

MOBILITY DESIGN INTERVENTION FOR PADDY CULTIVATION IN SMALL AND MARGINAL FARMS OF INDIA



Design Project III

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Mobility and Vehicle Design
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DECLARATION

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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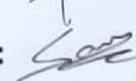
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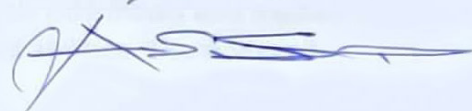
The Mobility and Vehicle design project report entitled "Mobility Design Intervention for Small and Marginal Farmers" by Parthkumar Chaudhari is approved in partial fulfillment of the requirement for Master of Design degree in Mobility and Vehicle Design.

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ABSTRACT

Indian agriculture industries have seen significant growth in the last few decades. Agriculture and allied industries remain first in providing a livelihood to the Indian population. However, due to inheritance land law, the size of operational holdings have kept decreasing. Around 86% of total holdings fall under small and marginal farms. These farms are facing problems such as lack of implementation of new technology, proper marketing of agriculture produces, infrastructure, and mobility for agriculture sectors. For generations, small and marginal farmers are following manual land preparation methods because current machines are not suitable for their operational holdings. Even though India is the world's largest manufacturer and the market for agriculture machinery, it lacks behind in providing a mobility solution for the small and marginal farms.

This project aimed to design a new compact agriculture vehicle which can perform various agriculture practices such as ploughing, tilling, puddling, sowing, & harvesting for small and marginal farms. For this project, a user study was conducted by visiting small and marginal farmers in Gujarat and Maharashtra to understand their methods of farming, problems with current agriculture machines, and needs. The design brief was generated based on insights from this study and led to the generation of different concepts which can perform multiple land preparation activities in one go. These concepts were evaluated on several parameters, and the most suitable concept was further detailed out.

The final concept is battery operated and can perform different paddy cultivation operations in one go and does not require implement changes. Unlike conventional farming machines, the new vehicle is compact, has better ergonomics and circularly perform farming operations.

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Introduction

1. Introduction

Indian agriculture sector has seen significant growth since last few decades. Although, percentage contribution in gross domestic product by agriculture sector has decreased, agriculture and its allied industries still remain first in providing livelihood to Indian population. After the green revolution per hectare production of agriculture produces has increased but modern agriculture is facing new problem such as lack of implementation of new technology, proper marketing of the agriculture produces, infrastructure and mobility for agriculture sector.

India is world's largest tractor manufacturer as well as the largest market for agriculture machinery. Still in many part of the India farming is done manually either because farmers can not afford big and expensive machines or current machines are not suitable for their small and marginal farms. Due to lack of technology and machinery India still lack behind in terms of per hectare production of agriculture items.

This project focuses on mobility design intervention for these small and marginal farms in India. Specially targeting paddy cultivation.

Preliminary Research

2.1 Preliminary Research

2.1.a A Brief History Of Indian Agriculture



Image 1. Indus Valley Civilization Cave Painting

Indian agriculture has a long history which starts with Indus Valley Civilization (which suggests the cultivation of rice and cotton) and even before that in the southern part of the India people use to practice agriculture activities. India is widely known for its production of spices, rice, sugar, and cotton. Agriculture in India gave a push to the colonialism, and agriculture-dependent villages came into the picture. People started trading spices and sugarcane overseas during the Mughal Era, which attracted the East India Company.

During the British Empire, Indian crops like cotton, rice, wheat, etc. gained its presence and global market. British regime in India developed an irrigation system for farms which used to produce nonfood crops rather than food crops for companies like ITC and Hindustan Unilever. Although Indian agriculture has seen constant growth throughout history, it got a boost during the British era due to movements like *Grow More Food* (1943 - 1951) and *Integrated Production Program* (1950). Unlike cash-crops focused policies, these movements targeted food crops production to meet food shortages following independence in 1947.

Post independent agriculture in India witnessed the green revolution (1960) during which, Indian agriculture converted into an industrial system due to the adoption of modern methods and technologies such as high yield seeds, tractors, irrigation facilities, pesticides, and fertilizers. It was the rise of current agriculture practices in India. (Ref. 1,2,3)

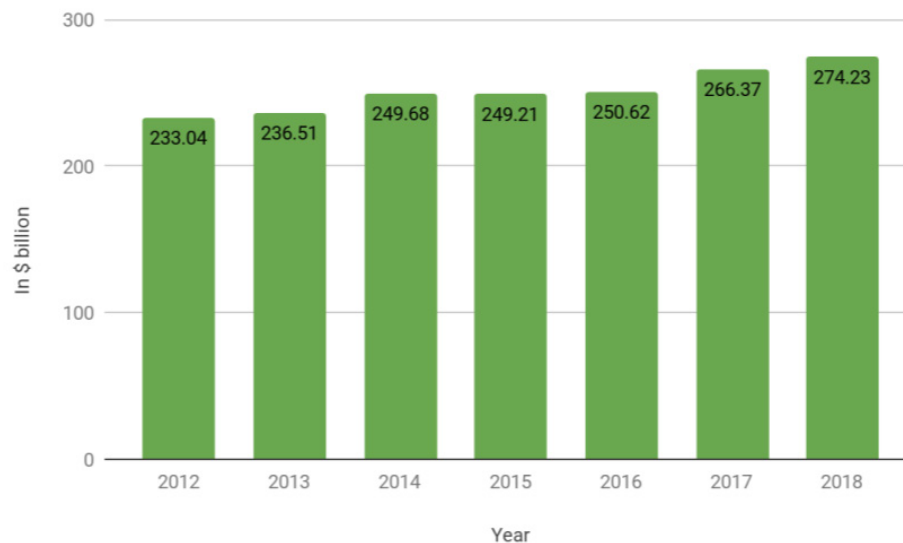


Image 2. Growth of Indian Agriculture based on Gross Value Added in National Income

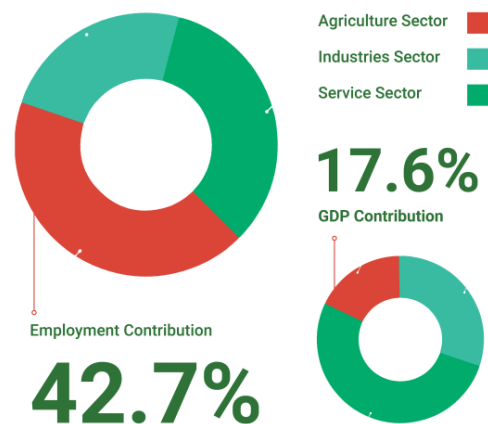


Image 3. GDP and Employment contribution by the agriculture and allied sectors during 2018

2.1.b Agriculture Sector and Indian Economy

Indian agriculture has seen constant growth in the last decade. According to the analysis of Indian Agriculture and Allied industries (Fishery and Forestry) by India Brand Equity Foundation (IBEF); population boom, rising urban and rural income and external demand is driving the overall growth of Indian agriculture. Indian agriculture has shown a 2.76% compound annual growth rate (CAGR) since the FY12. The agriculture sector has contributed around 271 Bn USD (Rs. 18.53 trillion) to GDP in FY18 (Image 2). Due to Govt policies like Pradhan Mantri Krishi Sinchayee Yojana, Long Term Irrigation Fund and Pradhan Mantri Fasal Bima Yojana, etc. India's agricultural productivity increased from 20 Bn USD to 200+ Bn USD between 1960 and 2018.

Although the agriculture sector has shown tremendous growth over the period, its overall contribution to the GDP has decreased continuously from 57.7% in 1950 to 17.6% in 2018 (Image 3). This scenario is common in all the developing country as the country develops, a contribution to the GDP by service sector increases while the participation by the agriculture sector decreases. But along with this, the agriculture sector's contribution to employment also falls. Which in the case of India is not happening. Even today, the agriculture sector employed 42.7% of Indians, which employed 68% in 1950. This data shows that the majority of the Indian still depends on the agriculture sector as their primary income and job.

The main reason for this imbalance between GDP and Employment contribution is due to complex land laws and old practices Indian agriculture follows. (Ref. 4,5,6,7)

2.1.c Agricultural Land Holdings

Due to inheritance law in India, the land belonging to the father is equally distributed among his sons. This distribution of land does not entail a collection or consolidated one, but its nature is fragmented. The size of the agriculture land is keep decreasing year to year while the number of operation holding* is kept increasing. Number of operational holding is increased from 71 million in 1970-71 to 145 million in 2015-16, against which agriculture operated area** is decreased from 162 million ha. in 1970-71 to 157 million ha. in 2015-16 (image 4 & 5). This data shows that even when the numbers of farms are increasing the average size of farms are decreasing resulting in more number of small and marginal farms.

India had 49 million operation holding with 33 million ha. Of the operated area which falls under the small and marginal category*** in 1970-71. As per 2015-16, this number has changed to 125 million operation holding with 74 million ha. of the operated area. The number of semi medium, and large operation holding was 21 million with 128 million ha. In 1970-71, which as per 2015-16 is 20 million with 82 million ha. respectively. So, even though small and marginal farms account for 86.2% of the total number of farms, has only 47.3% crop area against which semi-medium, medium, and large farms occupied 52.7% crop area with only 13.8% of the total number of farms (image 6).

This data shows that a significant amount of medium and large operational holdings have converted into small and marginal farms, resulting in a reduction of average farm size (image 7). As per 2015-16 average size of the small and marginal farm is 0.4 ha. and 1.4 ha. respectively. Most of the south-east and north-east states of India has an average farm size, which is less than 1 ha. While farms with more than 2 ha. average size is only in Rajasthan, Punjab, and Haryana (image 8).

(Ref. 8,9,10,11,12)

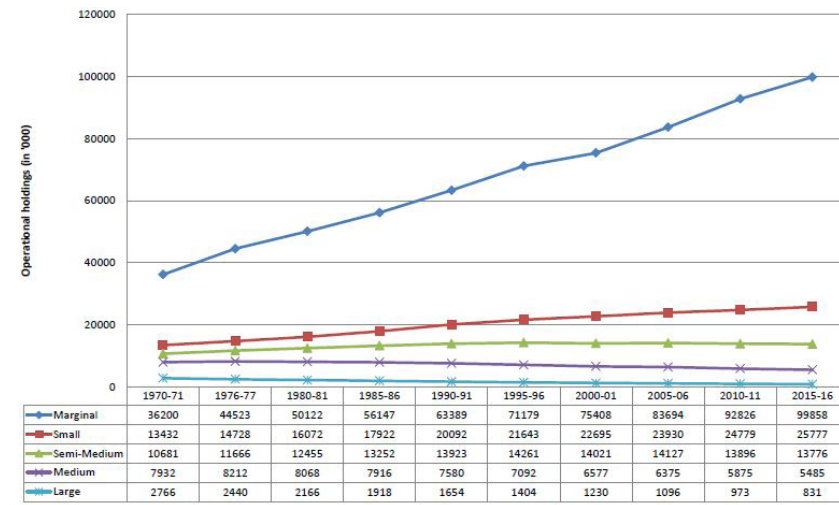


Image 4. Number of Operational Holdings as per different census



Image 5. Area Operated by Different Operation Holdings



Image 6. Percentage Distribution of Operational Holdings and Crop Area for 2015-16.

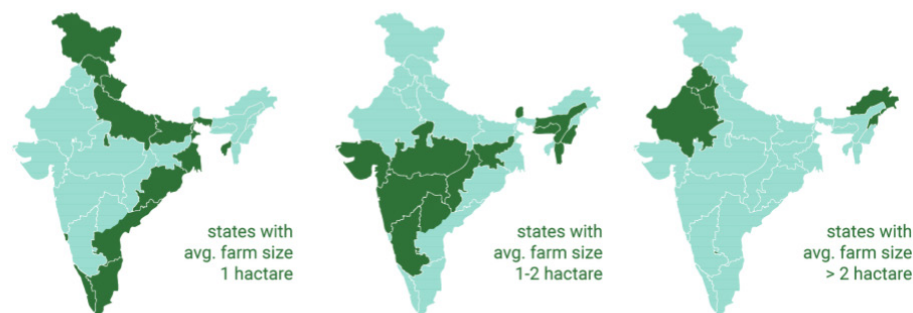


Image 7. State Wise Average Farm Size According to Agriculture Census Data 2015-16



Image 8. Average Farm Size of different holdings According to Agriculture Census Data 2015-16

* Operational Holding :

All land which is used wholly or partly for agricultural production and is operated as one technical unit by one person alone or with others without regard to the title, legal form, size or location

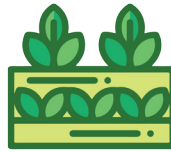
** Operated Area :

Operated area includes both cultivated and uncultivated area, provided part of it is put to agricultural production during the reference period. If, for instance, an operational holding consists of four survey numbers out of which one survey number is put to non-agricultural uses, the total area of the operational holding will be equal to the total geographical area of all the four survey numbers.

*** Classification of Different Land Holdings

Sr. No.	Group	Sr. No.	Class (in ha.)
1	Marginal	1	Below 0.5 ha.
		2	0.5 < 1.0 ha.
2	Small	3	1.0 < 2.0 ha.
		4	2.0 < 3.0 ha.
3	Semi-Medium	5	3.0 < 4.0 ha.
		6	4.0 < 5.0 ha.
4	Medium	7	5.0 < 7.5 ha.
		8	7.5 < 10.0 ha.
		9	10.0 < 20.0 ha.
5	Large	10	20.0 and above

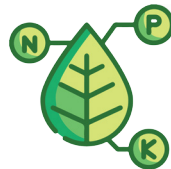
2.1.d Challenges for India Agriculture Sector



Small and fragmented land-holdings :

As discussed earlier India has the number of farms which fall under small and marginal criteria. The problem of small and fragmented holdings become more severe with densely populated and intensively cultivated states. These large number of small and marginal farmers makes it challenging for the government to reach them with new technology and farm support scheme. These farms with an average holding of just 0.4 hectares each are not enough to produce enough surpluses which can financially sustain their families.

Sub-division and fragmentation of farms cause low agricultural productivity and the backward state of agriculture. Irrigation becomes difficult for such farms. Further, the land is wasted in providing boundaries, due to this a lot of time and labor is lost in moving seeds, manure, implements, and cattle from one piece of land to another. Furthermore, current technologies and machinery are made, keeping in mind medium and large farmers. Design intervention for these small and marginal farmers is very less.



Seeds, fertilizer, manures, and biocides:

High-quality seed is essential for higher crop yields. Quality seeds are out of reach of majority of farmers, especially small and marginal farmers because of high prices and lack of marketing of quality seeds. Although the Government of India has started research facilities like National Seeds Corporation (NSC), State Farmers Corporation of India (SFCI), State Seed Corporations (SSC) and programs like High Yielding Variety Program (HYVP), policies are not strong enough to make it available to every farmer, mainly marginal farmers.

Since Indian soil has been used for agriculture activities over thousands

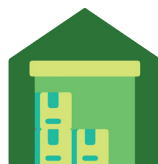
of years without replenishing, its fertility is kept decreasing. This poor soil condition results in low productivity. The average yield of most of the crops from India is among the lowest in the world. This low yield can be solved using more fertilizer and manure. For years Indian farmers are using cow dung as manure, which is proven to fertilize the soil. However, due to the rising population, and reduction in the supply of firewood in a rural area, this cow dung is used as their kitchen fuel, which has generated scarcity of organic manure for poor farmers. On the other side, chemical fertilizers are expensive and beyond the reach of the small and marginal farmers. It is the same case with biocides.



Lack of mechanization:

The Indian agriculture sector is highly mechanized since the green revolution, but this mechanization is limited to semi medium to large scale operation holdings. Even today, most of the agricultural operations are carried on by human power using conventional and straightforward tools and implements like wooden plow, sickle, and so forth. Little or no use of technology is made in different agricultural operations like ploughing, sowing irrigating, tilling, weeding, harvesting, threshing, and transporting produces. This mainly a case with small and marginal operation holdings. This non-mechanized agriculture practice results in substantial human labor wastage and lowers per hectare production as well as low yields per capita labor force.

The share of mechanical and electrical power for operational holdings has increased from 40% in 1971 to 86% in 2015-16. This increase is the result of the increasing use of tractors, power tiller, combine harvesters, irrigation pumps, and other machines. Although India is the largest producer and market for these agriculture machinery, there is a lack of innovation in the area of machines and implements which are suitable for small and marginal farms.



Inadequate infrastructure:

Indian agriculture sectors are lacking in proper infrastructure in terms of marketing, storage facilities, and transport.

Indian agriculture marketing is in bad shape in rural India. Even though the government of India has established APMC (Agricultural Produce Market Committee) in most of the states, these markets are no use for small and marginal farmers because of delay in payment, distance to procurement center, and cumbersome bureaucratic process. Further, these APMC markets are not equipped with proper facilities. India has only 6630 APMC market out of which only 15% have cold storage, and 49% has weighing facilities. These markets are weak in banking, Internet connectivity, and drying facilities. Those who can not reach to these markets due to inadequate transport facilities, usually small and marginal farmers end up selling their agricultural produces to the private agencies, local traders and middleman at below minimum support price. In India, a farmer only gets 10 to 20% of the final selling price of any agricultural product.

Further, due to the lack of quality transport facilities and cold storages, around 50% of total agricultural produce goes to waste, since perishable items like vegetables and fruits need temperature controlled environment during transport and storage.



Irrigation:

Indian agriculture is highly dependent on rainfall for the irrigation purpose. Only one-third of the total operated area is under irrigation. During summer most of the farming land become absolute. With uncertain and unreliable rainfall, Indian agriculture cannot achieve progress in farming until more than half of the operated areas are brought under proper irrigation.

(Ref. 13,14)



Image 9. Source of power – percentage share over 4 decades

2.1.e Indian Agriculture Machinery Market

The Indian agricultural machinery market is projected to grow at a CAGR of around 6.3% during 2018-23 to reach INR 1,245 billion by FY 2023. The steady growth of India's agriculture sector has also boosted the agricultural machinery market in India. India is the largest tractor market in the world. Government initiatives such as Kisan Credit Card, National Mission on Agricultural Mechanization (NMAM), and Tractor Subsidy Scheme have contributed to the growth of the machinery market. Mechanization is primarily driven by increased use of tractors, which is replacing manual and animal labor. Use of animals and Agro worker decreased over the decades from 45% and 15% respectively in 1970-71 to 2% and 3% respectively for the year of 2015-16. The use of tractors and tillers has increased from 8% in 1970-71 to 50% for the year of 2015-16 (image 9).

The growing Agro Machinery market opens up lots of opportunity for the new invention. Due to New technologies, new alloys, long-lasting batteries, solar charging stations, government support, and so forth have opened up gates for electric agriculture machinery which will play a crucial role in sustainable agriculture development. (Ref. 15,16)

The Indian agriculture machinery can be classified (image 10) further based on different agricultural operations as follows.

- 1) Land development, tillage, seed bed preparation
Tractors, Levelers, Ploughs, Dozers, Scrapers etc.
- 2) Sowing and planting
Drill, Seeder, Planter, Dibbler, Transplanter etc.
- 3) Weeding, inter cultivation, plant protection
Shovel /Plough, Harrow, Tiller, Sprayer, Duster, etc.
- 4) Harvesting and threshing
Harvester, Thresher, Digger, Reaper, Sheller, Sickle/Dao, etc.
- 5) Post harvest and agro processing
Seed extractor, Dehusker, Dehuller, Cleaner, Grader, Mill, etc.

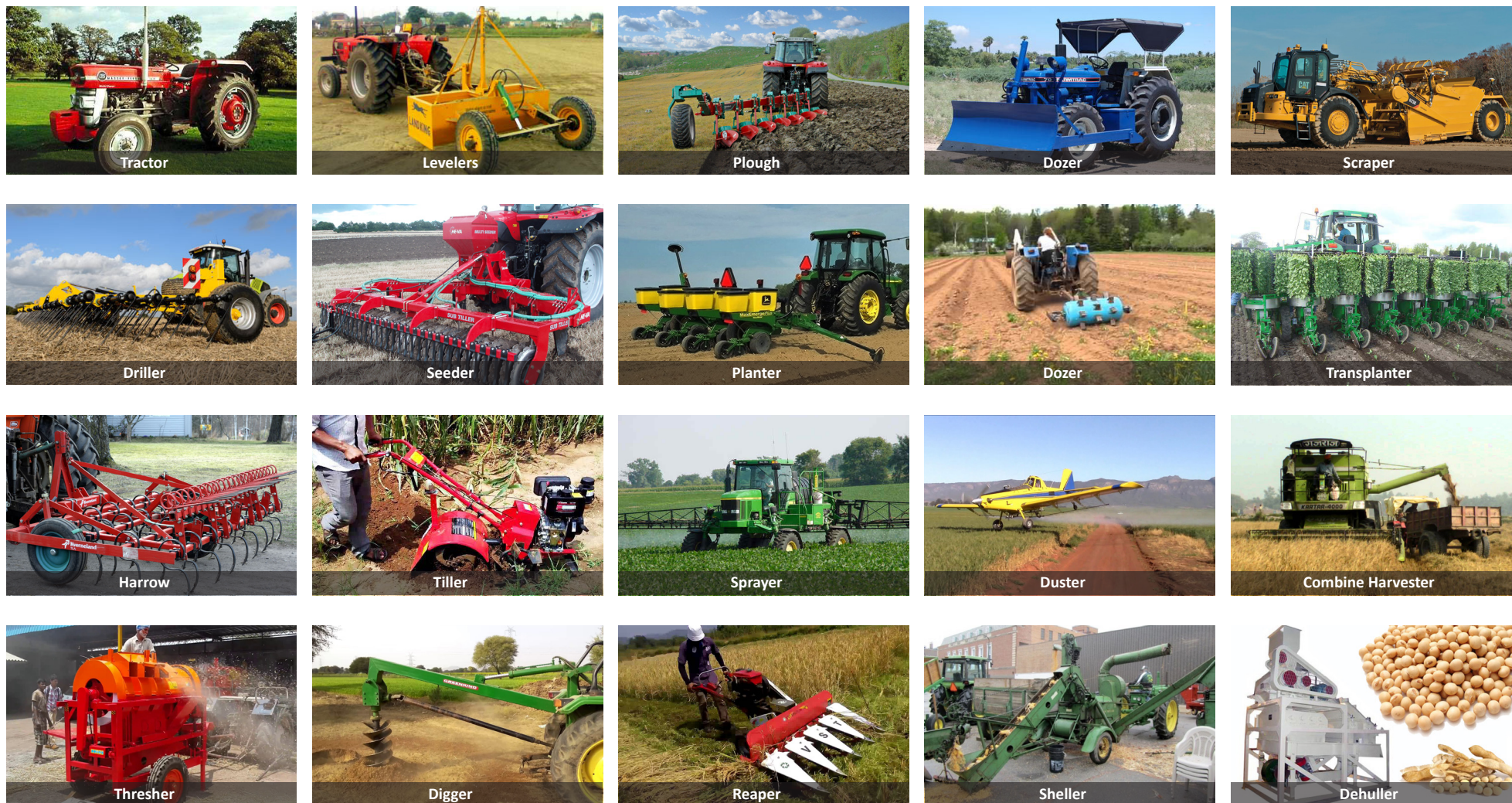


Image 10. Different Agriculture Machineries

2.1.f Agriculture Produces in India

Indian agriculture is highly dependent on different seasons based on the availability of water for the irrigation. Indian crops can be divided based on area, usage, season, economic value, and so forth. Although, any crop can be taken throughout the year based on the availability of water, but certain crops are grown only in particular season for higher yield. Based on the season these crops can be divided into Kharif, Rabi and Zaid crops.

Kharif Crops (Monsoon Crops)

Time Frame: June - July to September - October

Requirement: Requires lots of water for germination of seeds and maturation and humid climate to grow

Major Crops: Rice, Millets, Cotton, Groundnut, Jute, Pulses, Sugarcane, Watermelon.

Rabi Crops (Winter Crops)

Time Frame: October - November to April - May

Requirements: Requires warm condition for germination of seeds and maturation and cold weather for the growth.

Major Crops: Wheat, Gram, Pea, Barley, Potato, Tomato, Onion, Oil seeds,

Zaid Crops

Time Frame: Grown between Rabi and Kharif crop seasons (March - June)

Requirements: Requires less water and less time to mature.

Major Crops: Watermelon, Bitter Gourd, Few Pulses like Moong Dal, etc.

These crops can further be divided based on their usage,

Food Crops:

Rice, Maize, Wheat, Millets and Pulses, etc.

Cash Crops:

Sugarcane, Tobacco, Cotton, Jute, and Oilseeds, etc.

