locally available spare parts, supports the machine's potential for sustainable adoption and long-term impact in rural agricultural settings.

5.2 RECOMMENDATION

Integrate active plant lifters or guides in front of the machine. These guides gently lift low hanging maize leaves out of the way before the machine passes preventing mechanical damage to the crop and ensuring the leaves don't get coated in herbicide and also for the convenience of the operator.

Use of a ground wheel driven Pump instead of a manually operated tensioner. Linking the sprayer pump to the rotation of the ground wheels ensures that the herbicide application rate is directly proportional to the walking speed preventing over dosing when the operator slows down and under-dosing when they speed up.

Incorporate vibration dampers around the engine mounting points. This will help improve operator comfort while operating the machine.

Incorporate a reverse gear to ease maneuverability.

Incorporate scrappers on the blades. This helps to remove the logged weeds and muddy soil.

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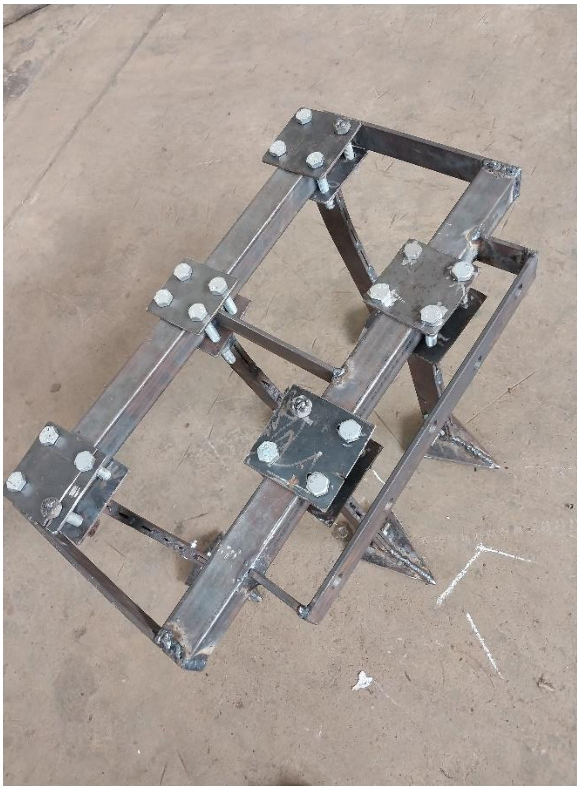
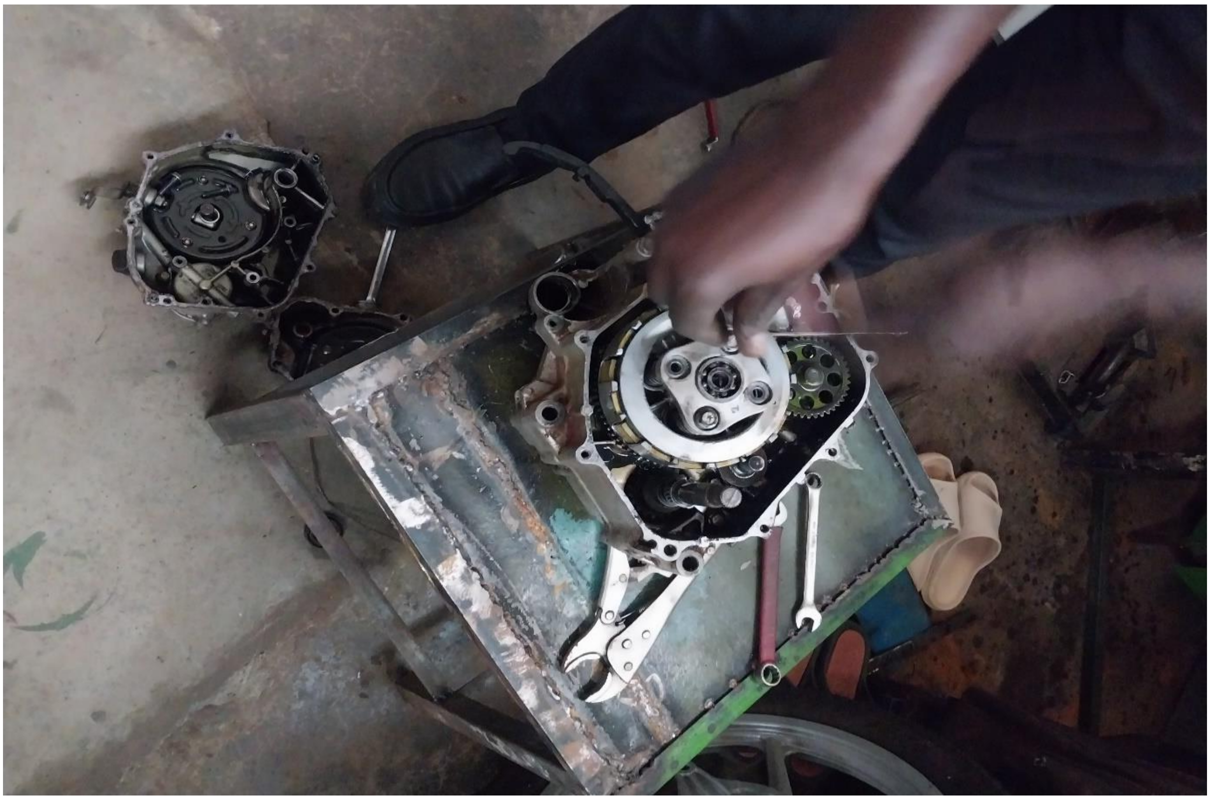
APPENDICES



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