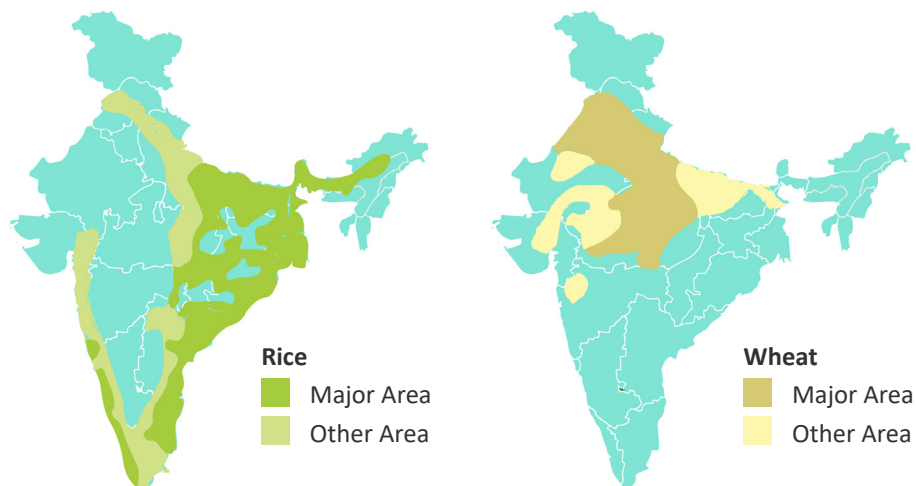


Image 11. Leading Producer State of Rice and Wheat

Plantation Crops:

Coffee, Coconut, Tea, and Rubber, etc.

Horticulture Crops:

Fruits and Vegetables

Indian agriculture sector produces almost all kind of crops, fruits, and vegetables. Though primary produce in India are Rice (2nd largest producer in the world), Wheat (2nd largest producer worldwide), Cotton (3rd largest producer worldwide), Jute (world's 85% of the jute is cultivated in Ganges Delta), Sugarcane (2nd largest producer in the world), Tea (2nd largest producer in the world), Coffee and Spices! Image 11 shows the leading producer state for major food crops of India: Rice and Wheat.

(Ref. 17,18)

2.1.g Methods of Farming

Conventional Farming

During the green revolution between 1950-1960, the government of India pushed a lot of foreign methods of farming to increase the production of cash as well as food crops, make India self-sustainable in the food sector, make quick money. Farmers started using more and more chemical fertilizers and biocides to increase the yield of crops, provide required nutrients to plant, get rid of pests, rodents, to fight diseases in crops, and to meet the food demand of the growing population of late India.

Although the use of chemicals to get more yield and fight pests is an easy way out, it has an adverse effect on land and the environment. Excessive use of chemical pesticides, fertilizers, and mechanization created severe problems. Resistant variety of pests/insects and diseases, land exhaustion (reduction in soil fertility), water pollution due to nitrate run-off (nitrate in artificial fertilizer get dissolved in rainwater further pollute the water sources), air pollution (stubble burning, fuels used by heavy machines), soil erosion (due to deep ploughing) and soil compaction*.

Organic farming

On the other hand organic farming relies on principles like biodiversity and composting instead to produce healthy crops. According to USDA**, “Organic production is not simply the avoidance of conventional chemical inputs, nor is it the substitution of natural inputs for synthetic ones. Organic farmers apply techniques first used thousands of years ago, such as crop rotations and the use of composted animal manures and green manure crops, in ways that are economically sustainable in today’s world. In organic production, overall system health is emphasized, and the interaction of management practices is the primary concern. Organic producers implement a wide range of strategies to develop and maintain biological diversity and replenish soil fertility.”

To revert the hurtful effect of “chemical farming” Indian government has started promoting organic farming through initiative like National Mission for Sustainable Agriculture (NMSA). This initiative plans to promote organic farming in eastern India and wants to transform Bihar, Odisha, West Bengal and eastern Uttar Pradesh into an organic farming hub of India under Mission Organic Value Chain Development in North Eastern Region scheme. Sikkim has become 100 per cent organic state in India.

Although, Organic farming in India is facing issues like lack of awareness, Output Marketing Problems, Shortage of Bio-mass, Lack of Financial Support, Low Yields, and Inability to Meet the Demand. Even in organic farming people still use machines which are run by conventional fuel so it is not 100 per cent sustainable practice but it is still better than conventional farming in many ways. (Image 12) (Ref. 19,20,21,22)

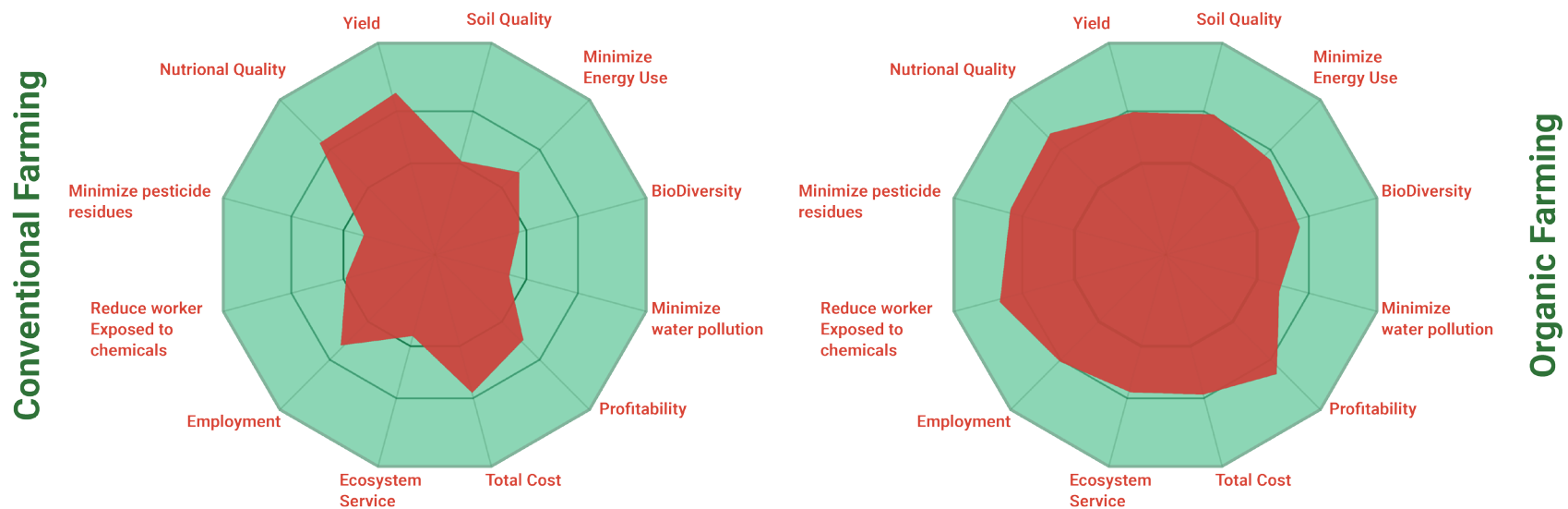


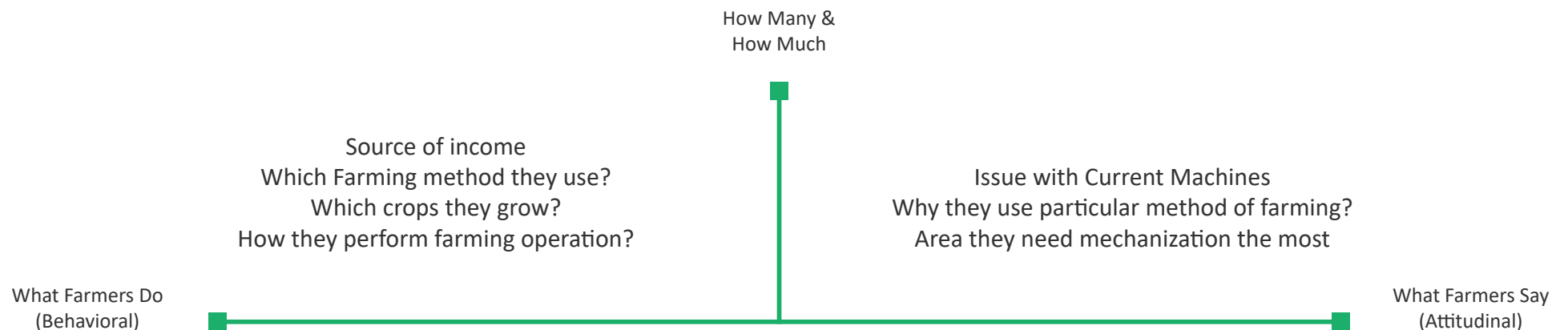
Image 12. Conventional Farming vs Organic Farming

User Study

2.2 User Study

2.2.a Methodology of User Study

To get a better understanding of how farming is done, a user study was conducted with farmers of Ambach Village (Tapi, Gujarat), Sati Village (Dang, Gujarat), Krushi Mahotsav (Nashik, Maharashtra) and Vanvasi Gaon (Jawhar, Maharashtra). The user study contains the set of questions to understand their way of farming, which crops they grow throughout the year, which implements and machines they use and what are the issues they are facing with those machines. Also, the observational study was made to understand the type of land. Indian agriculture is a large system which has many problems, as mentioned earlier. The inferences from ethnographic user study helped to narrow down the issues and generate a proper design brief for the project. A set of questionnaire was made to understand farmers behavioral and attitudinal dimension. Questions were divided into major two sections, as shown below. Along with the interview, implements and machines used by them were also documented.



In India, there are no standard methods to measure the land. People in the village use local means of measurements like Guntha and Bigha, etc. The conversion of these local measures into a standard measure like hectare and acres varies in each state. Conversion used here is most commonly used by many states like Gujarat, Maharashtra, UP and Madhya Pradesh etc. The conversion is given below.

1 Hectare = 100 Sq. Meter = 100 x 100 Meter

1 Hectare = 2.5 Acre

1 Guntha = 100 Sq. Meter = 10 x 10 Meter

1 Bigha = 25 Guntha

4 Bigha = 100 Guntha = 1 Hectare

Name / Age / No. of Family Members		Source(s) of Income	
Type and Size of The Operated Area			
Method of Farming		Why Particular Method and Why not Other?	
Kharif Crop	Rabi Crop	Zaid Crop	Others
How they perform Farming Operation			
Animal	Labor	Machines	
Issue with Current Machines/Aspiration		Area they need mechanization the most	

Image 13. User study questionnaire

Kaushya / 48 years / 10 people		Farming and Small Grocery Shop	
Plain fields. 6 bigha (4+2 bigha) (1.5 ha.)			
Conventional Farming		Conventional farming is easy. Fertilizers and biocides are easily available. Organic farming has no market. Also, low yield is the main factor.	
Rice	Chana Tuvar	Watermelon	None
How they perform Farming Operation			
Animal (Own Two Bulls) Ploughing	Labor () Transplanting (Hire) Spraying (Self) Harvesting (Hire) Threshing (Hire)		Machines Puddling (Rent Tractor) Irrigation (Rent Water Pump) Crop Transportation (Rent tractor) Transportation (Own Splendor)
Current machine are expensive, will not invest lakhs of rupees to plough once in a year.		Machine for ploughing and puddling suitable for small farms	

Image 14. Example 1 of User Feedback



Image 15. Example 1 of User Feedback (Land Type)

2.2.b Inferences From the User Study

Land Related

Indian farms are fragmented. Which means, for example, even when a farmer has 4 acres of the operated area, this area might be distributed in a different location. He might have 2 acres of a farm in his village other 2 acres of the farm in some other village or in the same village at a different place. Even semi medium and medium farms are fragmented, so it brings them down in the category of small and marginal farms when an individual farm is taken into consideration.

Gujarat, Maharashtra and many other states due to its demography have many farms field which is on the slope or steps. This slope varies from 10 to 30 degree, and steps height is around 4 to 5 feet. These make use of tractors and power tiller even more difficult. Also, the shapes of the farms are uneven. (image 14)

Crops Related

Primary crop for most of the farmers are either rice, wheat, maze or sugarcane. Along with this primary crops they grew other items like vegetables, fruits, pulses etc. based on availability of the water. Even today, many farmers can not take crops during summer or late winter due to lack of irrigation facility.

Transport Related

People use modified bikes or attachment to the bike (jugaad) to transport cattle food, fertilizers, stubbles, and crops, which is illegal as well as unsafe to use on the farm fields and during monsoon. (image 15)

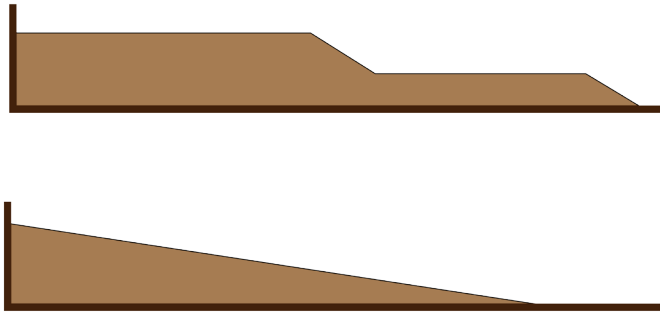


Image 16. Graphical representation of farms on hilly area



Image 17. "Jugaad" done by farmers to transport produce



Image 18. Graphically representation of issues with tractors in small field

Farming Operation Related

Ploughing, Tilling and Puddling is done using Ox, Tractor and Power-tiller. Those who can not afford to own those machines rent them five to seven times a year based on different operations. (Tractor rent: 800 inr/hr, Ox rent: 800 inr/day, Power tiller rent: 600 inr/hr, Harvester rent two Quintel crops / Acre)

Even planting of the seeds, weeding and harvesting is done by hiring labors. Finding labor is a major issue faced by farmers. (Labor charges: 200-250 inr / day, 2000 / team)

Machine Related

Using big tractors in small farmers is not suitable. Its big turning radius makes it difficult to plough in corner hence leaving corners unploughed, and farmers had to do it manually. With farm shapes more uneven, this problem is a significant issue. (image 16) Even though power tiller seems best solution for small and marginal farms it has several issues which are,

Less depth of cut - A person has to apply so much load on handle to achieve more depth of cut when it comes to hard soil.

Ergonomics - A lot of mechanical vibration, gear position makes it difficult to handle it by producing lots of body strain.

There is no steering link, both tires are separate so turning becomes difficult and may cause accident.

Person is walking behind the machine while ploughing which makes it unsafe, a farmers may get hurt during this.

Farming Operations

2.3 Farming Operations

The whole cultivation process of the crop was studied. Any crop cycle can be divided into mainly three steps where machines and implements are involved the most and frequent. All the operations can be performed by animals, tractors and power tiller based its availability and convince.

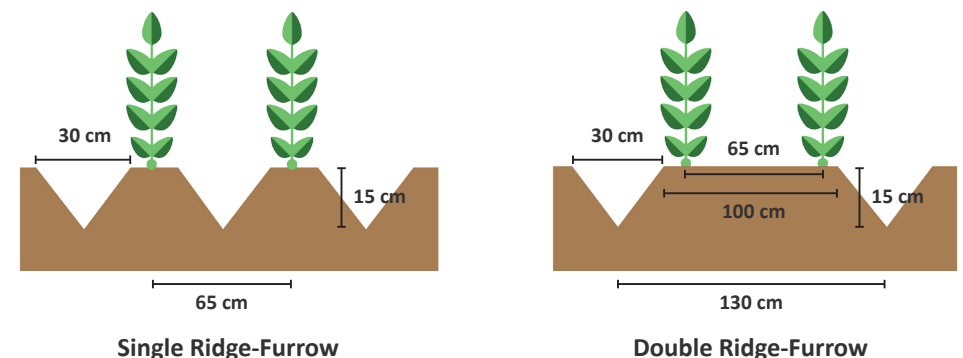
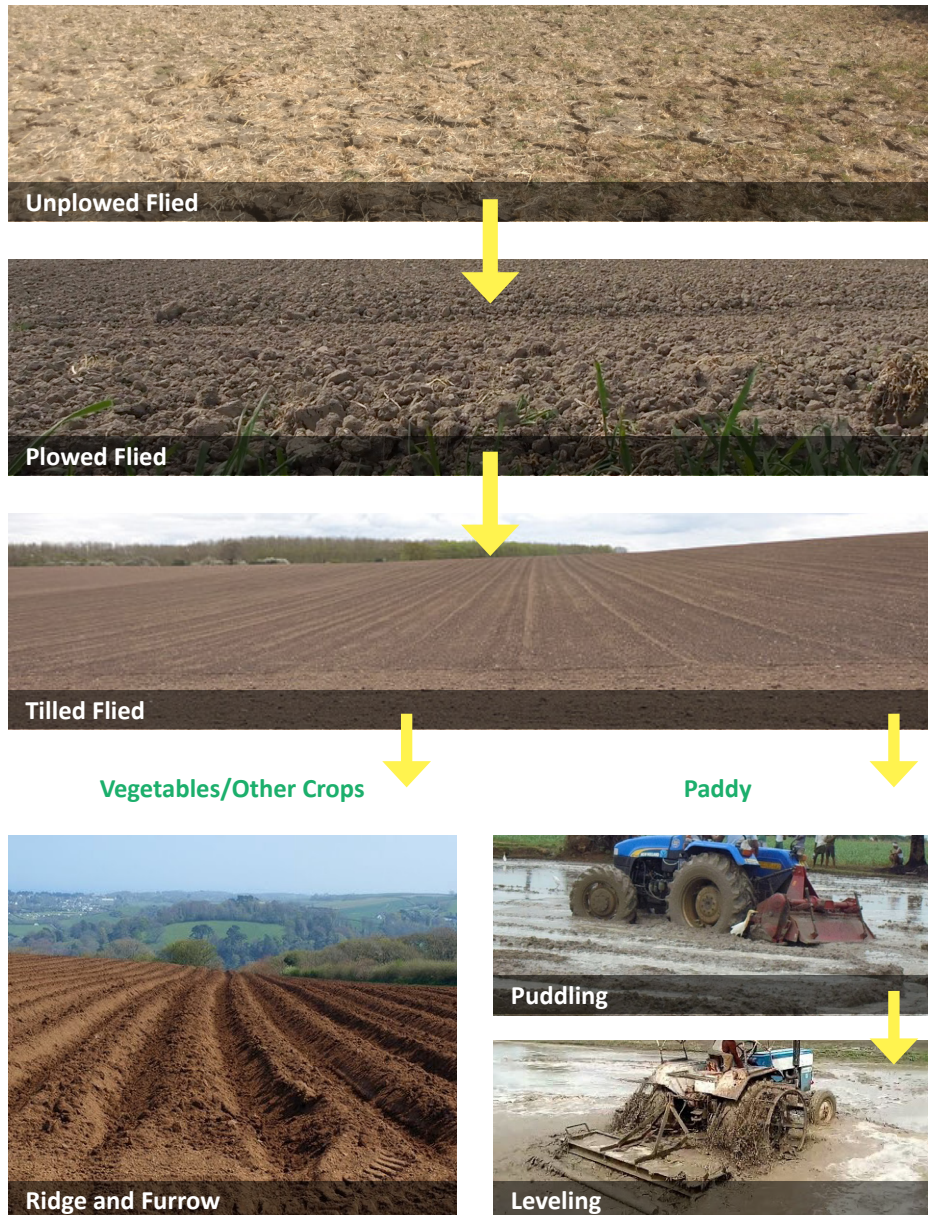
1. Land Preparation

Land preparation is done after the last harvest to make the soil suitable and productive for the next crops land preparation includes,

Ploughing: It is done to break the soil into clods, rotate the layer of the soil and remove roots/crops residue. To plough minimum 7 to 10 hp is required. (for Single furrow plough).

Tilling/Harrowing: It is the second stage after ploughing, it is done to break the clods into smaller size and bury the crops residue

Furrowing and Ridging: Furrowing is the process to create a water channel in the plowed field, so each plant gets an equal amount of nutrition, sunlight, and water. Image below shows the standard size of the furrow and ridge, although the spacing between two plants varies based on crops.



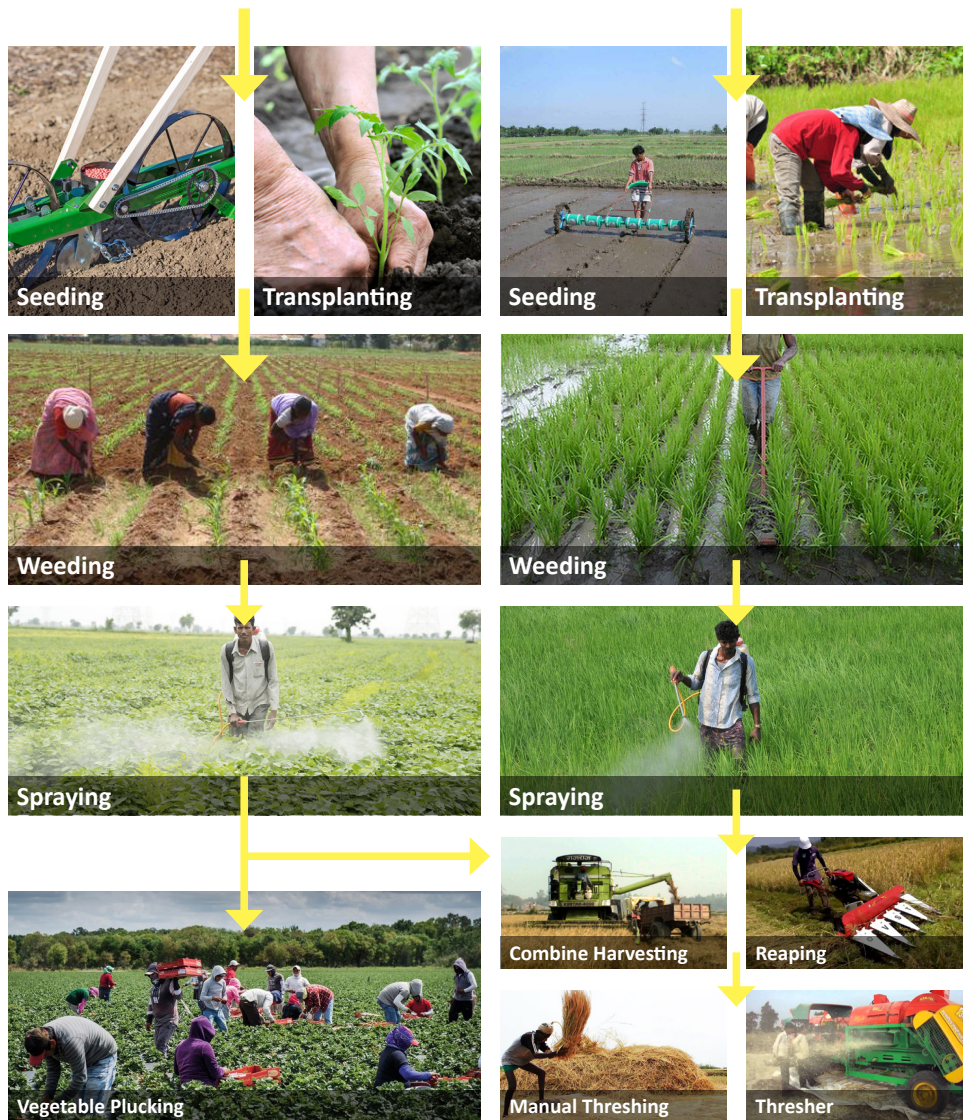


Image 19. One crop cycle for agriculture and horticulture crops

Puddling: It is a wet-tillage operation that mixes soil and water to produce an impervious layer. It is achieved by plowing the flooded land and harrowing it at progressively lower water contents — puddling benefits rice by controlling weeds and conserving water.

Leveling: In case of rice cultivation, leveling is done after puddling operation so that planting and seeding happen at the same level since rice cultivation does not involve creating furrow and ridge.

2. Plantation and Cultivation

Seeding: It is the process of sowing seeds at certain depth directly into fields and covering it with soil for better germination and growth. Various methods, such as broadcasting, drilling, and dibbling. Most of the granular crops are planted using this method.

Transplanting: In this method, the plant is grown in necessary first for controlled growth and protect young plants from weed. These saplings are then planted in the fields using manual labor or transplanter. Most of the vegetables and fruits are planted using this method.

Interestingly, rice can be planted using both methods, seeding, and transplanting. Each method has its pros and cons*.

Weeding: It is the process of removal of unwanted weed from the crop field, which may slow down the crops growth process by sharing nutrition with it. Manual weeding is the most common practice in India using a sickle. It can also be done using power tiller and weeder.

Spraying: It is the process of spraying pesticides and liquid fertilizers

3. Harvesting

Reaping: It is the process of cutting the crops from the field either manually or using reaper. In the case of vegetables, the product is plucked from the plant manually.

Threshing: It is the process of separating grains from the straw. Even today, threshing is done on communal based by running a tractor or ox over the crops or by smashing crops against the hard surface. Threshers are also used to carry out the operation.

Combine Harvesting: Here, combine harvester is used which carry out reaping and threshing process in one go reducing time and labor spent in the process. (Ref. 24)

Direct Seeding	Transplanting
Broadcasting (Dry) : Broadcast 60–80 kg / ha of seeds uniformly by hand for 1 ha of land	Preparing Seedlings : Modified mat nursery, Wet bed, Dry bed methods, Seedling trays to prepare seedlings.
Drilling (Dry) : Precision equipment, such as the Turbo Happy Seeder, can be used to drill seeds (80 - 100 kg / ha)	Random Method (Manual) : In random method, seedlings are transplanted without a definite distance or space between plants. (40 to 50 kg/ha)
Dibbling (Dry) : Bamboo/Metal scoop is used to make dibble into field and seeds are sown into it	Straight-row Method (Manual) : Straight rows facilitate management practices such as hand or rotary weeding and application of fertilizers, herbicides, or insecticides. (40 to 50 kg/ha)
Broadcasting (Wet) : Broadcast 80–100 kg per ha of pre-germinated seeds to recently drained, well-puddled seedbeds or into shallow standing water.	Mechanical transplanting : Transplanters with varying levels of complexity and sizes can be used. (30 to 40 kg / ha)
Drum seeding (Wet) : Drum seeders are used for fast planting. It operates best on a well-leveled, smooth, and wet seedbed (80 kg / ha)	

*Methods of rice plantation pros and cons

Design Brief

3 Design Brief

Mobility design intervention for paddy cultivation in small and marginal farms of India.

The conventional farming machines does the operation in sequence and requires implements to be changed after each operation. The new design focuses on doing these operations in one go and does not require implement changes.

The design should satisfy the following:

The vehicle should be able to perform various land preparation operations like ploughing, tilling, puddling, cultivation operation - planting and harvesting operation - reaping.

Farm shapes are uneven. The vehicle should be compacts enough to perform operations in corners effectively.

The vehicle should have improved ergonomics and maneuverability.

Design Ideation

4 Design Ideation

4.1 Direction 1

Direction 1 focuses on using current implements like plough, harrow, rotavator (tiller), and reaper etc. All the concepts were design taking a consideration of small and marginal farm size. Diesel engine acts as a power source here. Concepts are equipped with Power Take Off (PTO) to attach current implements.

Technical Specifications for Direction 1,

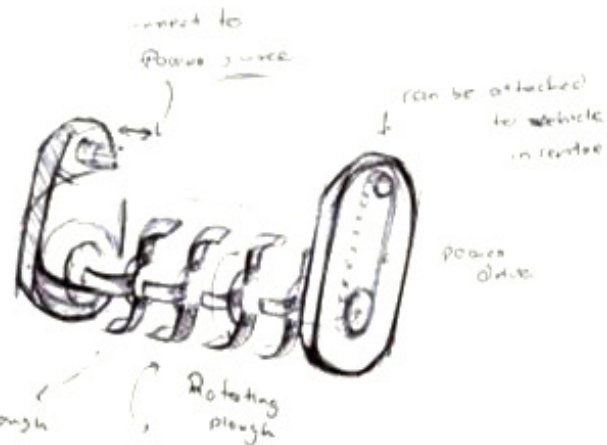
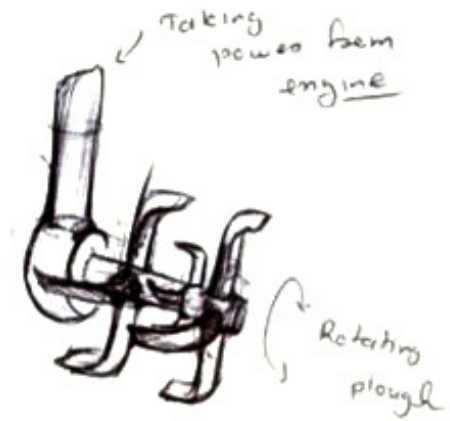
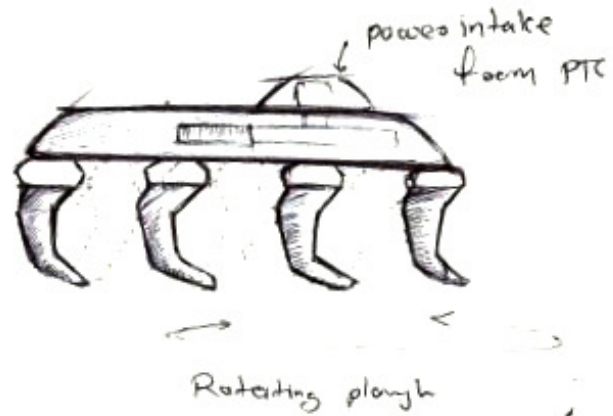
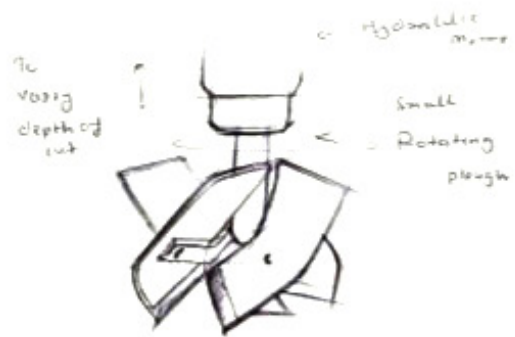
Dimension: Length - 7ft, Width - 4ft

Ground Clearance: 1 ft

Power Source: 20 HP Diesel Engine

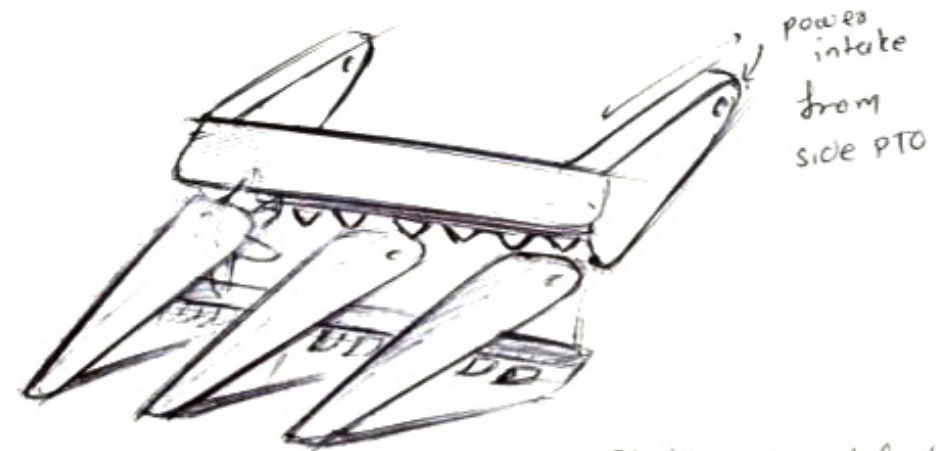
Steer: All wheel steer

Small ploughing equipment



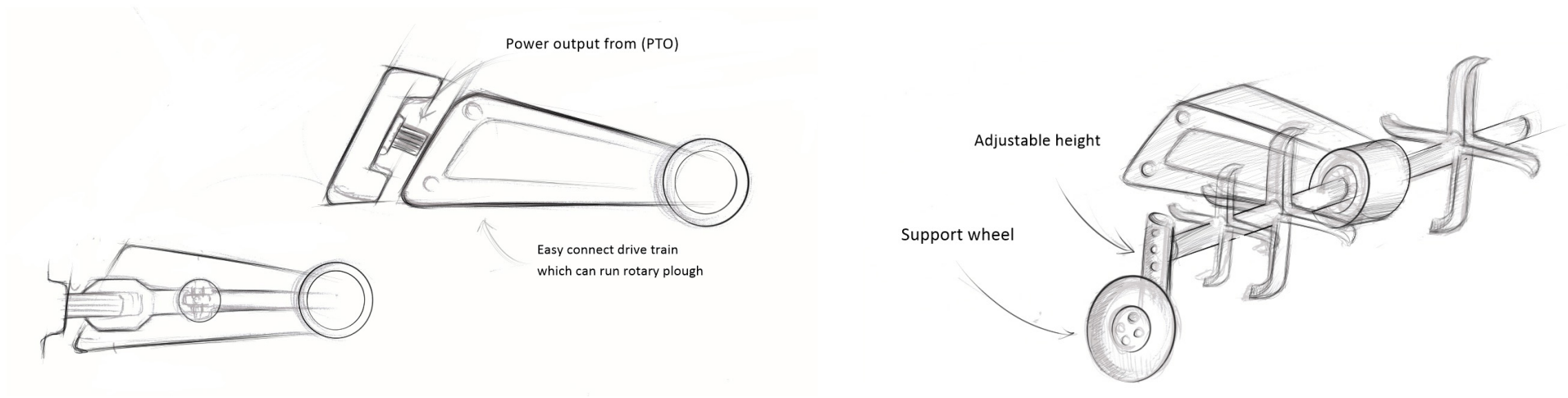
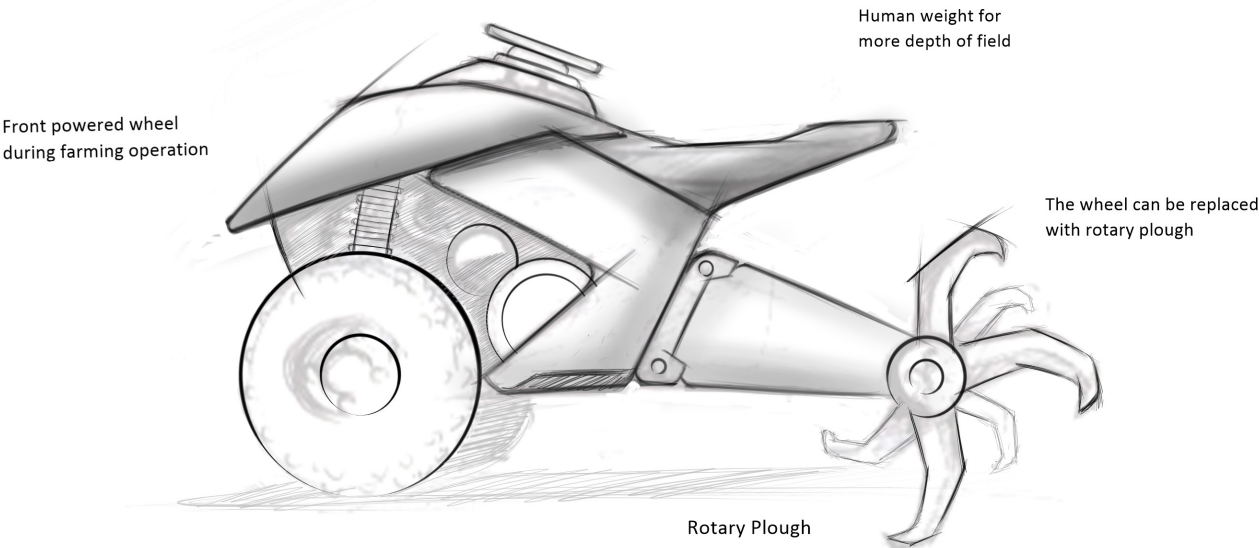
Instead of plough
different implements
can also be used like
disk rotor,
harrow etc

lake

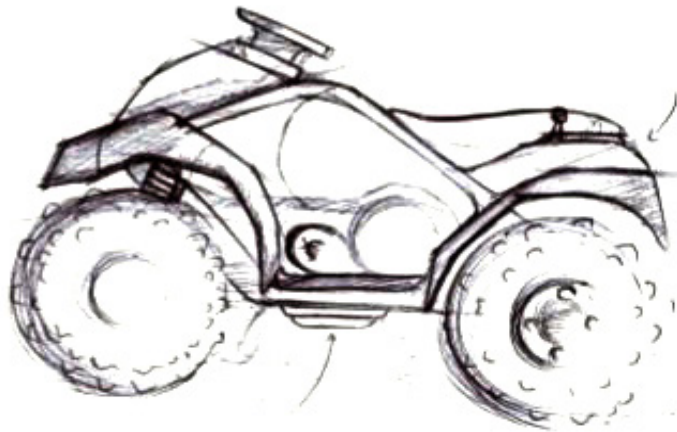


Rice / Sugar cane / wheat
harvester

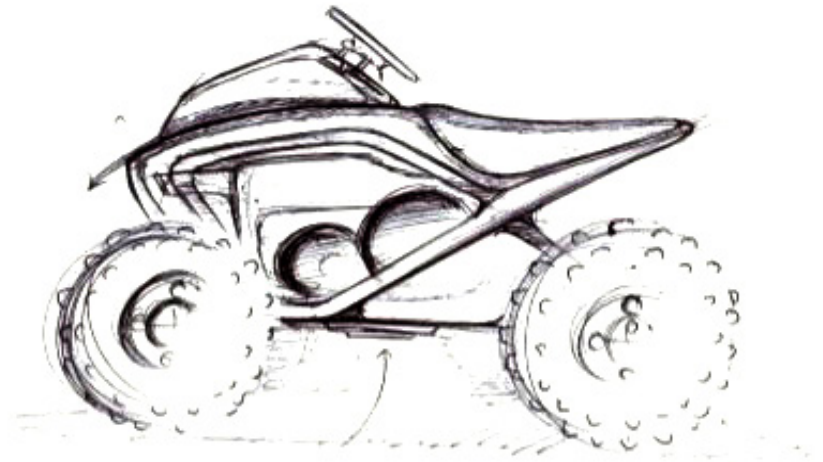
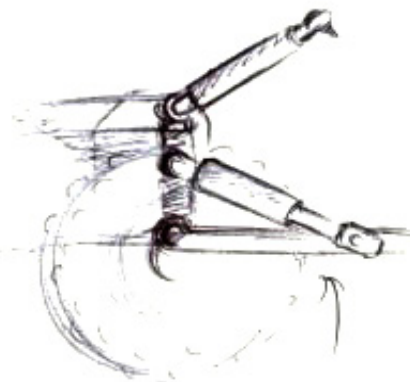
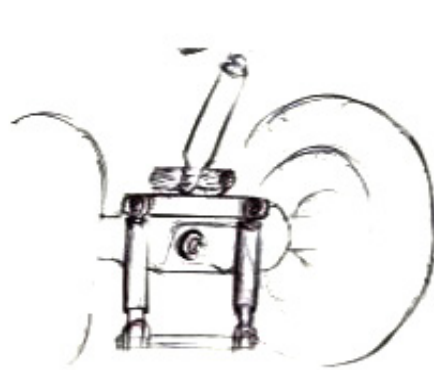
Direction 1.a



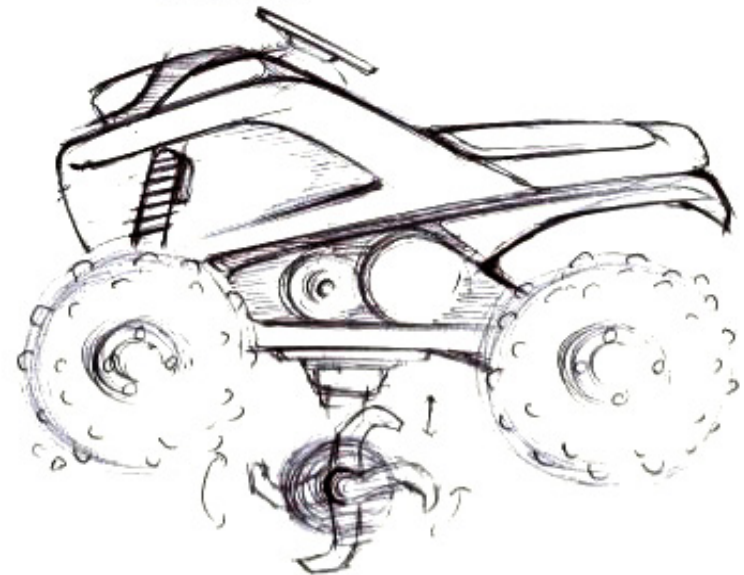
Side
power
output
for hoes etc.

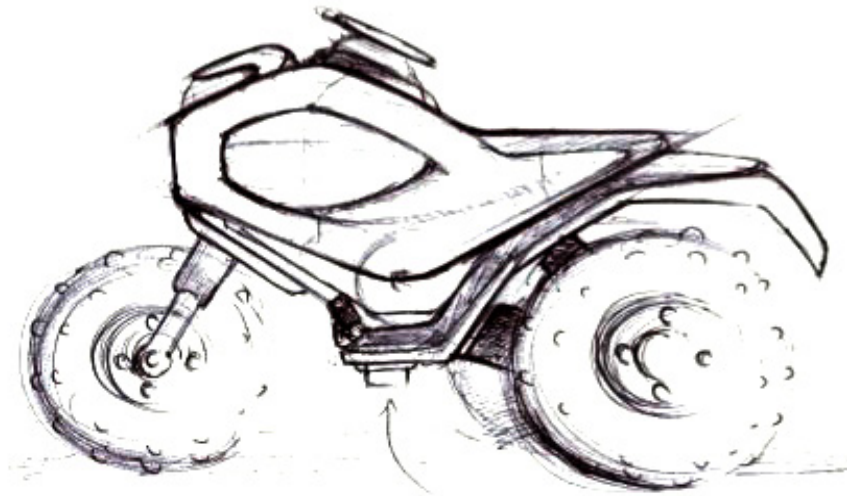


power output
for mid mount
plough / Rotary etc.

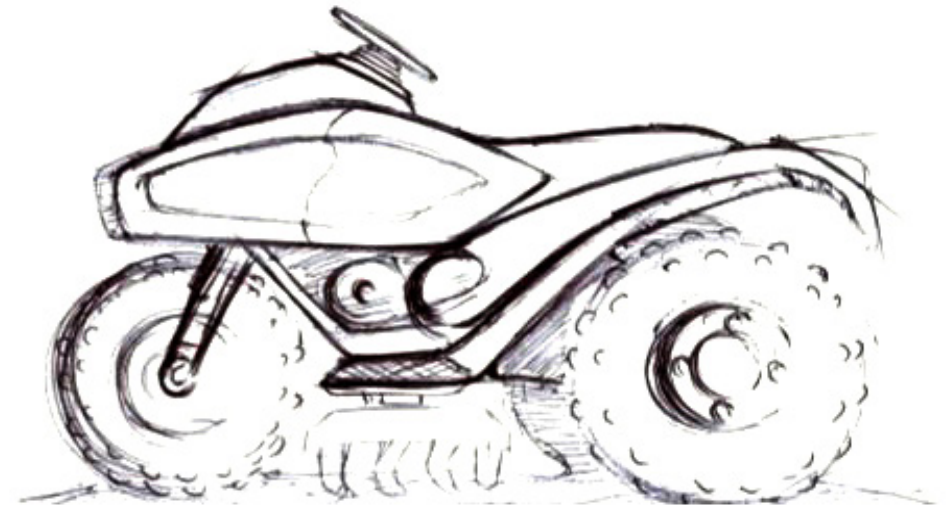
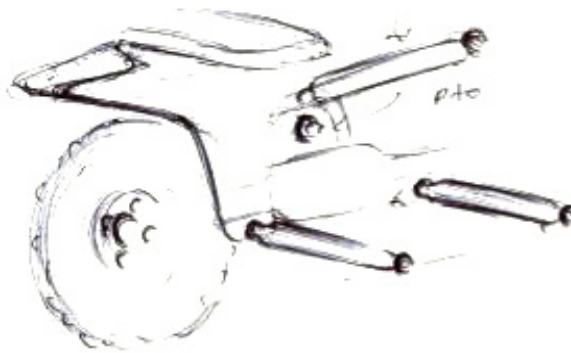
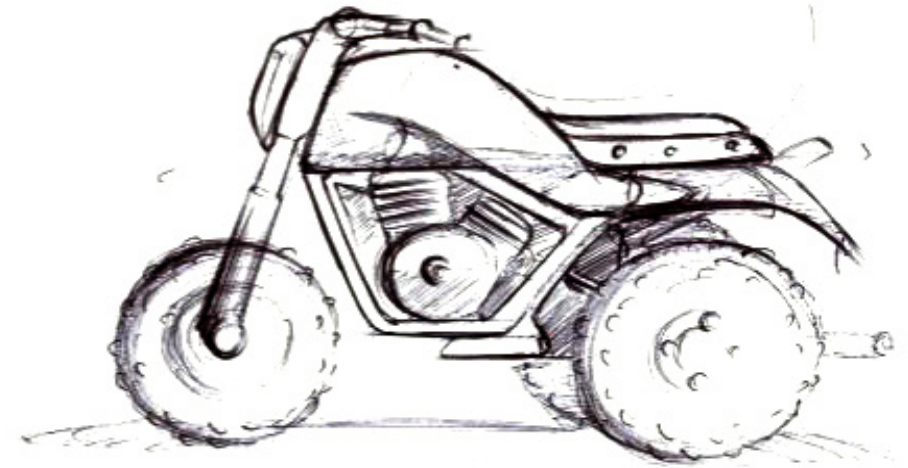


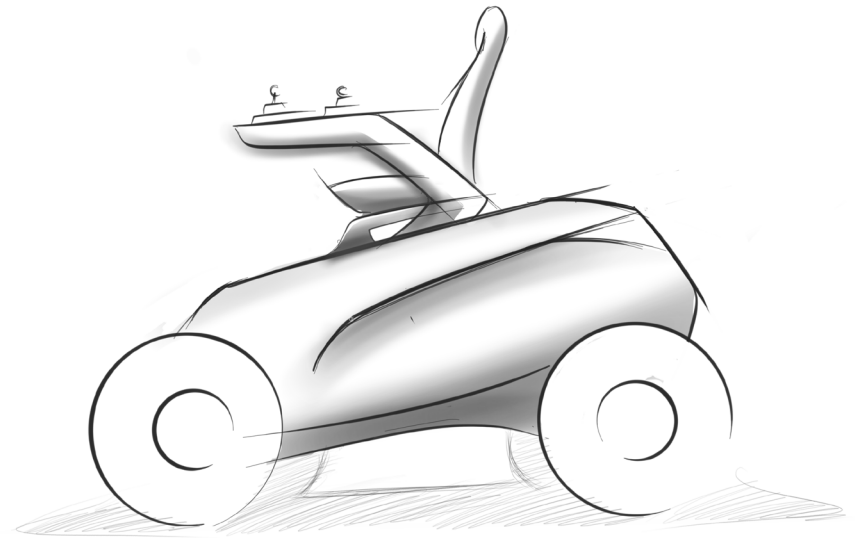
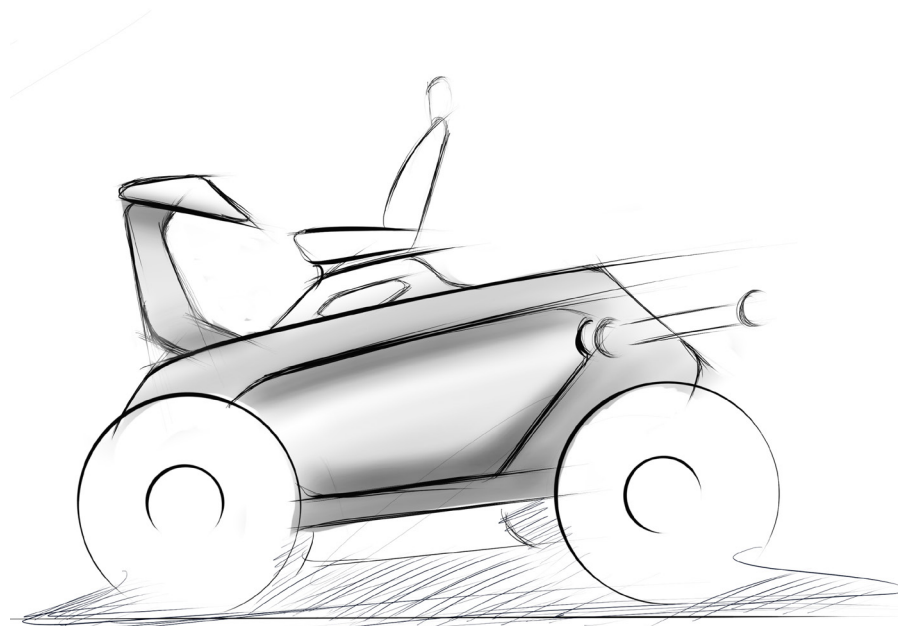
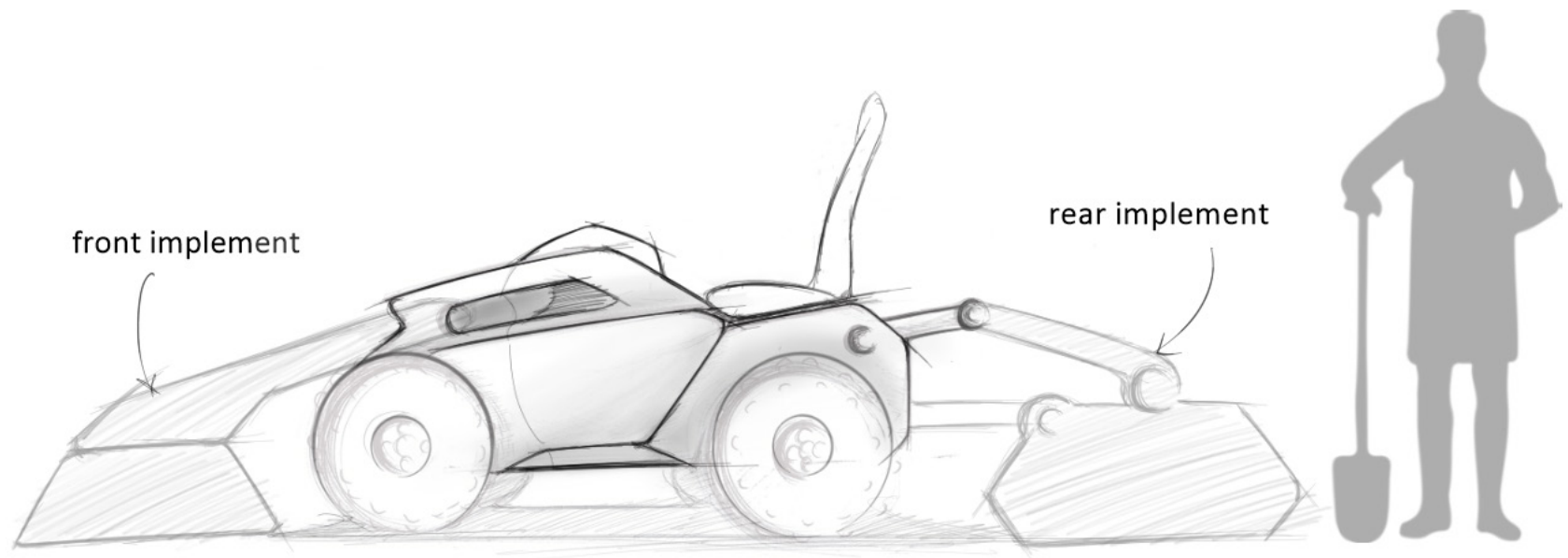
Power output



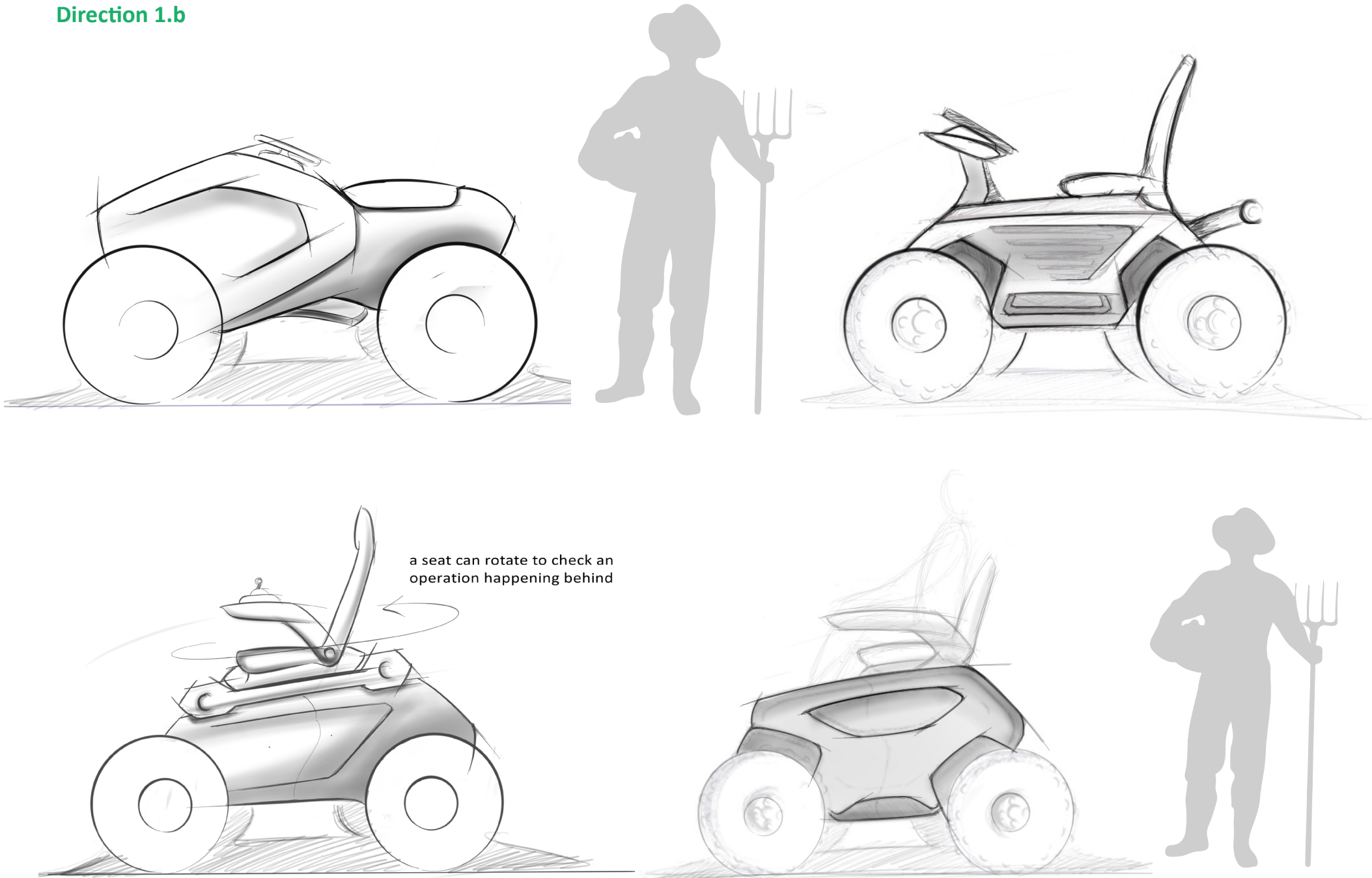


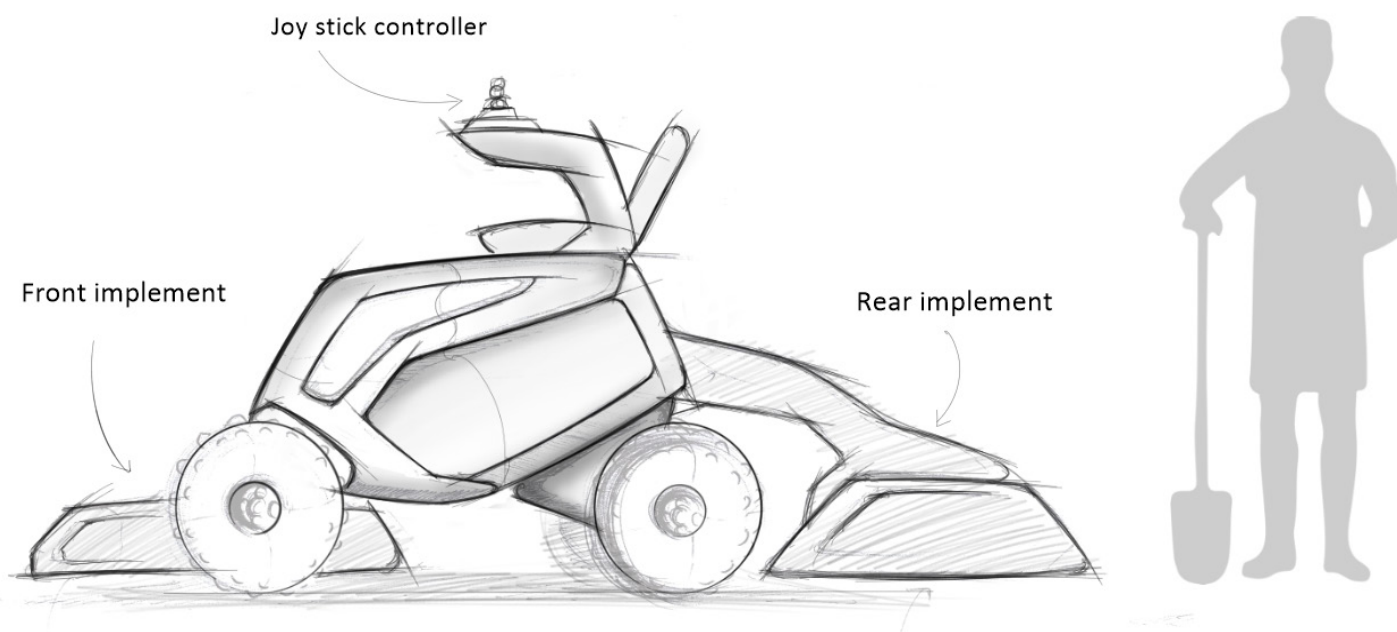
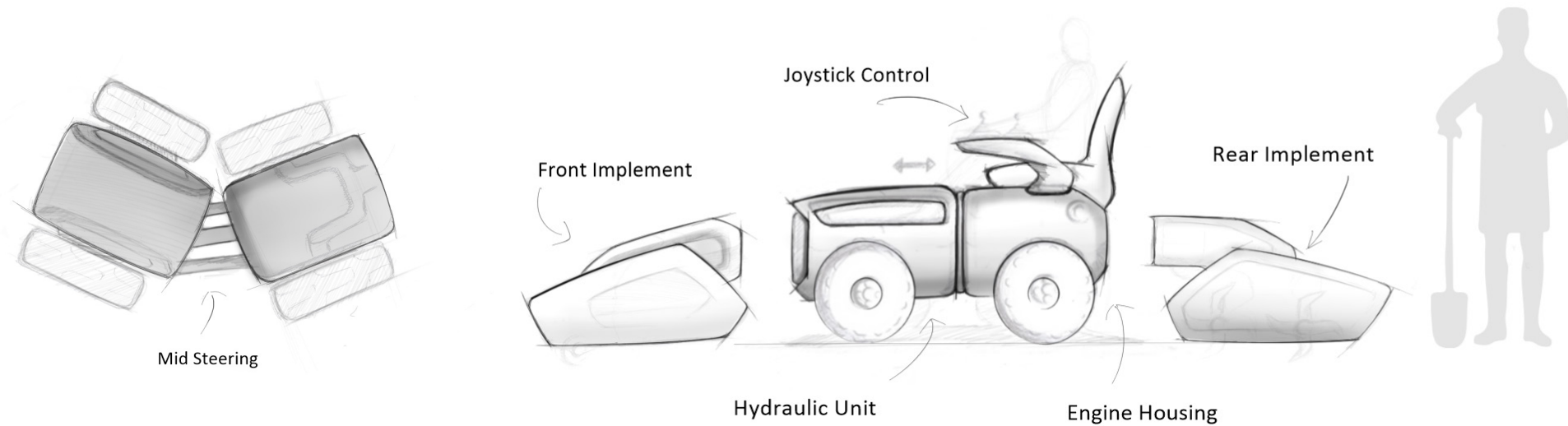
powered
implement.

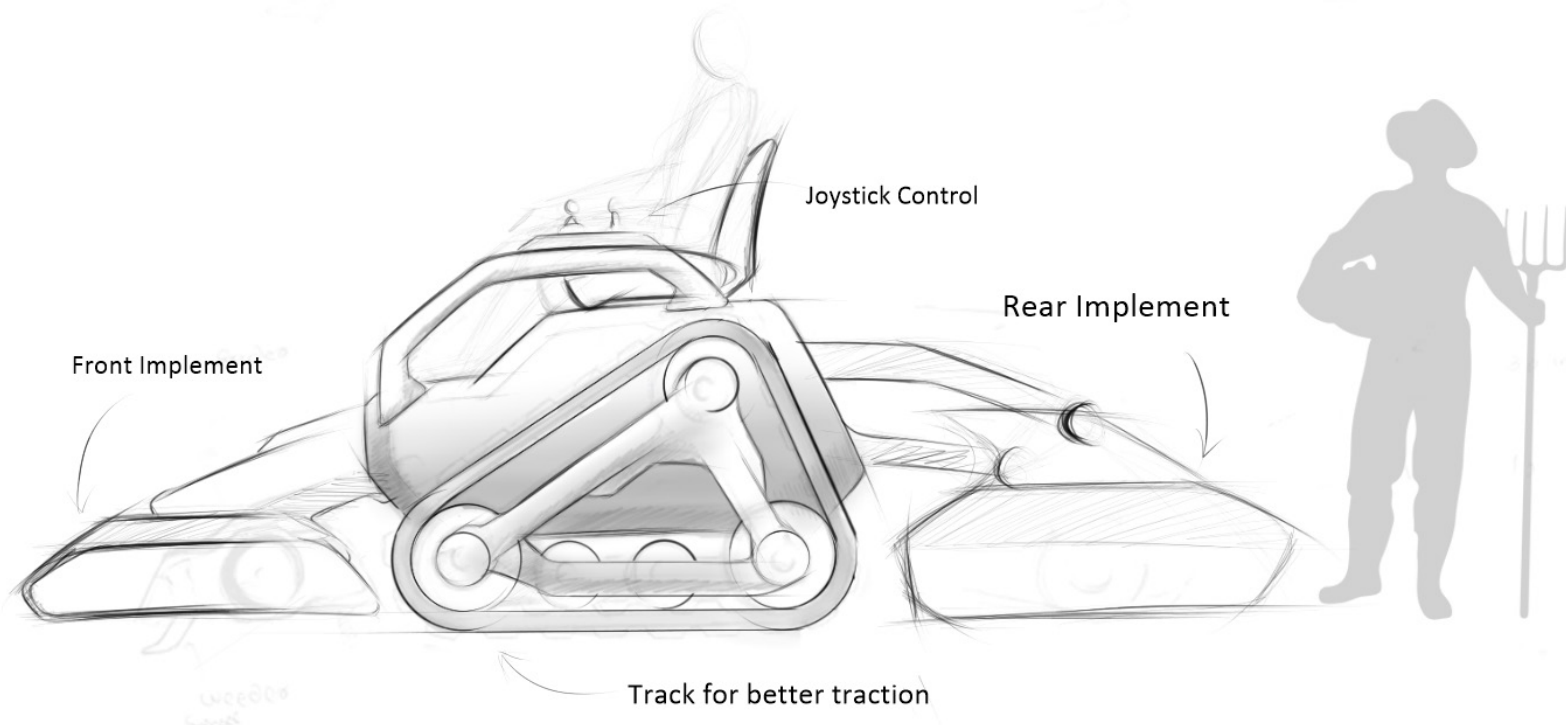
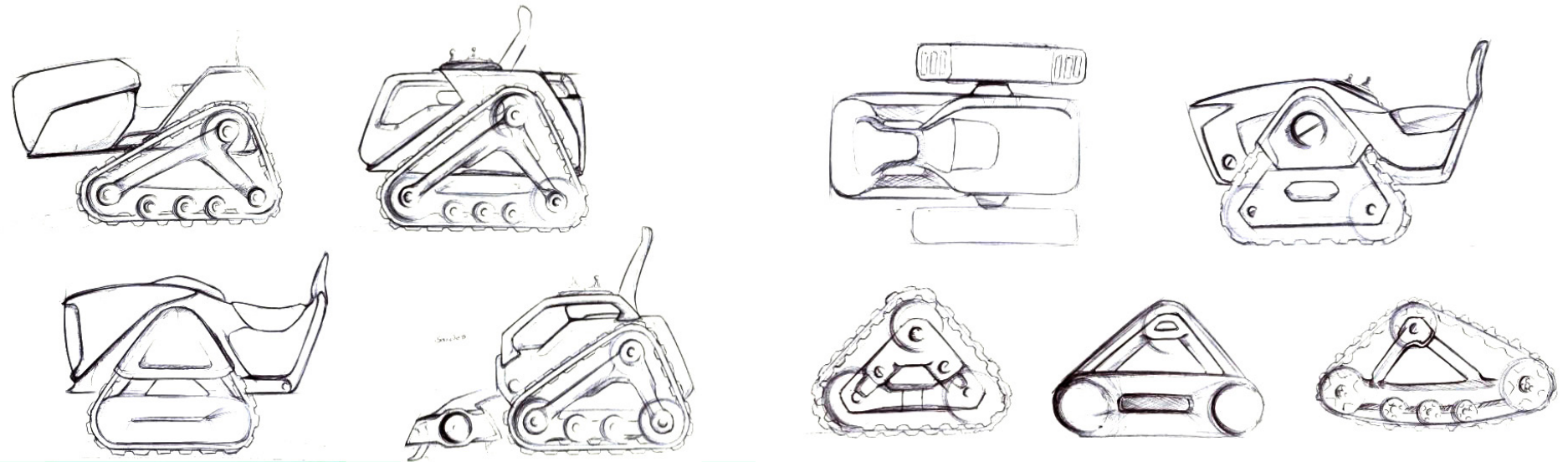




Direction 1.b







4.2 Direction 2

A new set of implements were made which can perform several operations in one go for these concepts. Tools were either attached at the center bottom of the concept or can be pulled. The direction 2.a uses the implements which are at bottom center and also has small cargo space for crops transportation. The direction 2.b has two body which can be rotated from the middle for better steering, these concepts pull the implements.

Direction 2.a

Dimension: Length - 7ft, Width - 5ft

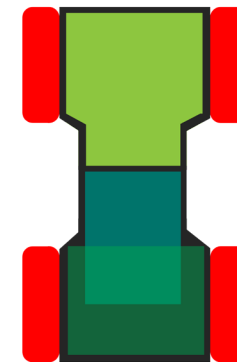
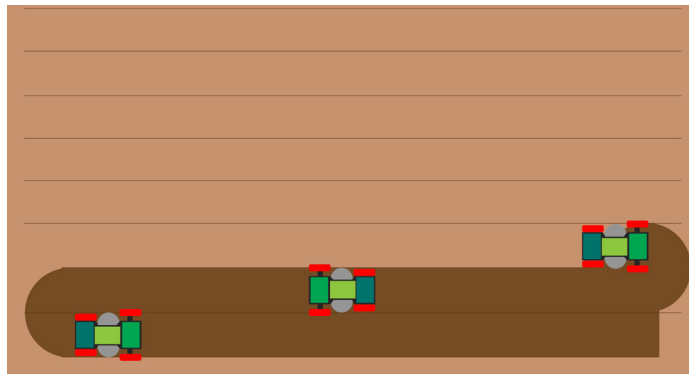
Ground Clearance: 1 ft

Power Source: 20 HP Diesel Engine

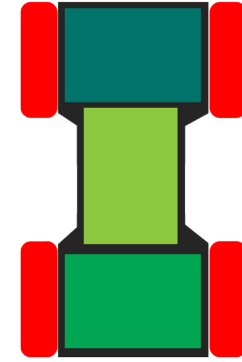
Steer: All wheel steer



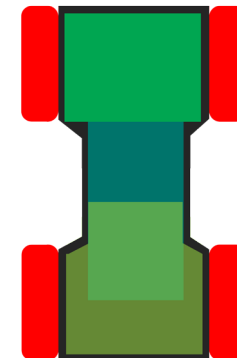
Farming Pattern



Config 1



Config 2



Config 3

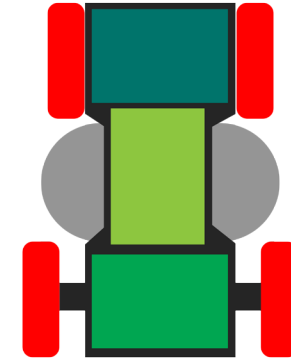
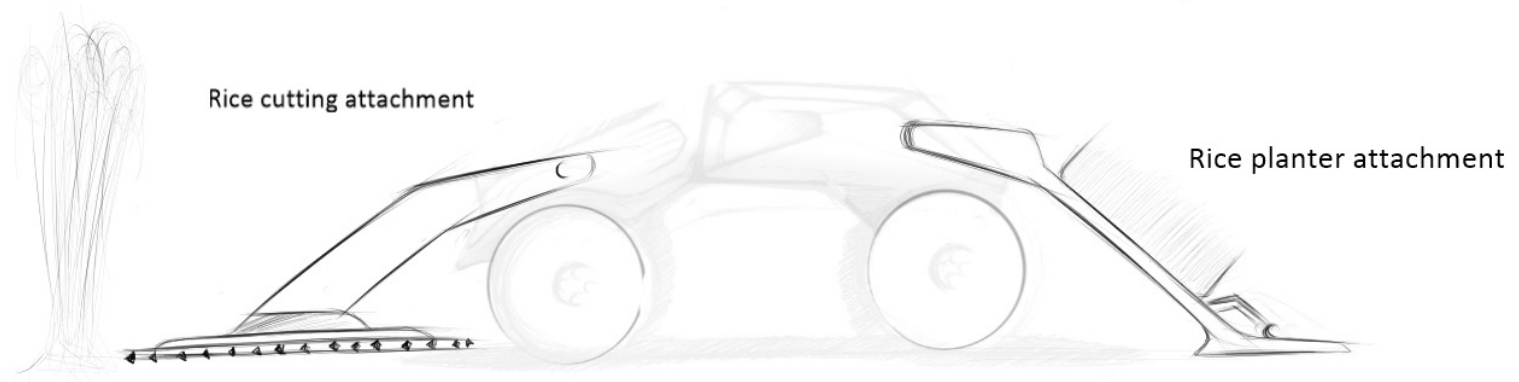
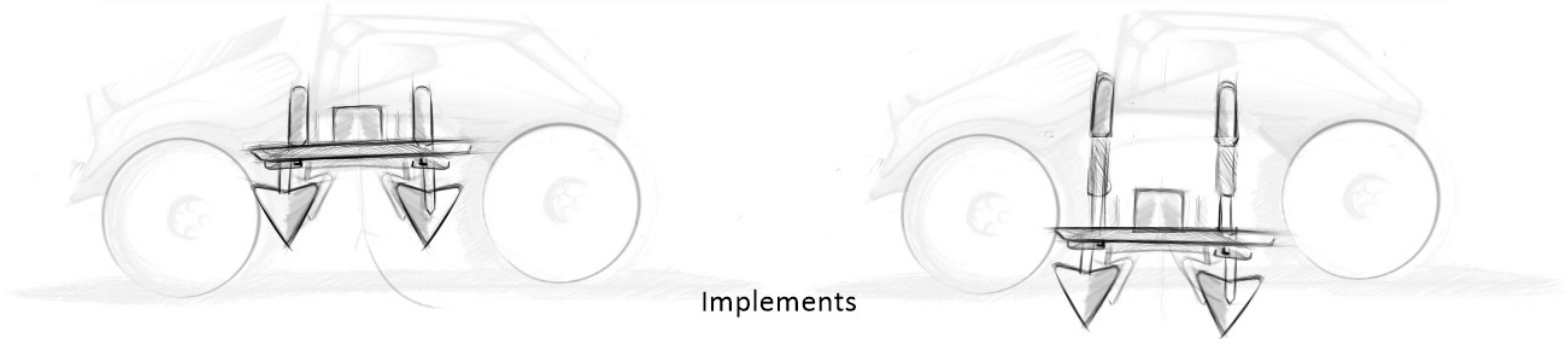
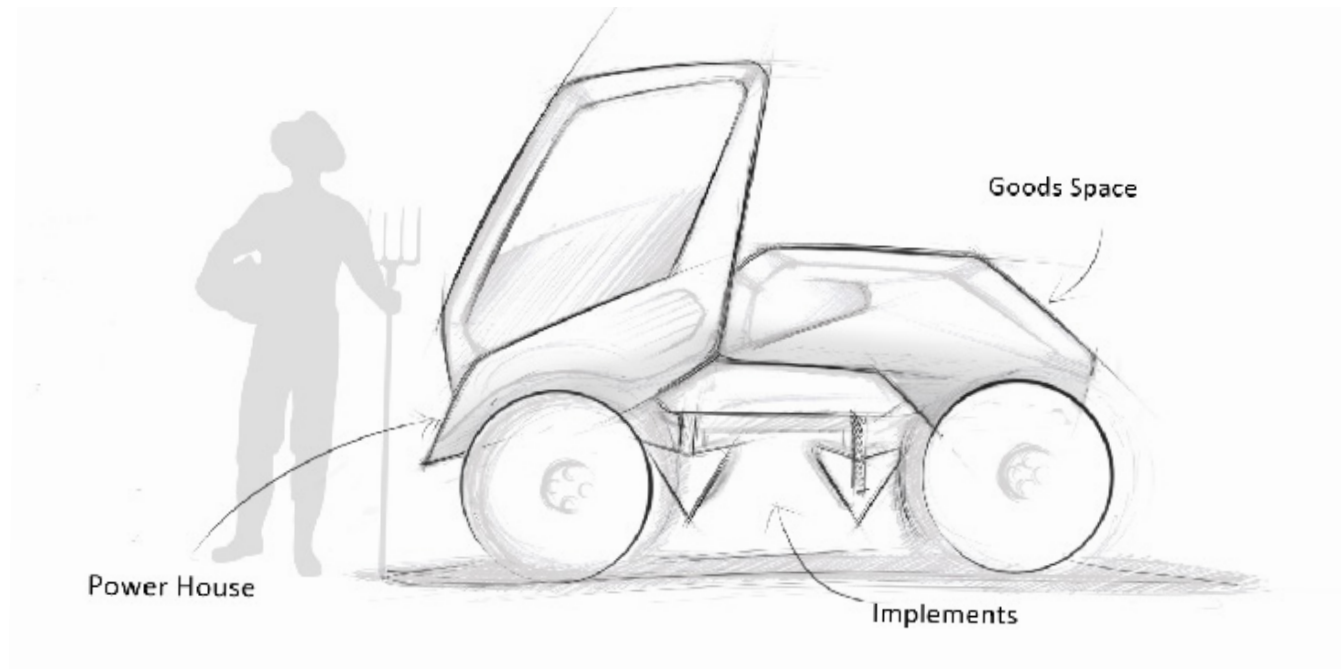
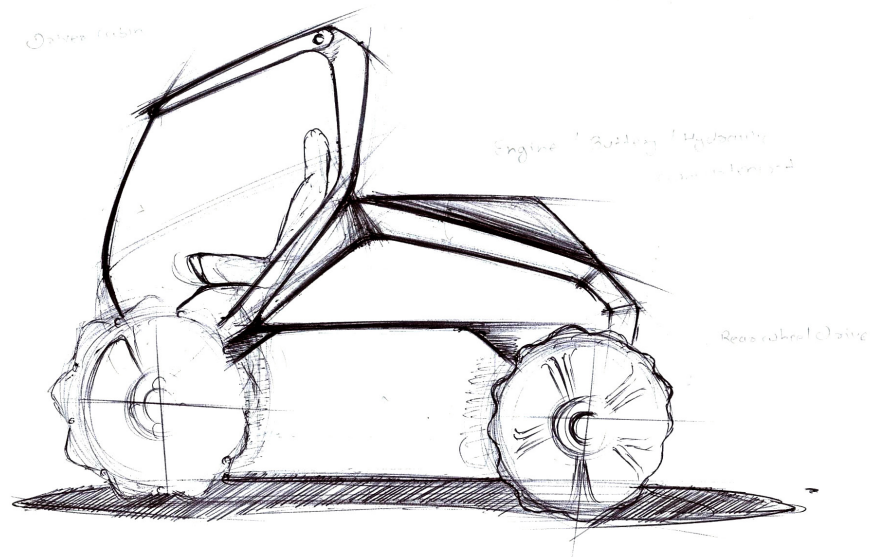


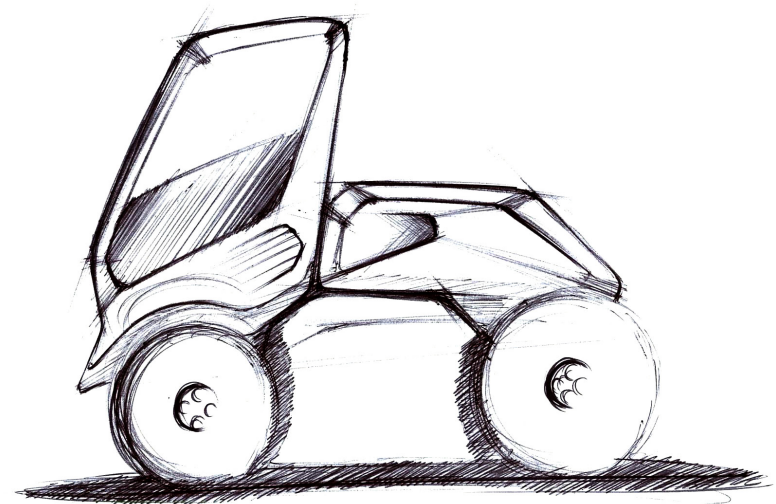
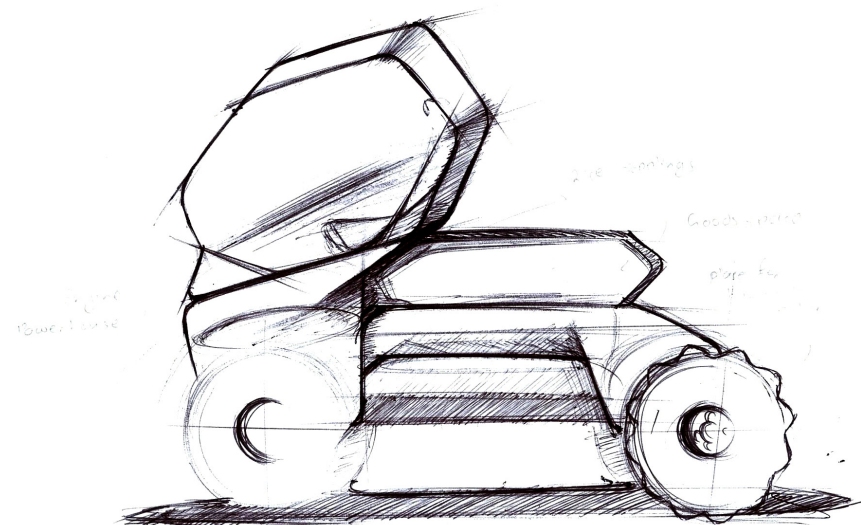
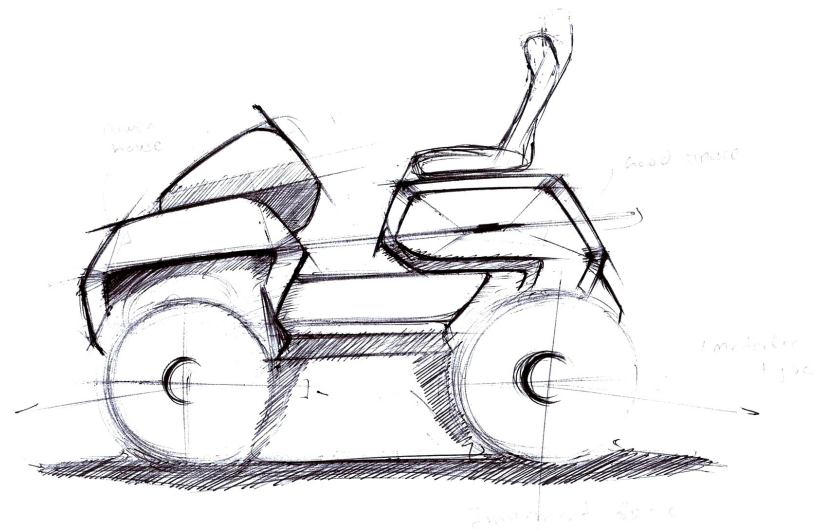
Image 20. Implements for concepts from direction 2.a

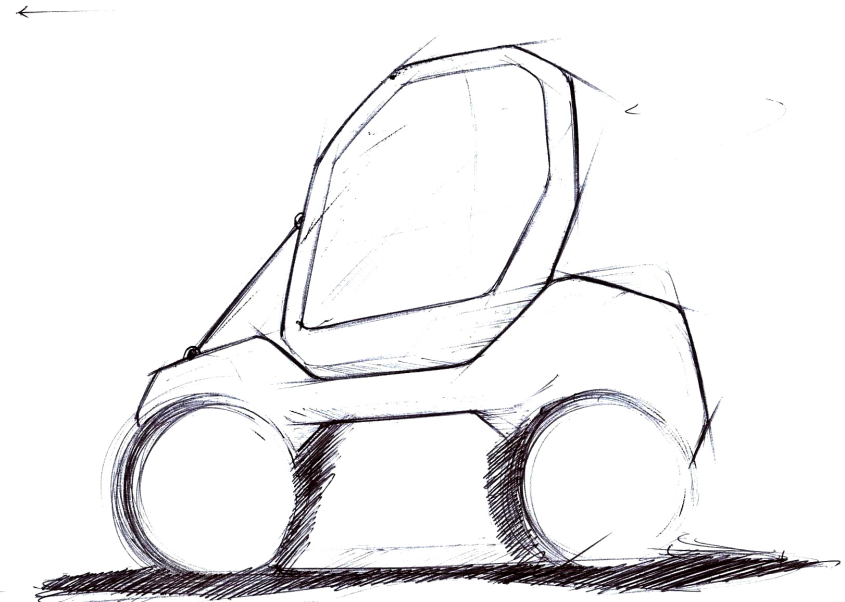
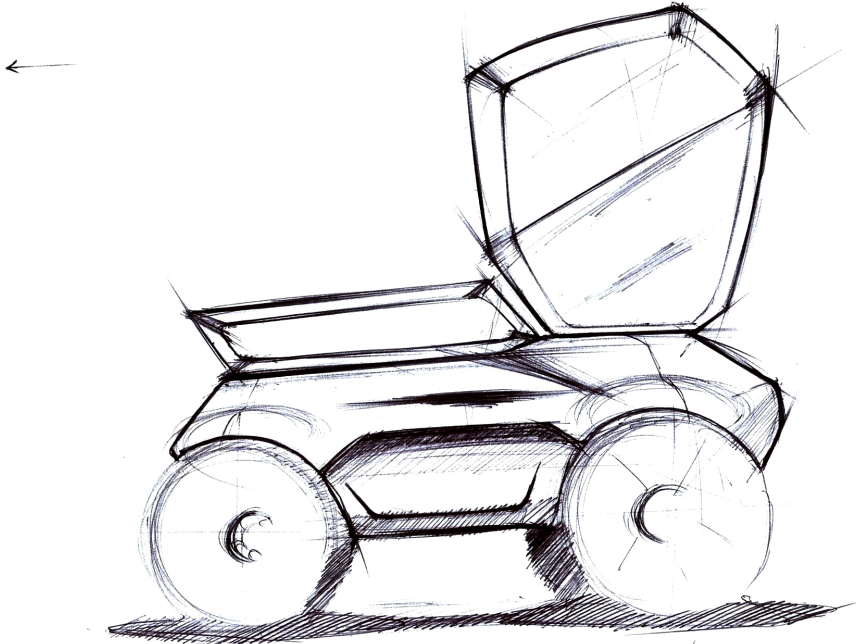
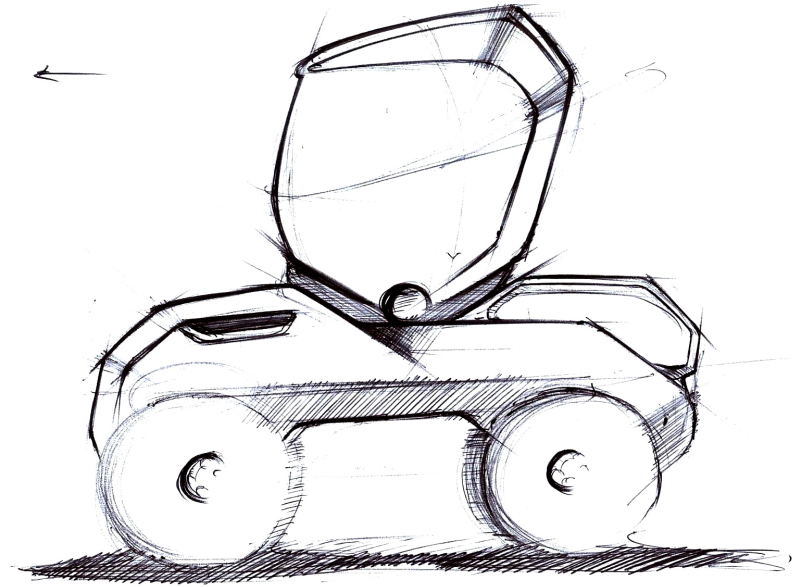
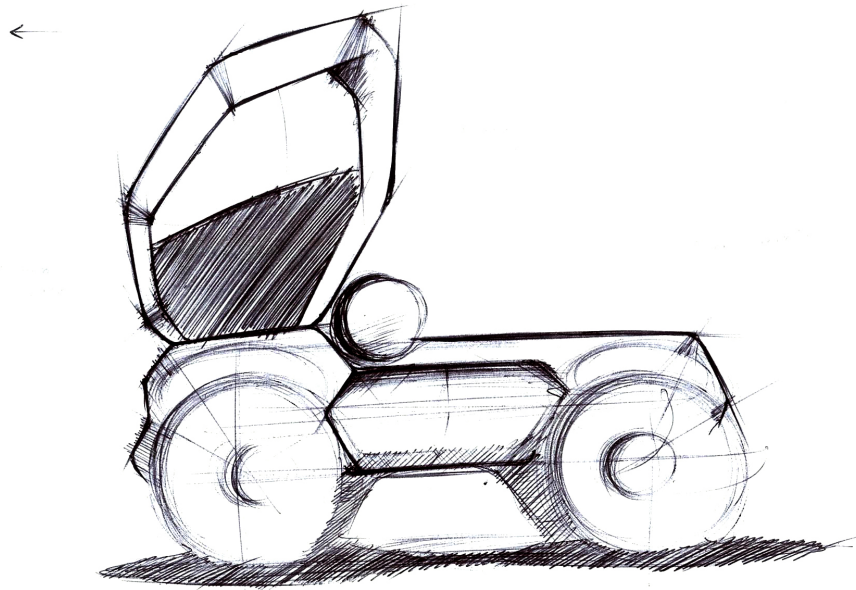






Implement housing





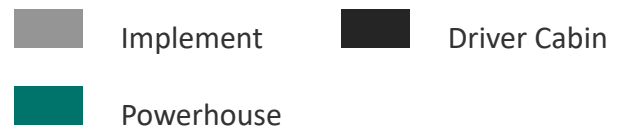
Direction 2.b

Dimension: L - 5ft (7ft with implement), Width - 4ft

Ground Clearance: 1 ft

Power Source: 20 HP Diesel Engine

Steer: Hydraulic Multi Body Steering



Farming Pattern

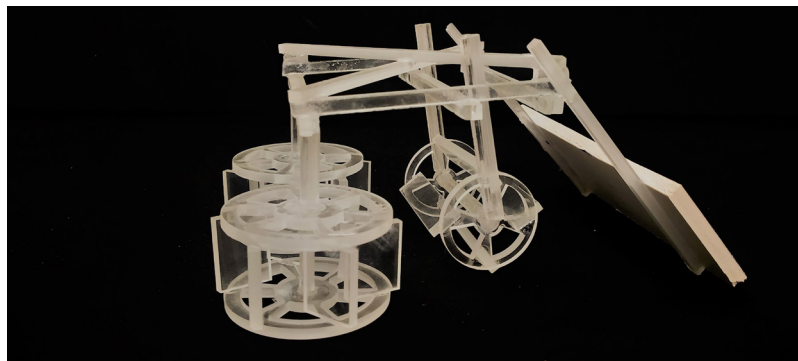
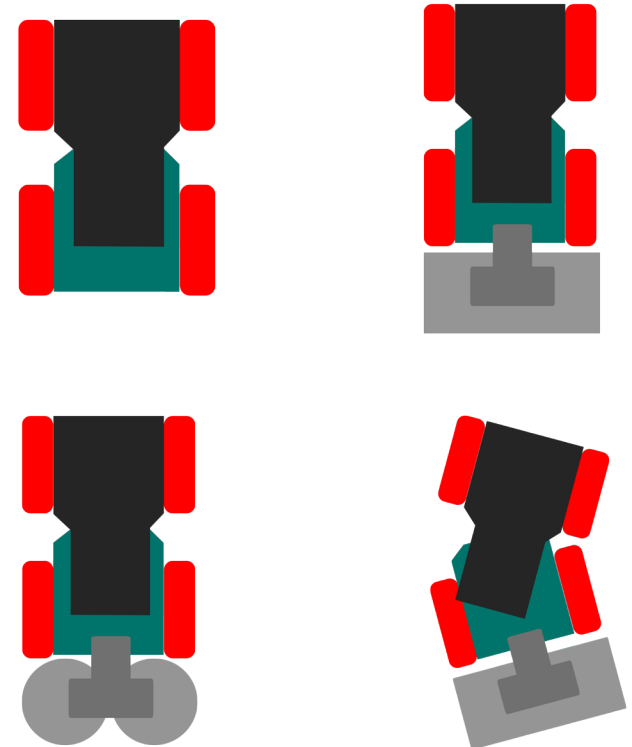
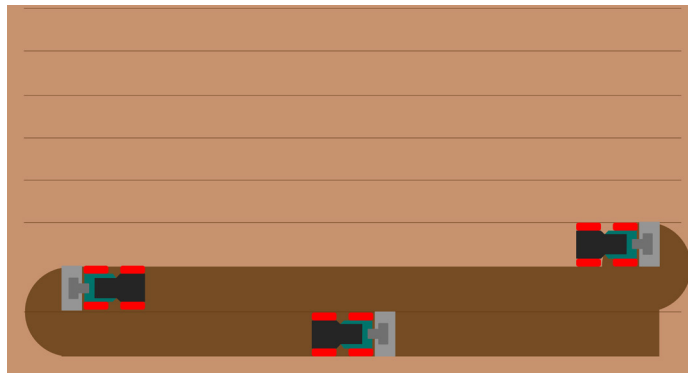
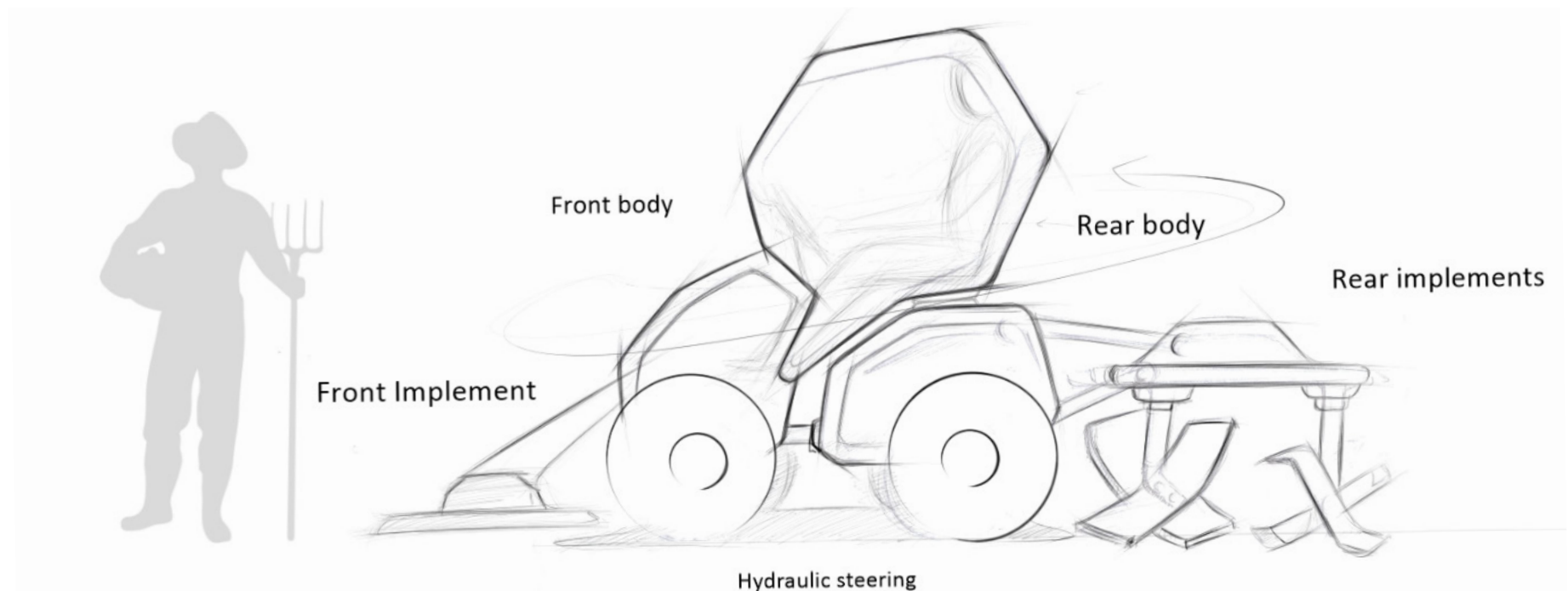
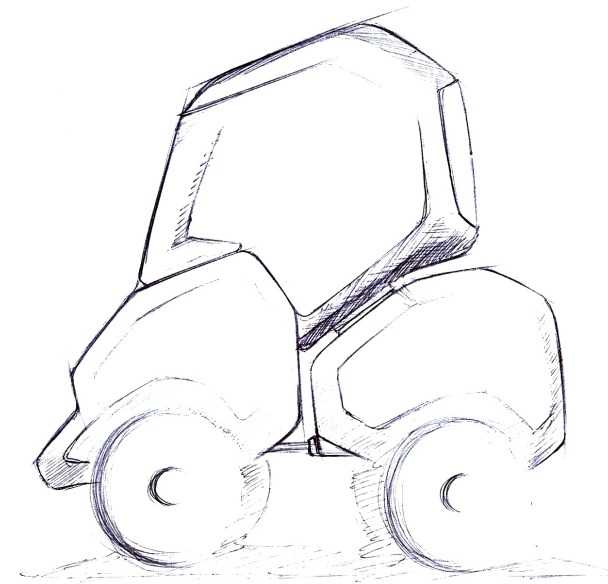
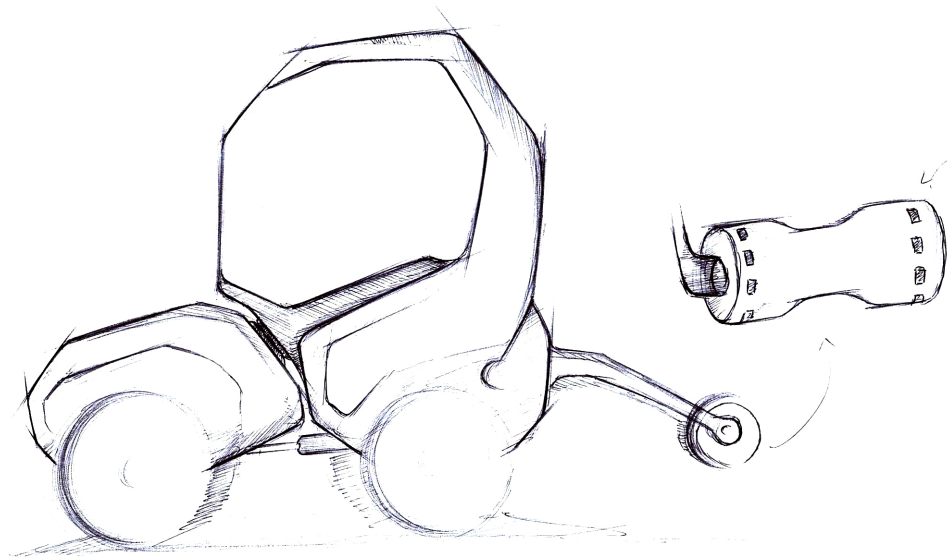
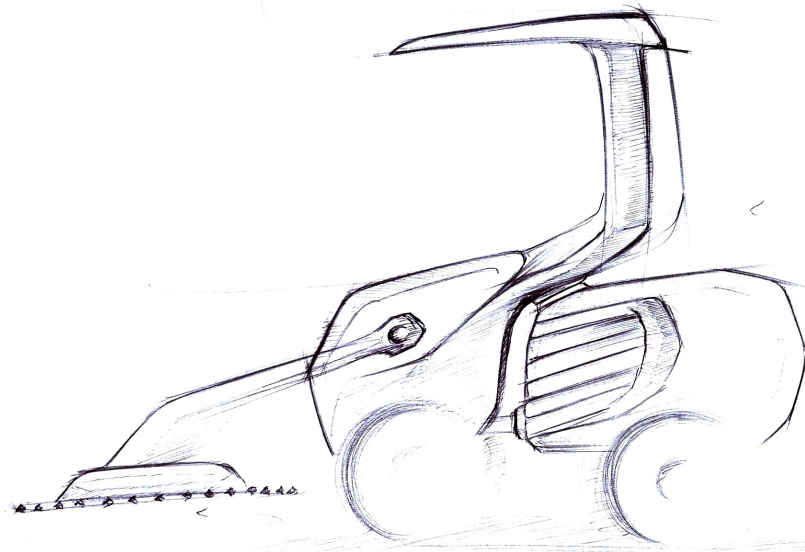
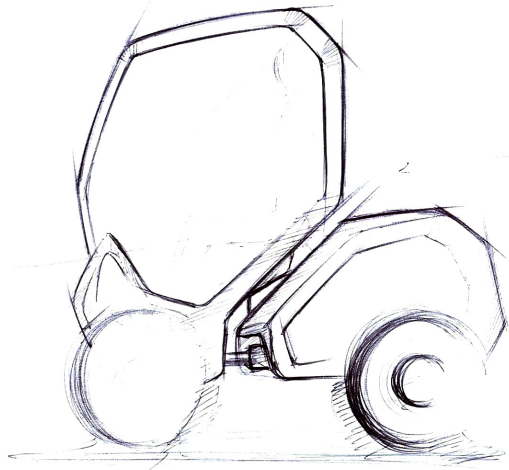
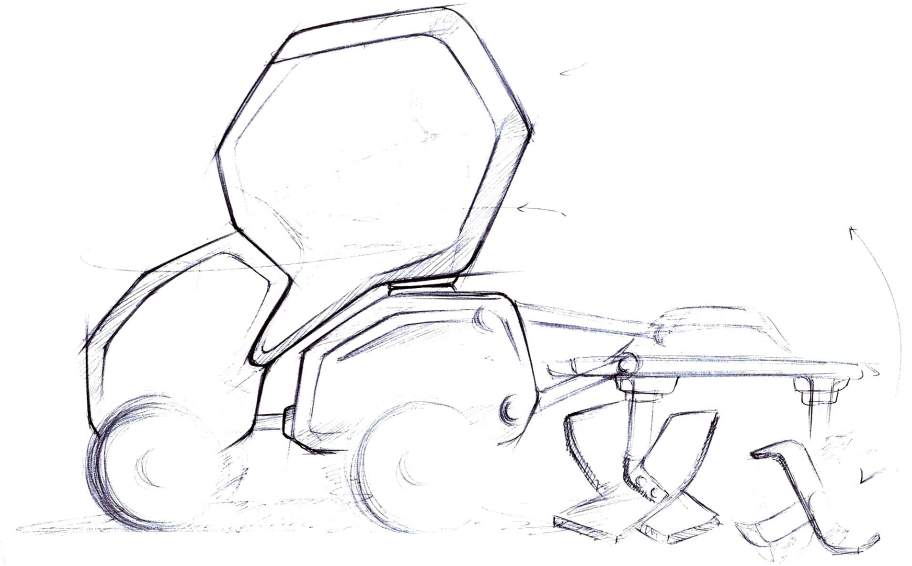
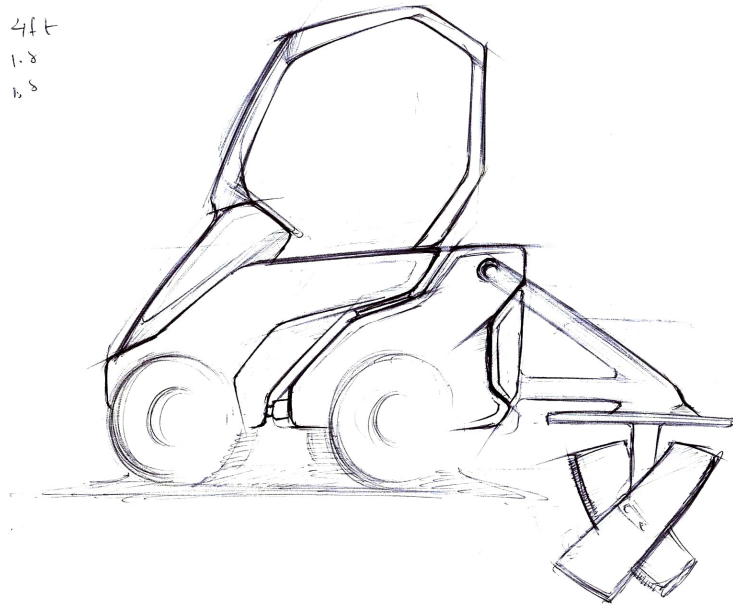


Image 21. Implements for concepts from direction 2.b, which can perform multi operation in one go



4ft
1.8
1.5



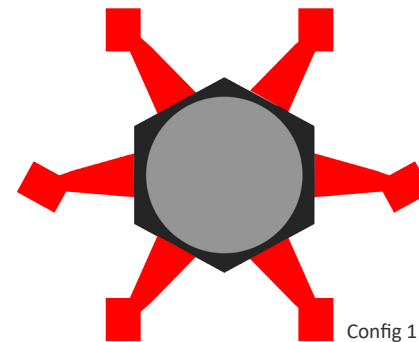
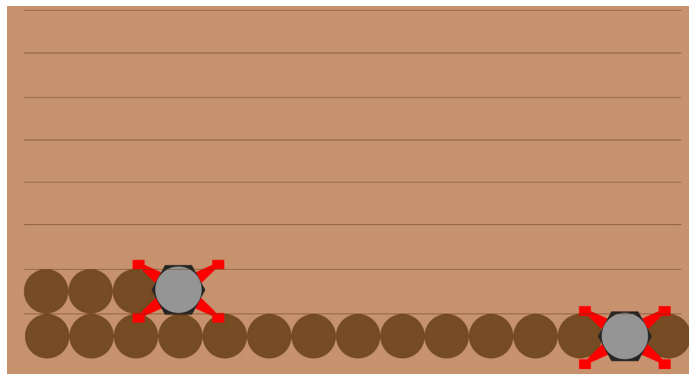
4.3 Direction 3

Direction 3 concentrate on having various implements like plough, tiller etc. in one machine. This concept works based on selective farming in which the machine first plough particular area, tillage is performed following it. After completing one operation cycle the machine move forward and do the task. The center of the machine is equipped with electric motor to run the different implements and hydraulic pump.

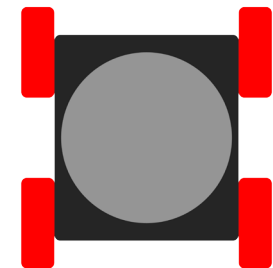
Dimension: Length - 4ft, Width - 4ft
Ground Clearance: 1 ft
Power Source: 7 Kw electric motor, Hydraulic Pump
Steer: Hydraulic Arms / Tyre



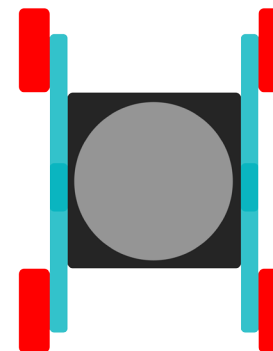
Farming Pattern



Config 1



Config 2



Config 3

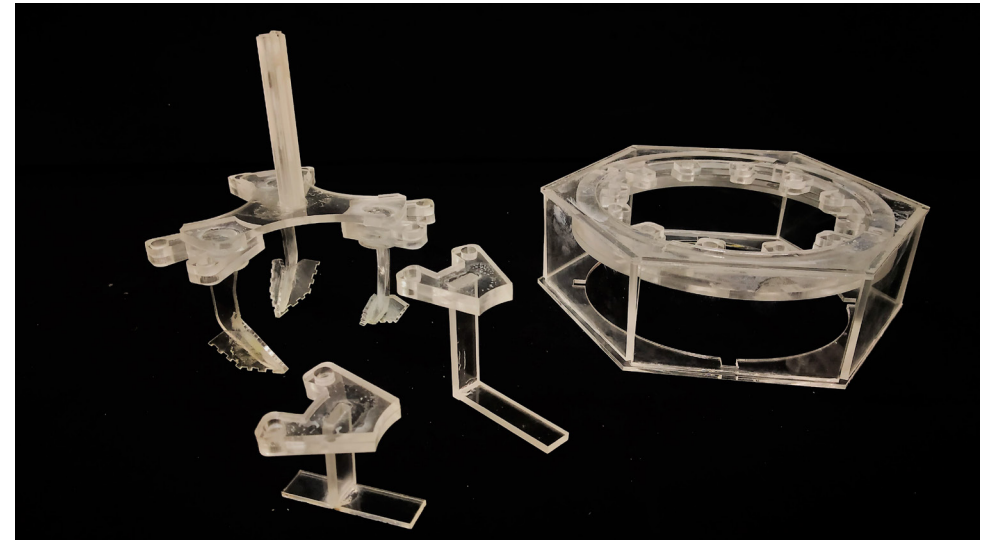
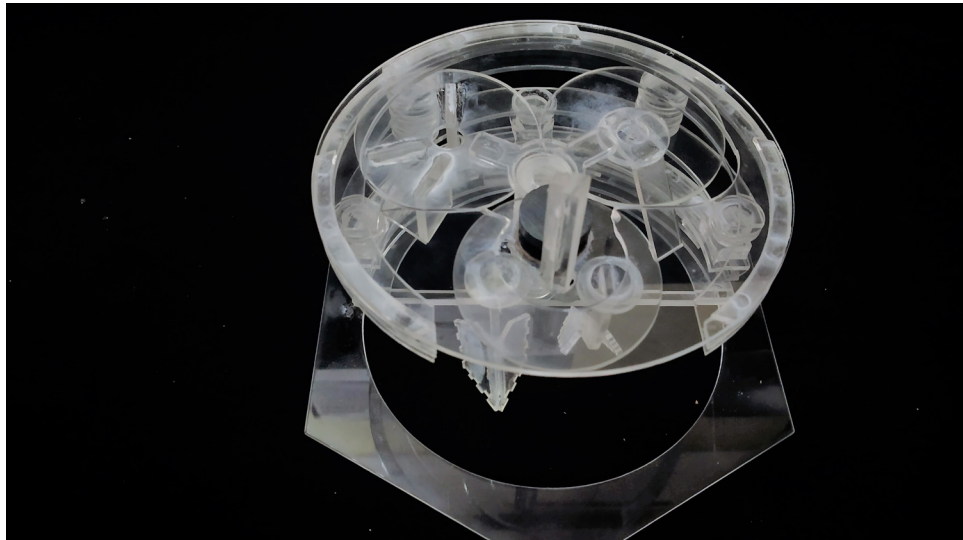
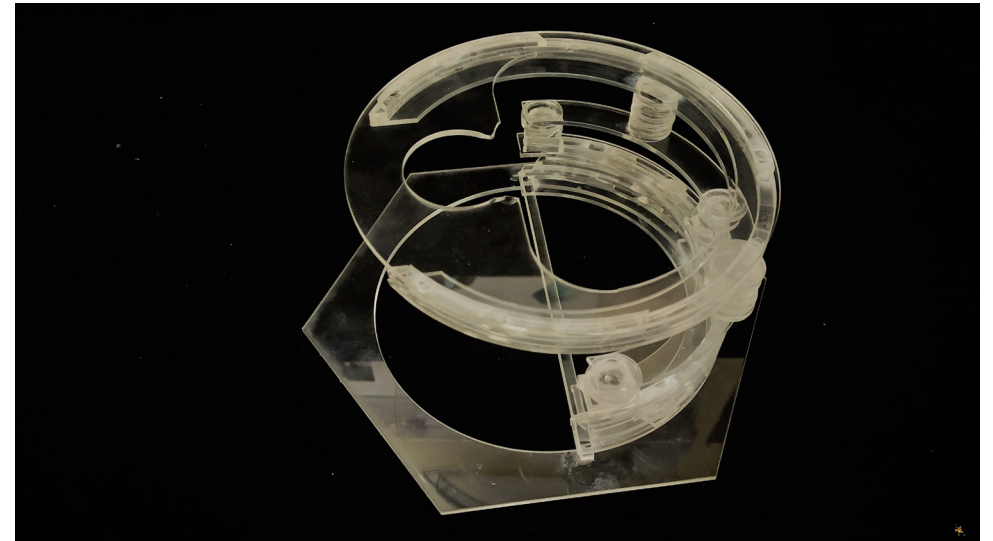
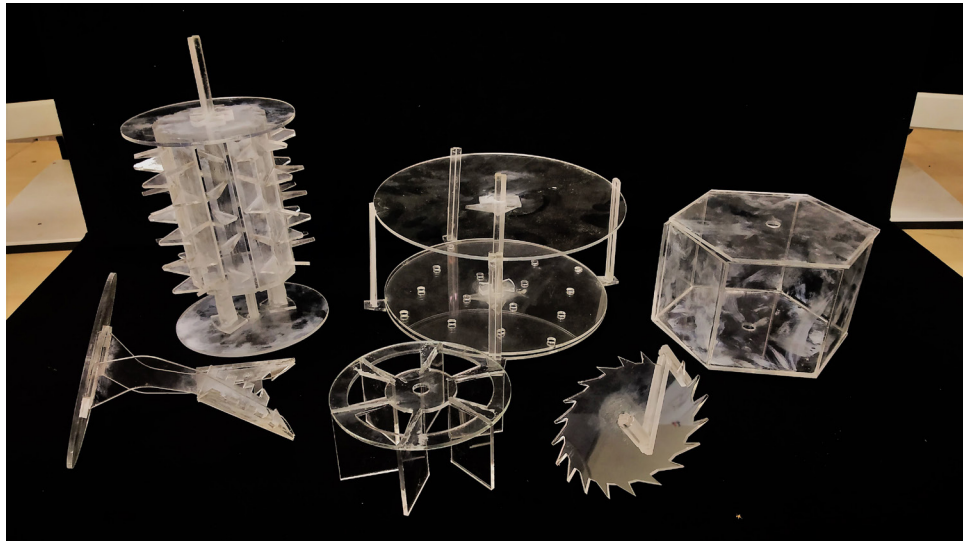
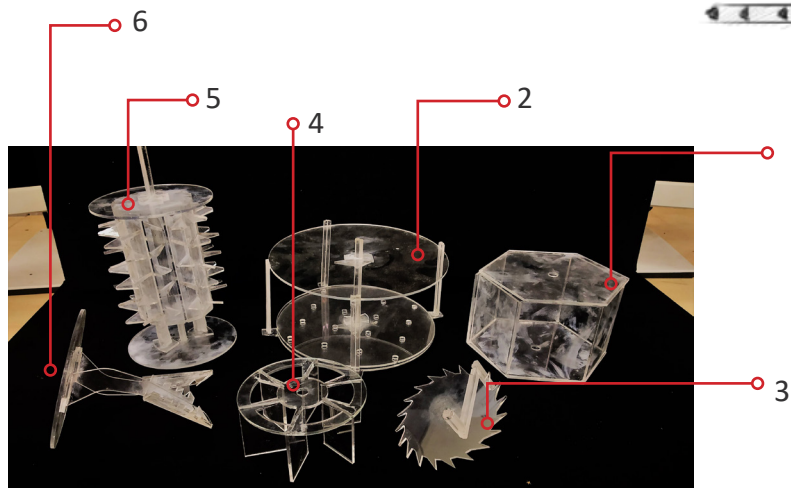
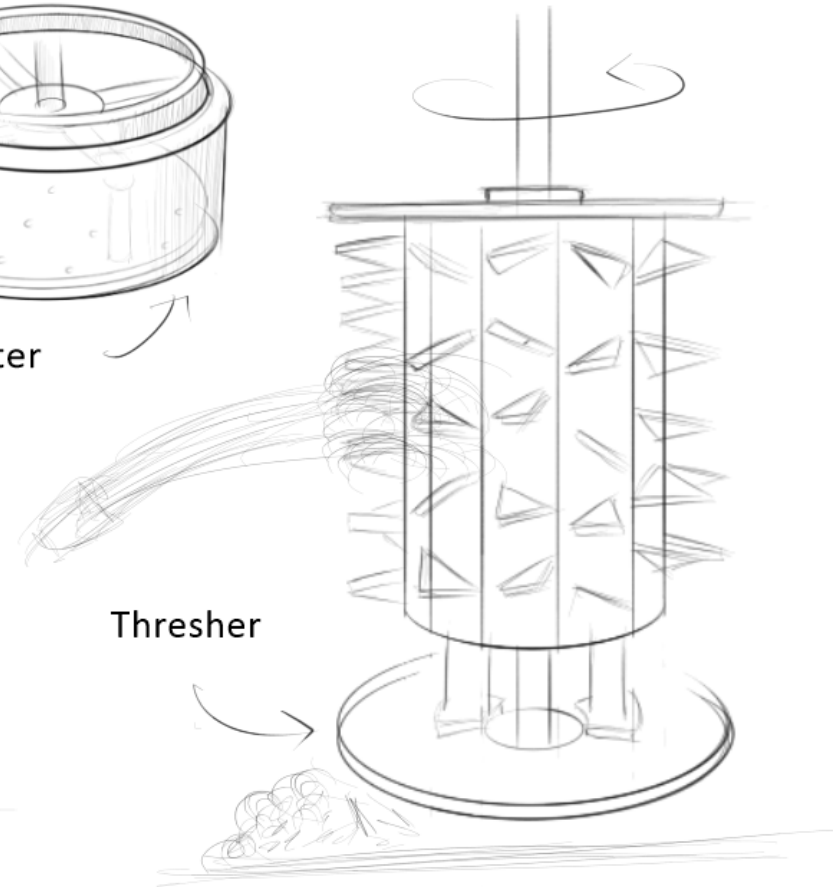
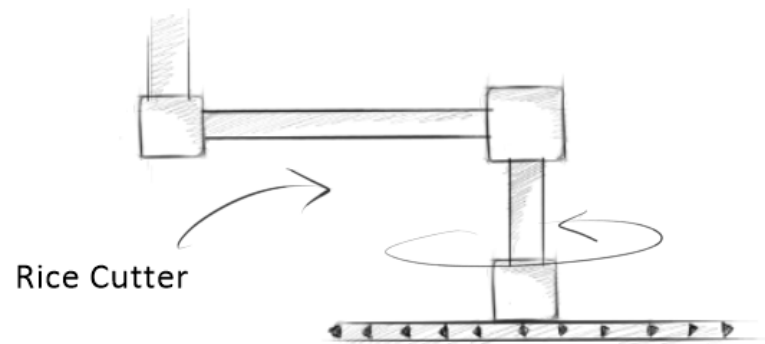
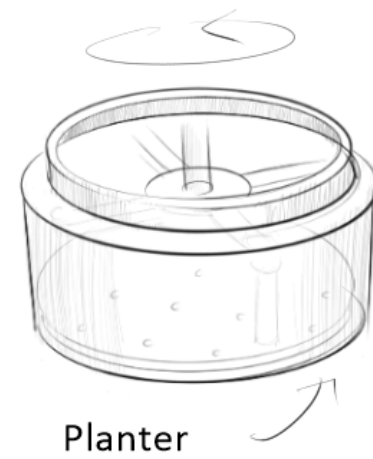
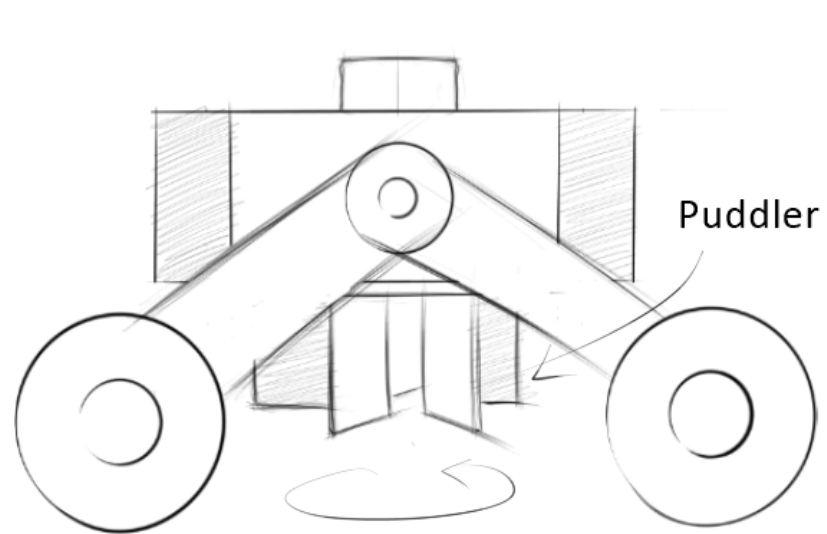


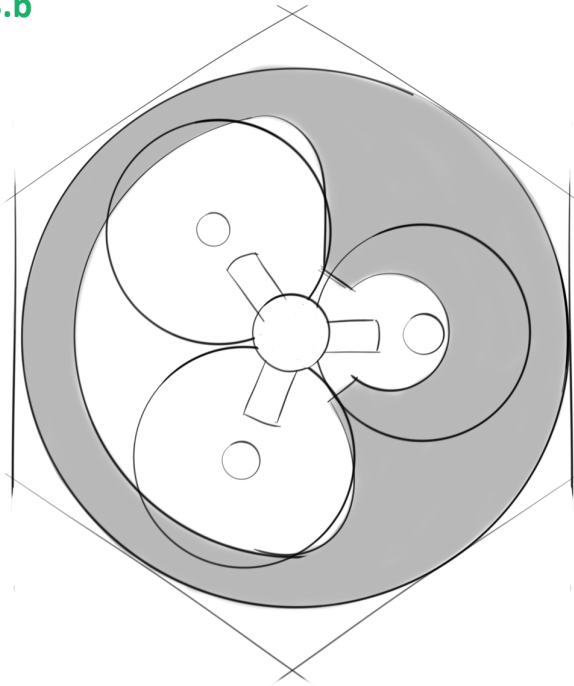
Image 22. Implements for concepts from direction 3



- 1 Power House
- 2 Seed Planter
- 3 Crop cutter
- 4 Puddler
- 5 Thresher
- 6 Plough

Direction 3.b

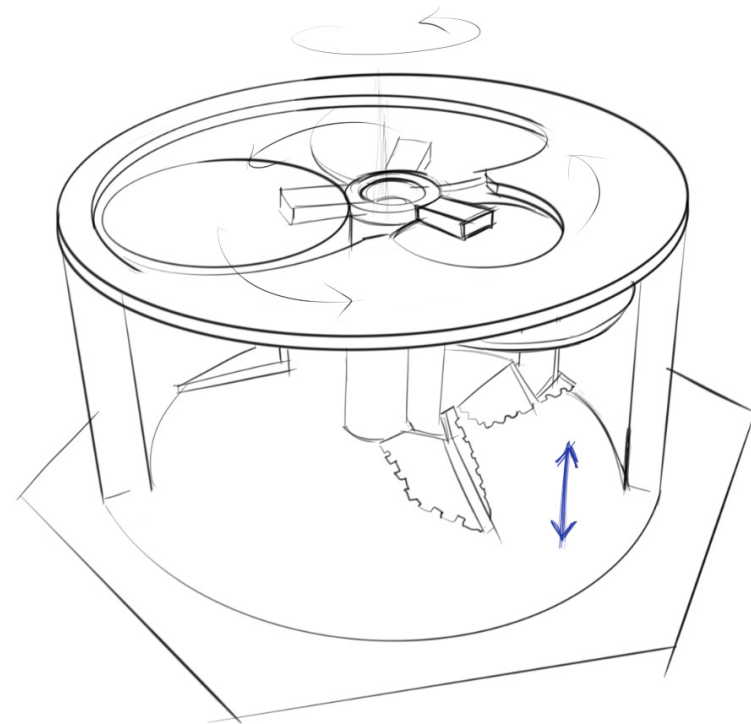
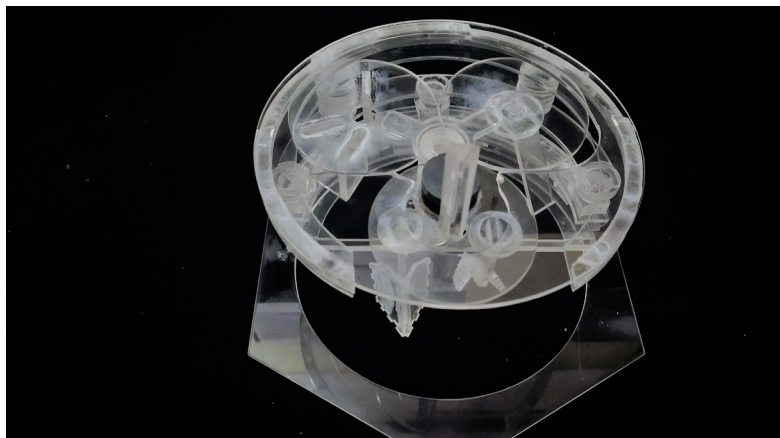
Implement 1

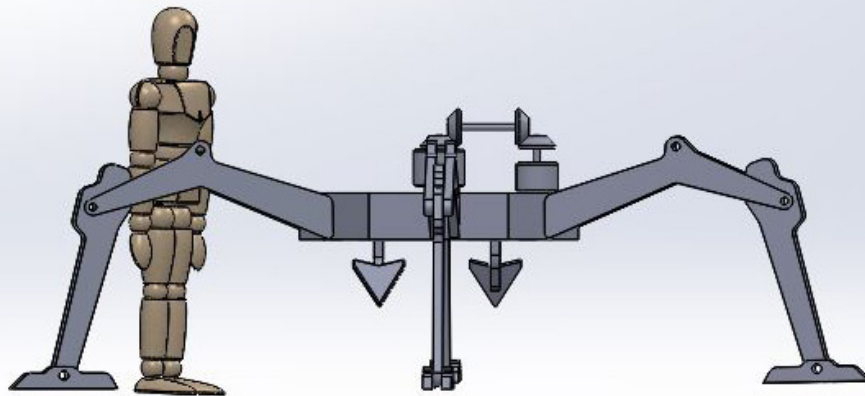


Implement 2

Here the three implements are housed in frame which can be rotate on center axis and can be attached to motor spindle based on operation requirement. This motor goes down by means of hydraulic actuators and provides the vertical feed during an operation.

Implement 3





In this concept the machine is moved using six hydraulic actuated arms. The implement is placed at the center.

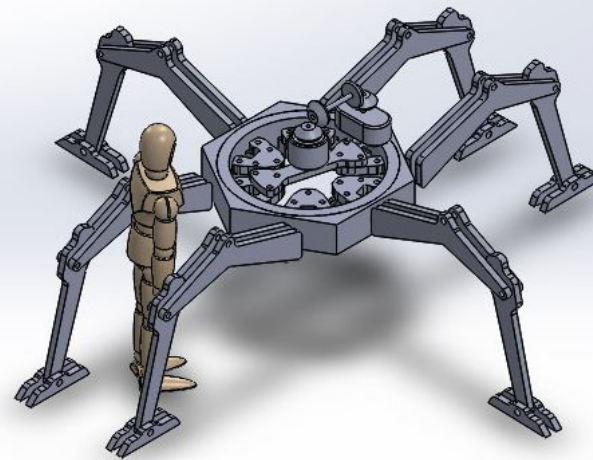
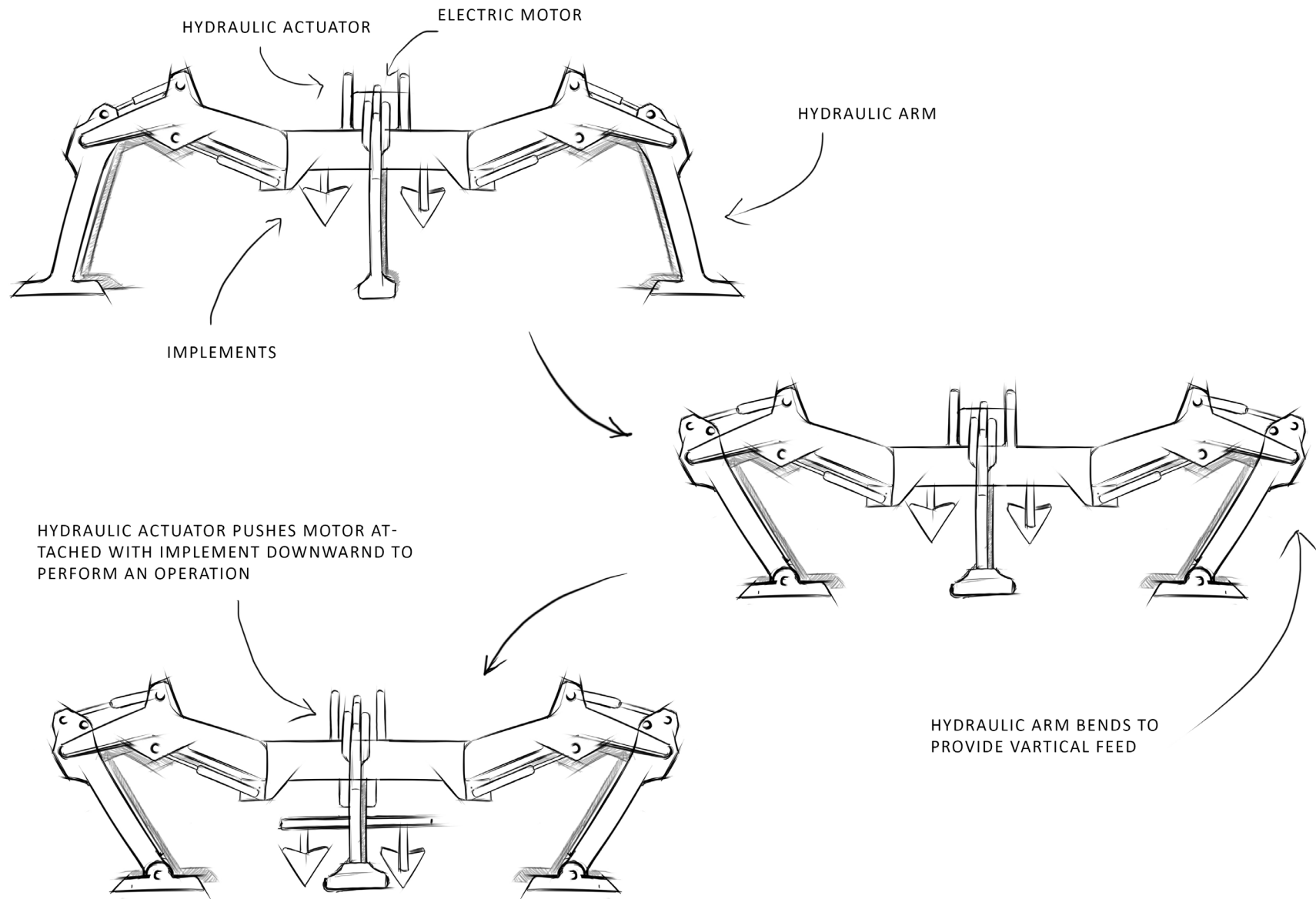
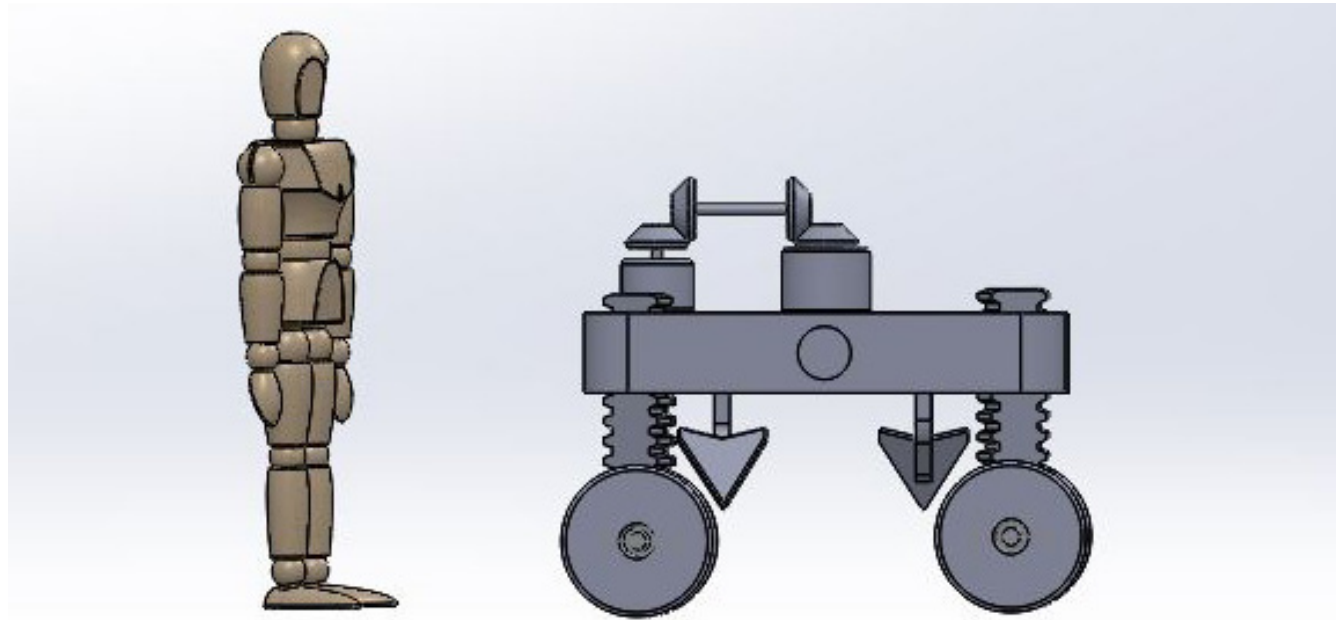


Image 23. Configuration 1





In this concept the machine is moved by hydraulic motors which are equipped at rear tyre. While the motor at front tyres act as steering. Vertical movement of the implement is done by hydraulic actuators attached with electric motor. While the whole implement mechanism can slide over supporting arms to provide feed during operation.

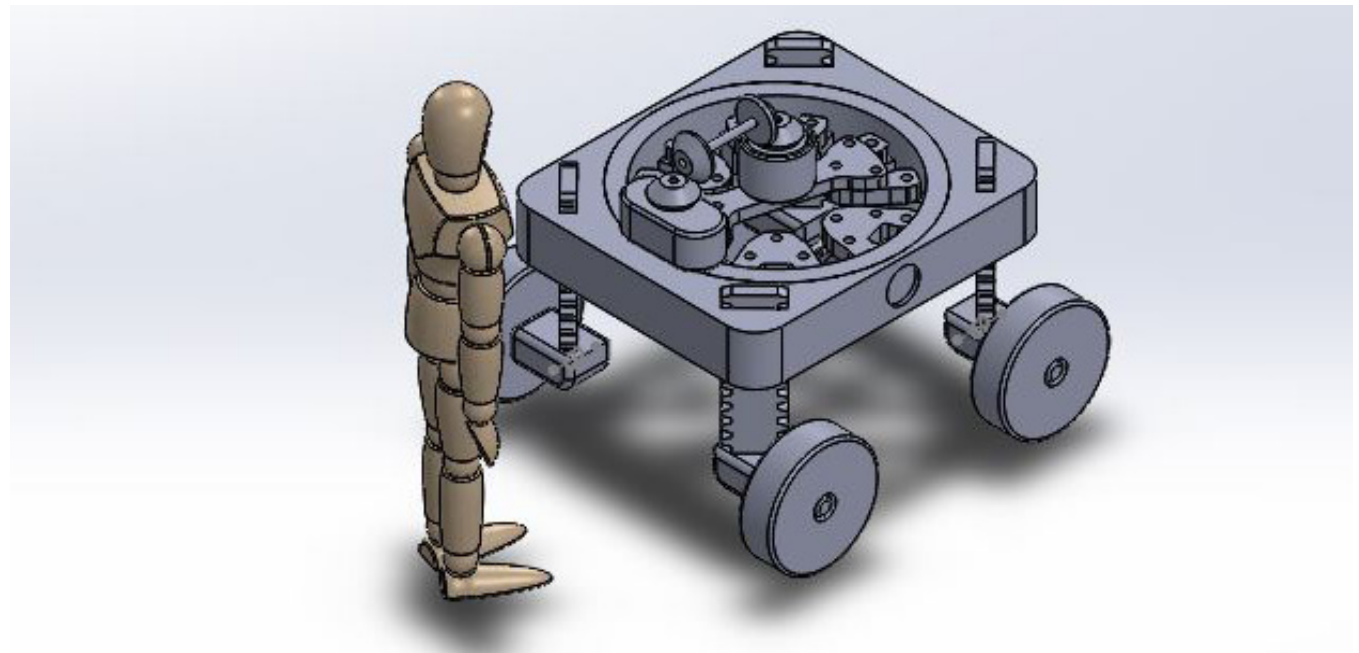
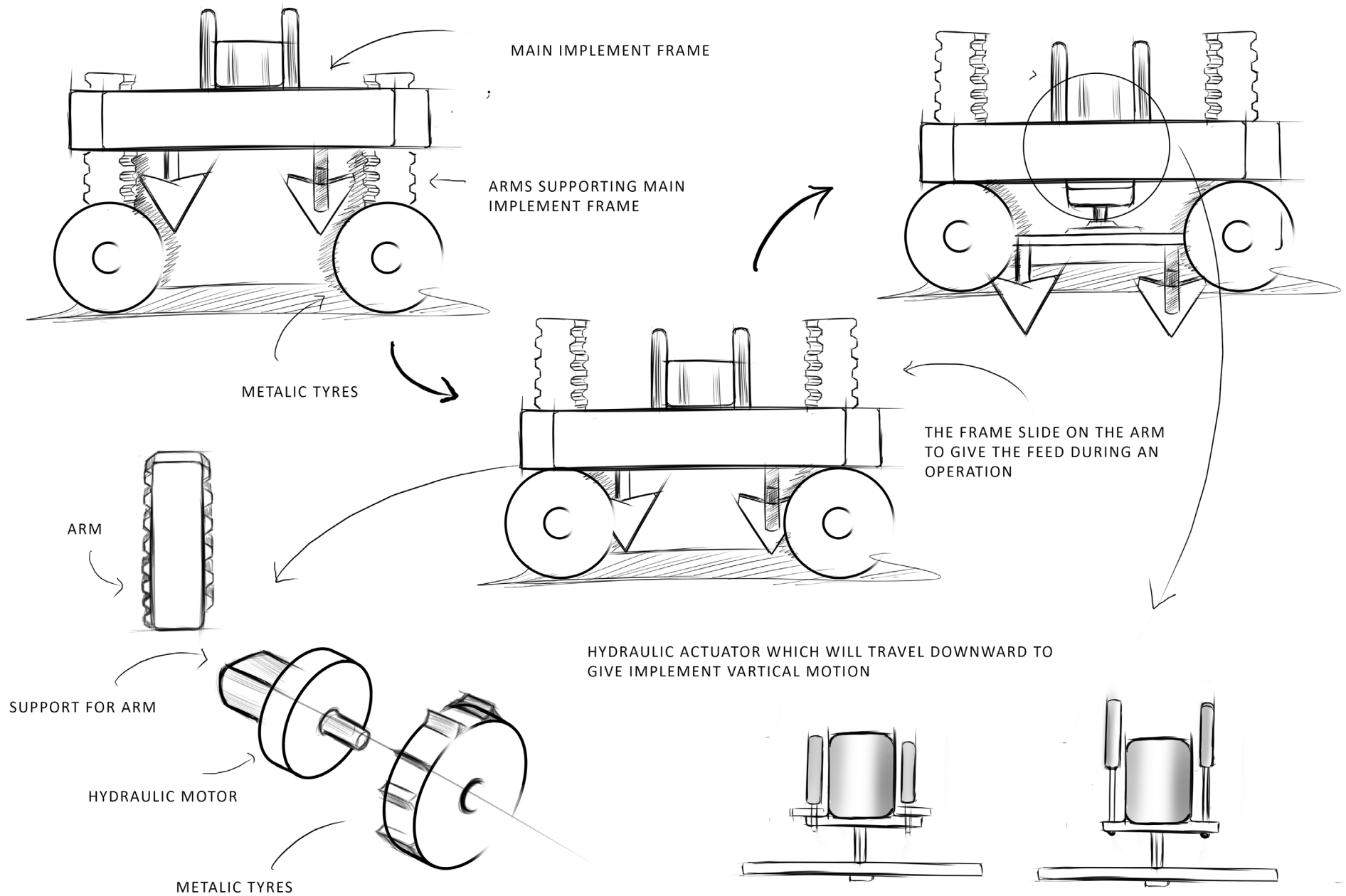
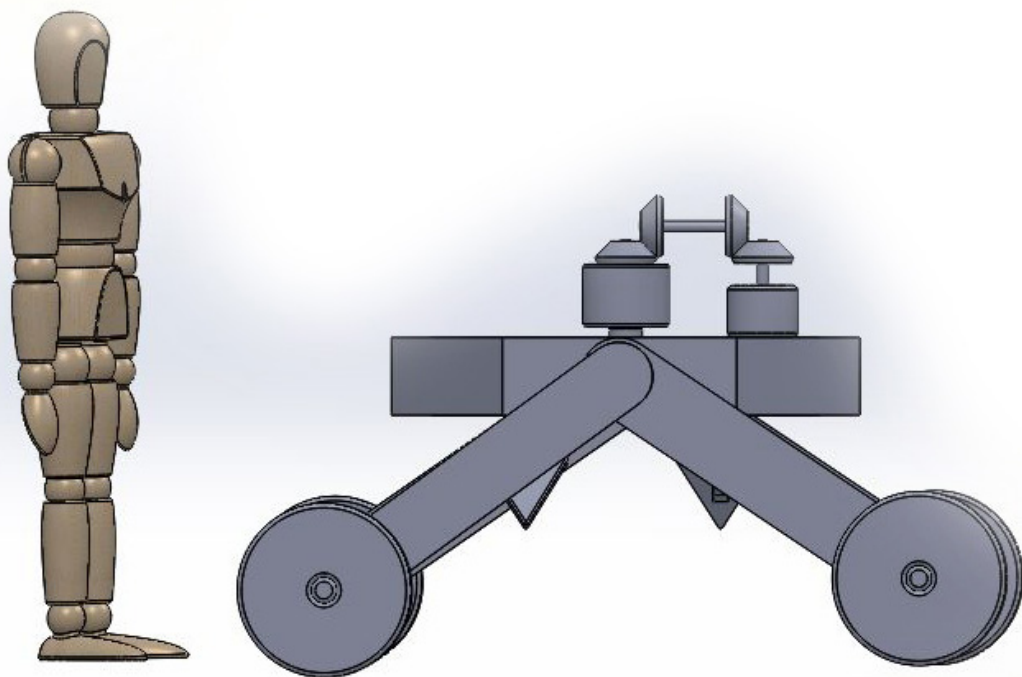


Image 24. Configuration 2





In this concept the machine is moved by hydraulic motors which are equipped at rear tyre. While the motor at front tyres act as steering. Vertical movement of the implement is done by hydraulic actuators attached with electric motor. Here, feed is provided by means of sliding the front and rear wheels apart.

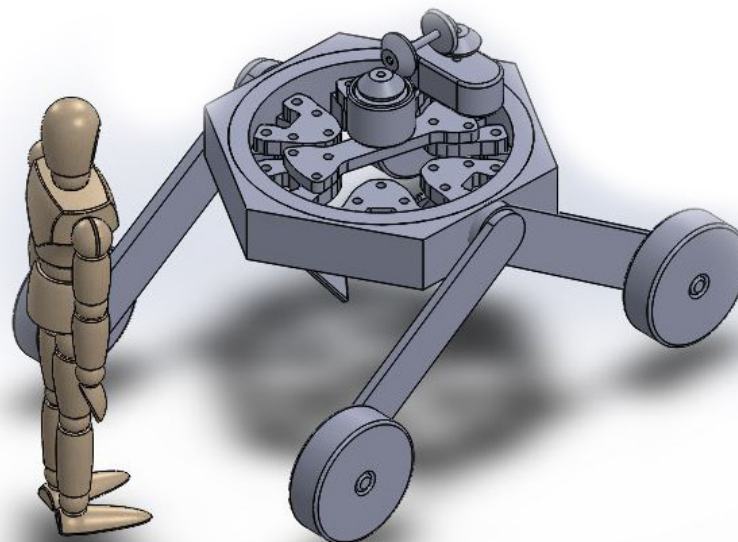
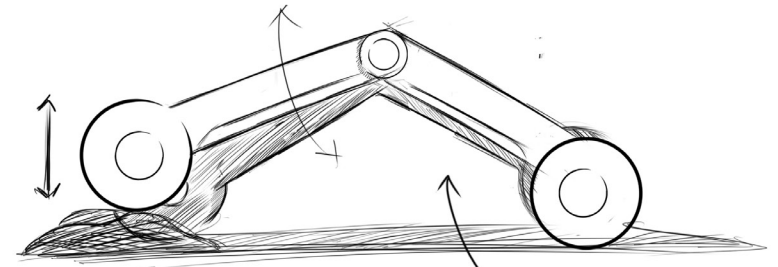
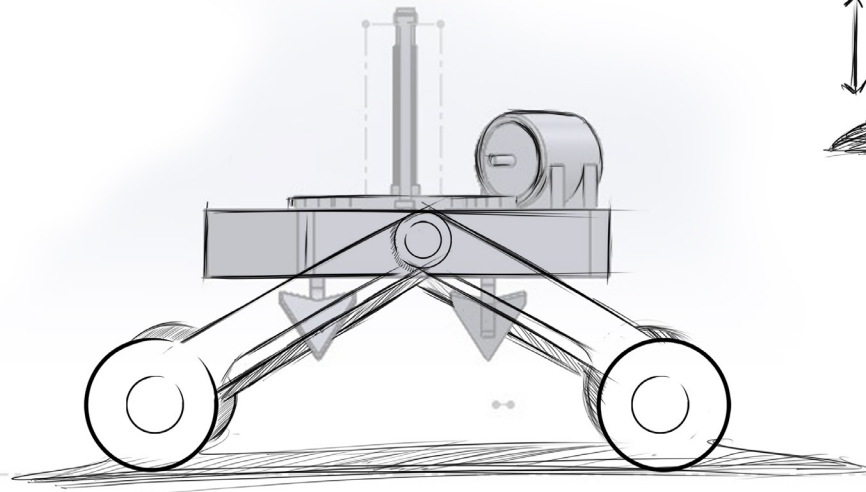
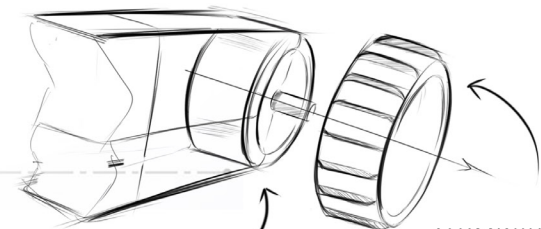


Image 25. Configuration 3

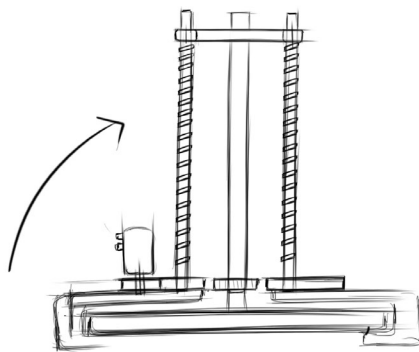


INDEPENDENT WHEEL
ARMS FOR ROUGH
TERRAIN

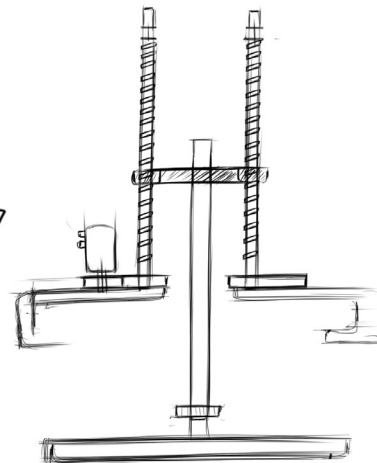


HYDRAULIC MOTOR
POWERED WHEEL

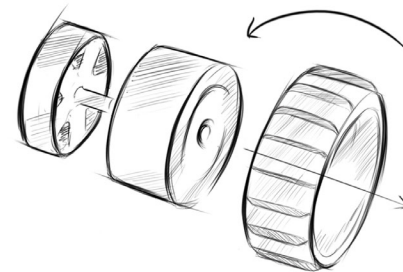
ALUMINIUM WHEEL
FOR MORE TRACTION



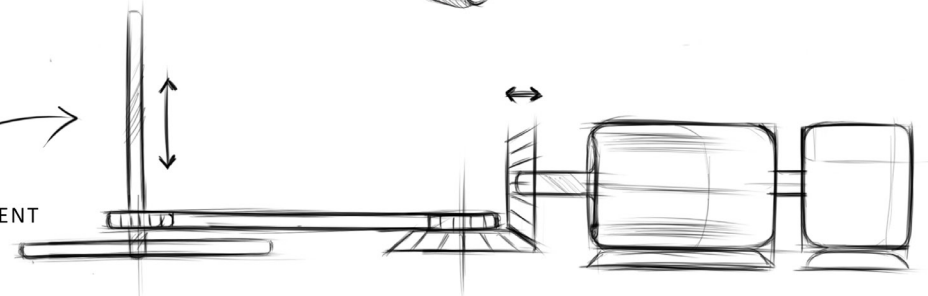
HYDRAULIC MOTOR DRIVEN VERTICAL
MOVEMENT OF IMPLEMENT SHAFT

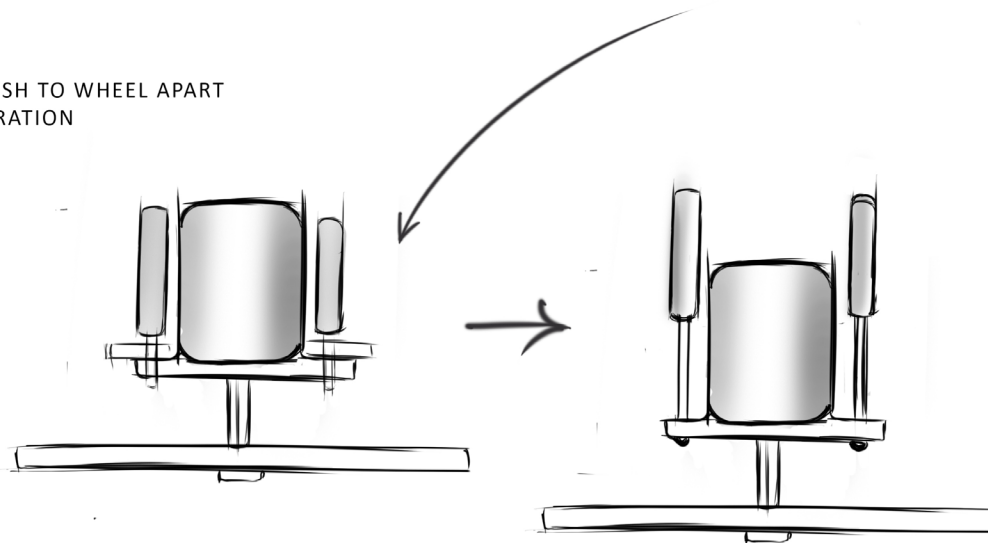
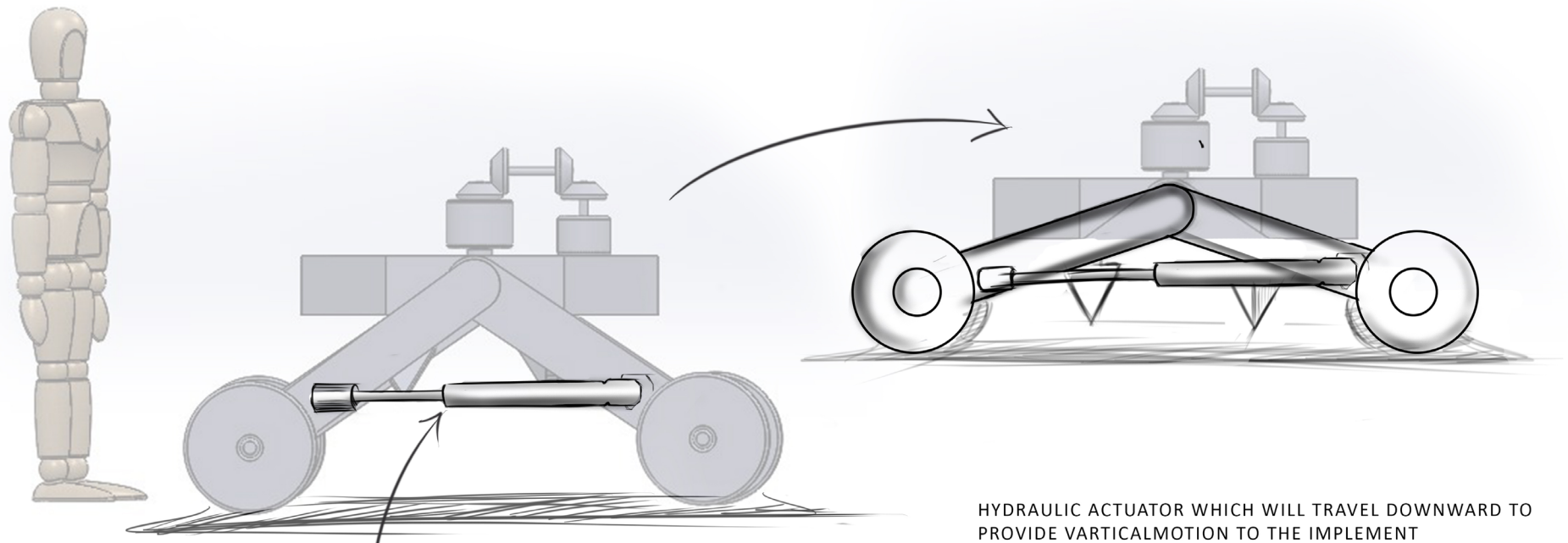


ELECTRIC MOTOTR DRIVE FOR IMPLEMENT
AND HYDRAULIC UNIT TO RUN



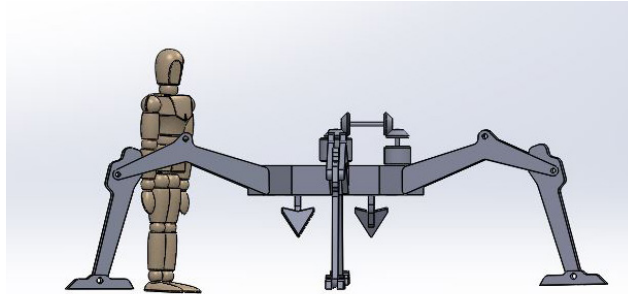
ELECTRIC MOTOR
POWERED WHEEL



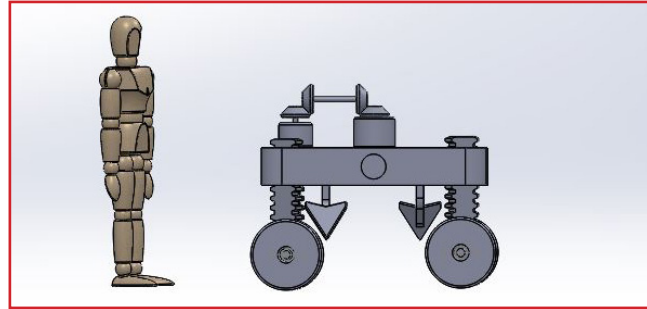


Comparison Chart

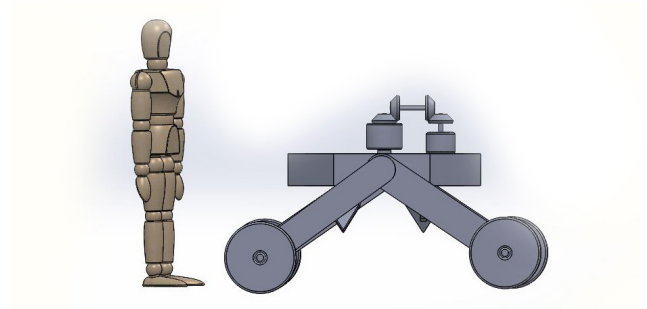
All the three concepts were evaluated based on various factors like, maneuverability, overall weight (dimension), speed of one operation cycle, maintenance and cost of the machine. Scale of particular factor for any concept was given based on comparing that concept with other two.



Concept 1



Concept 2



Concept 3

Maneuverability (Steer: Easy, In Corner: Difficult)

This concept uses six hydraulic arms to move. It is difficult to perform an operation at the edges with these arms. On the other side steering becomes easy here since these arms can move in any direction without having steering mechanism. The overall dimensions of the concept varies during steering and operation.

Maneuverability (Steer: Moderate: In corner: Easy)

The overall machine is very compact in nature and vertical feed of the implement is done by sliding over a support arms. Further, the overall length of the machine remain constant through out the operation which makes it easy to perform in corner or at edges. While the steering happens using hydraulic link at the front wheel.

Maneuverability (Steer, In corner: Moderate)

To give the vertical feed of the implement, the wheel base increases by sliding front and rear wheels apart, which increases its overall length during performing an operation. While at corner and edges increasing wheel might be difficult. Also, when wheel base increases the overall turning radius of the vehicle also increase.

Overall Weight (Very Heavy)

Overall Weight (Moderate)

Overall Weight (Moderate)

Speed of one operation (Slow)

Here vertical motion is motion is provided by manipulating arms using hydraulic actuator and the horizontal movement is also done using the same arms. Because of that two movement can not be perform simultaneously and overall time for one operation cycle increase.

Speed of one operation (Fast)

The vertical motion is done by means of supporting arms while horizontal movement happens by tyres run. The vertical and horizontal movement are independent to each other which speeds up the operation cycle.

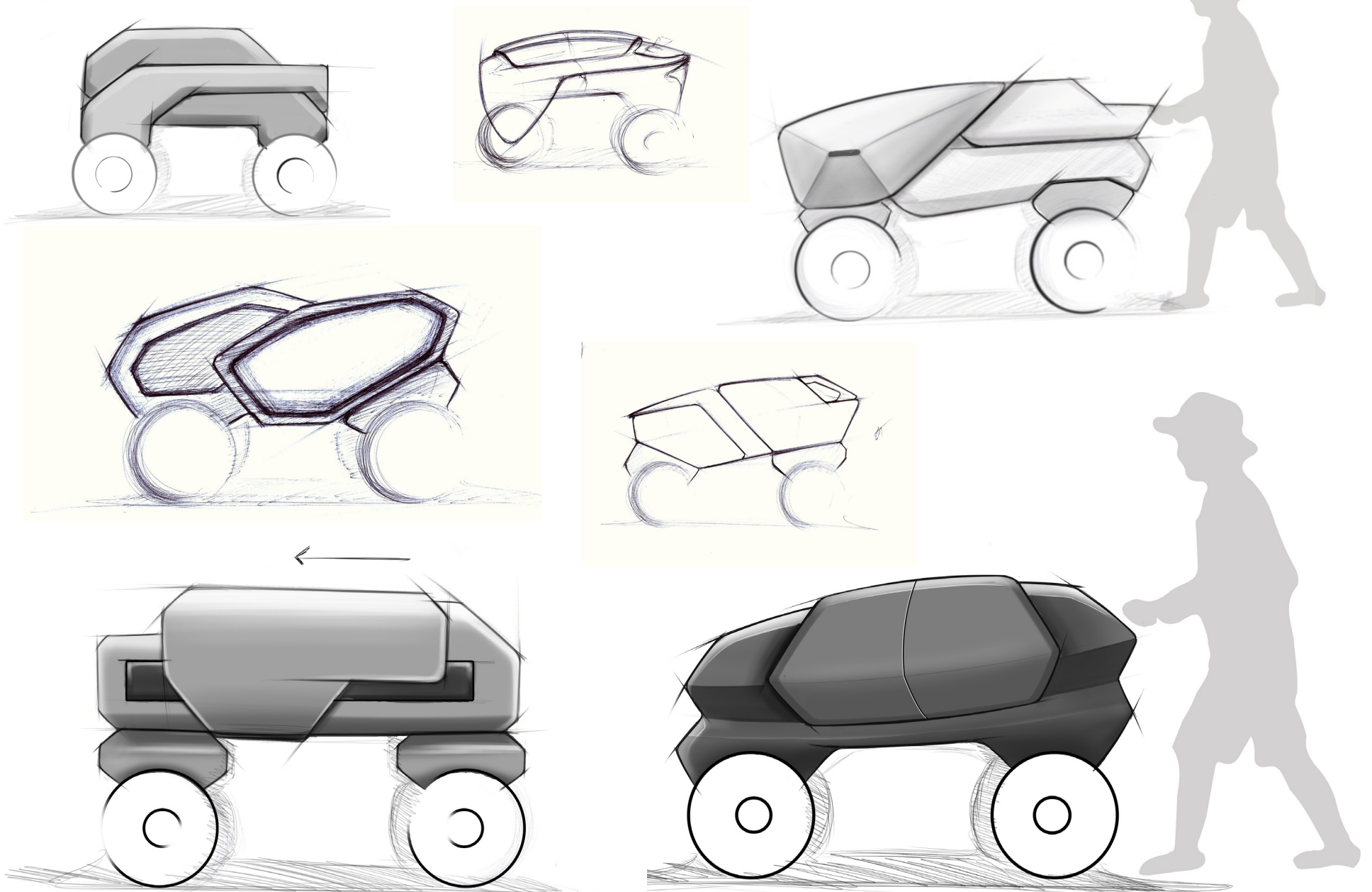
Speed of one operation (Moderate)

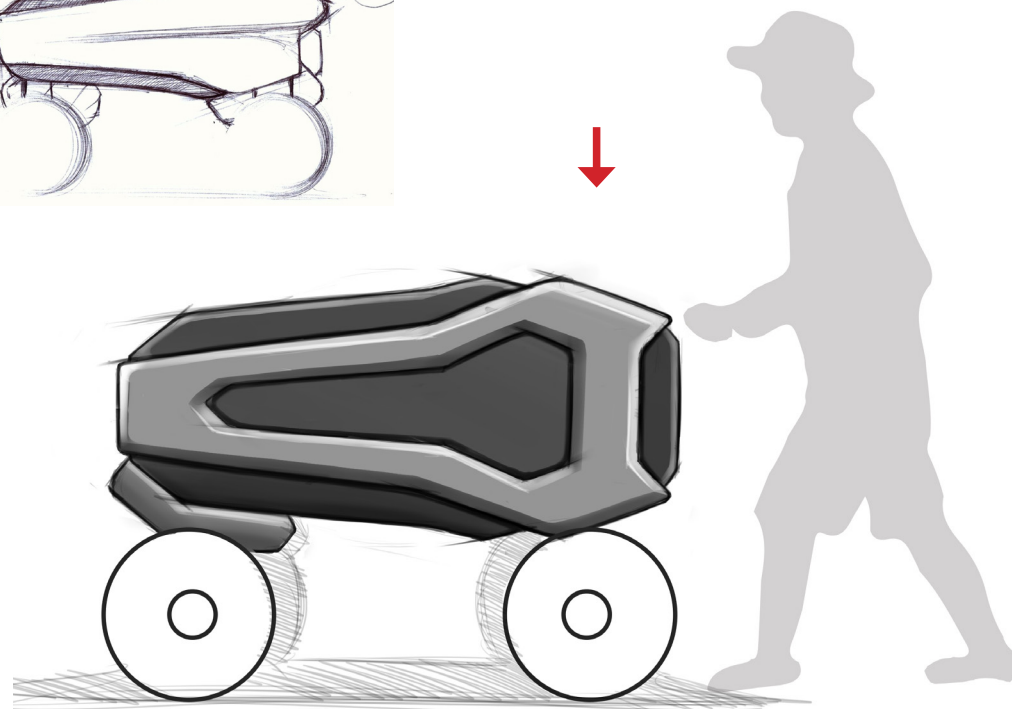
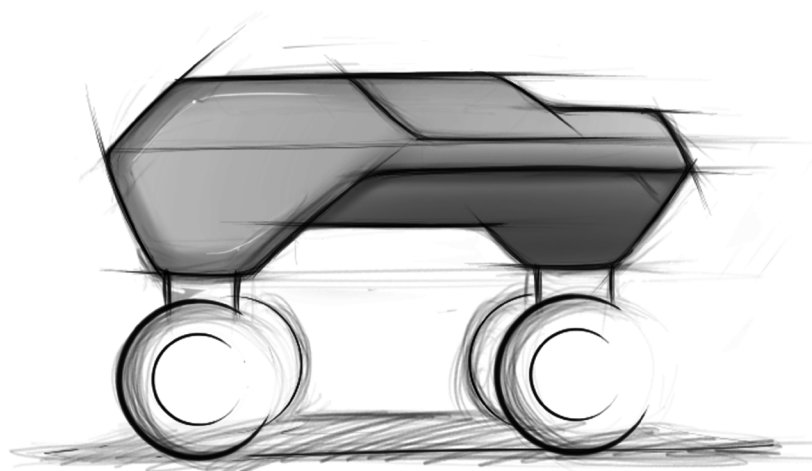
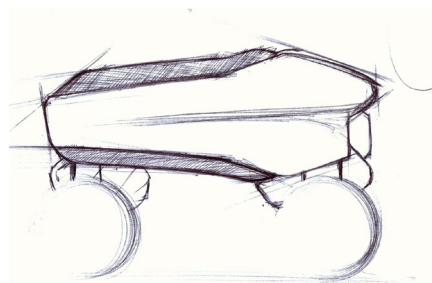
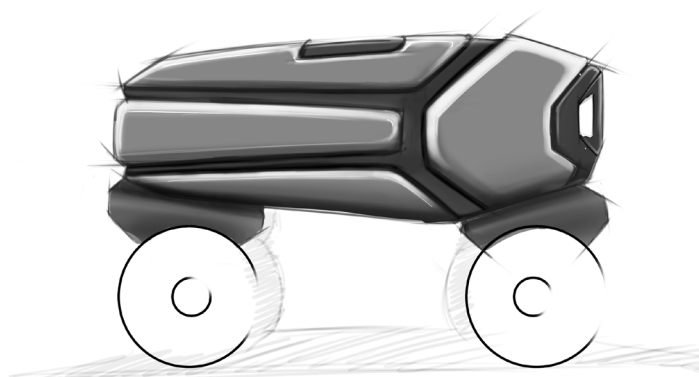
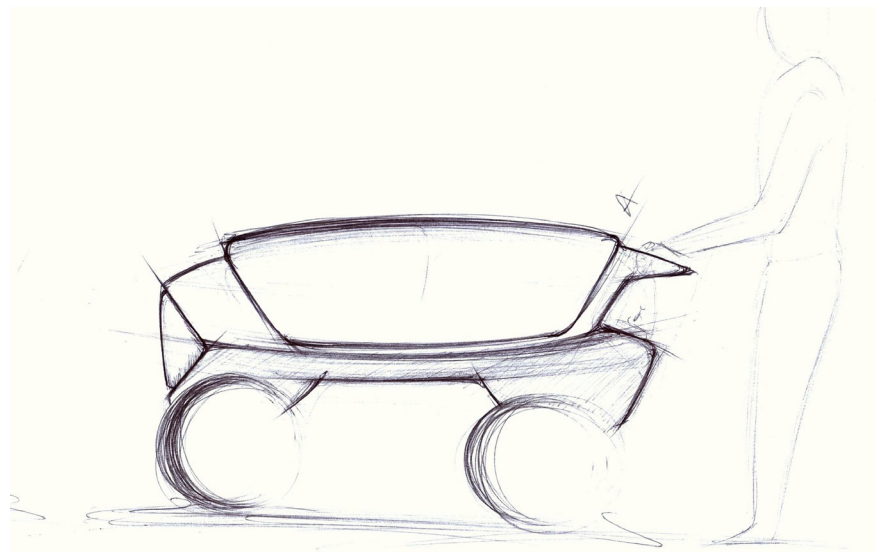
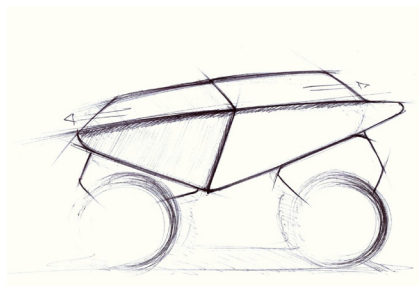
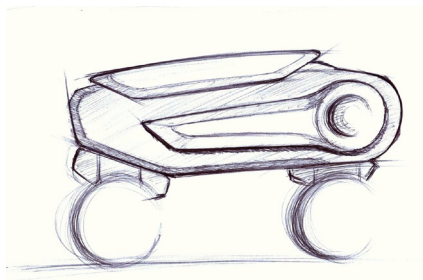
The vertical motion is done by means of supporting arms while horizontal movement happens by tyres run. The vertical and horizontal movement are independent to each other which speeds up the operation cycle.

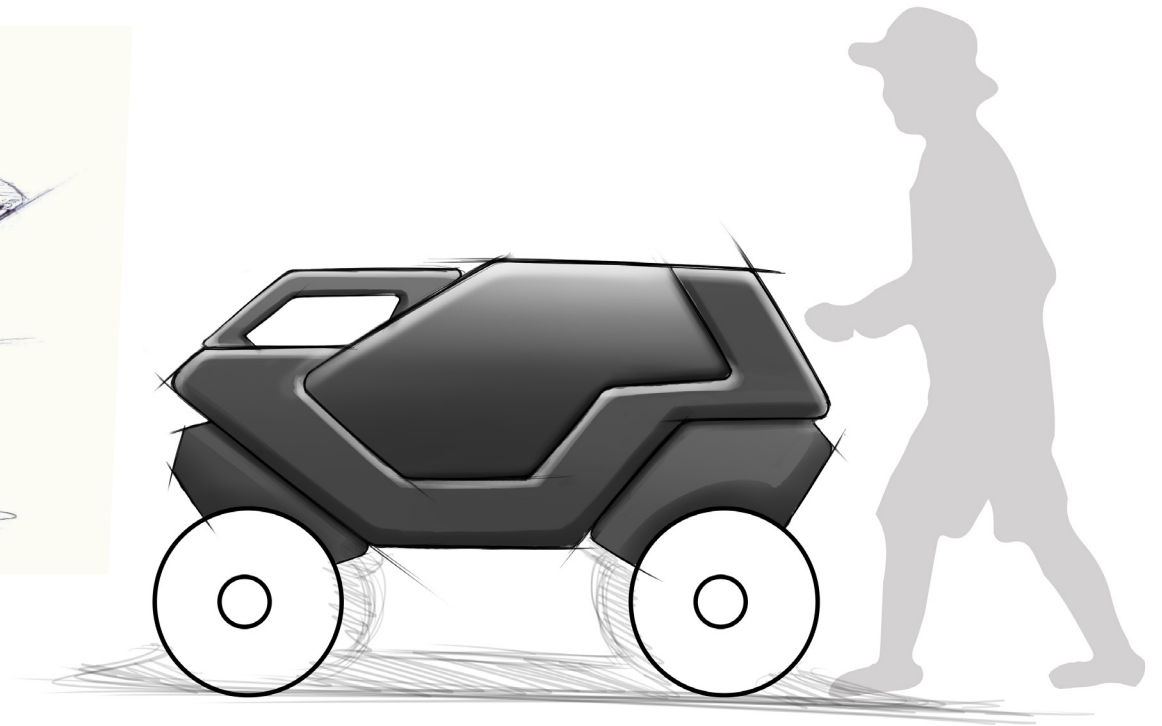
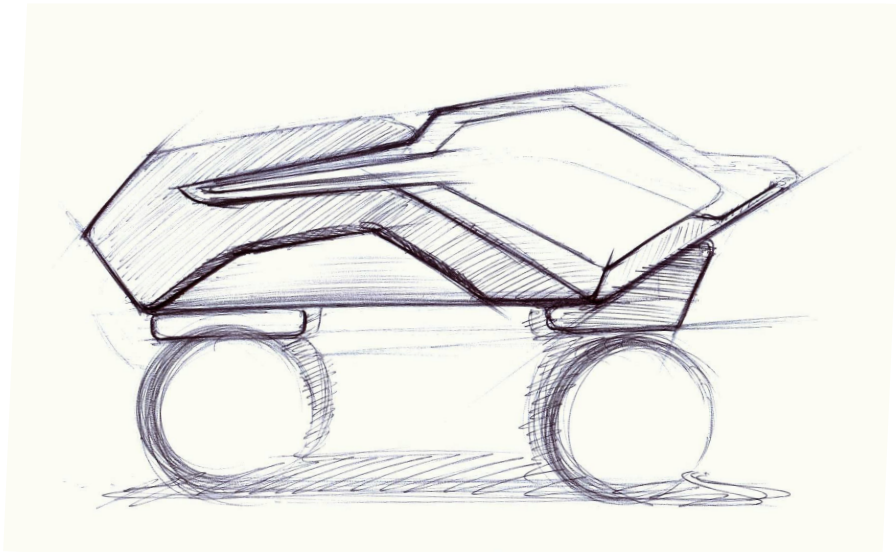
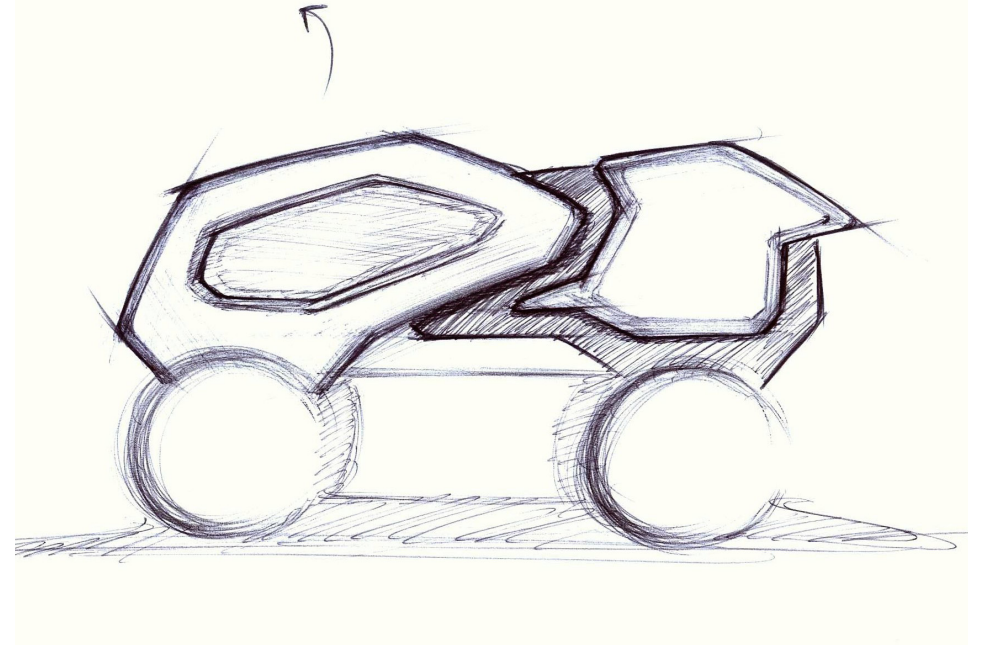
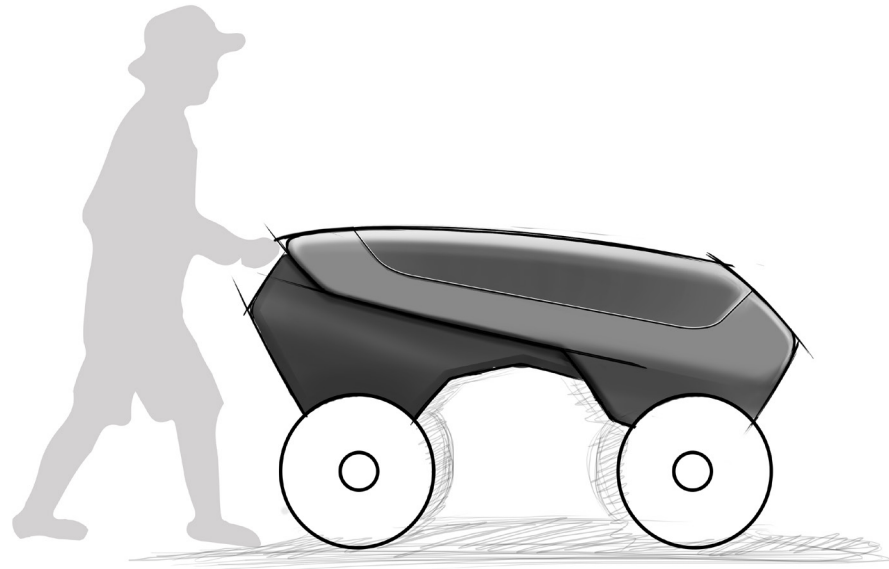
Concept 1	Concept 2	Concept 3
Cost of machine (Very Expensive) It has more number of parts and complex driving mechanism so the overall cost is high. Number of Parts: Electric motor (1), Hydraulic Actuator to drive (6), Hydraulic actuator to give vertical motion to implements (2), Hydraulic pump (1), Battery pack and Implement mechanism which is common for all concepts (1)	Cost of machine (Moderate) Concept 2 and 3 both as almost equal number of parts and the driving mechanism which makes them less expensive than concept 1 Number of Parts: Electric motor (1), hydraulic motor to drive and steer (4), Hydraulic actuator to give vertical motion to implements (2), Supporting arms mechanism (1), Battery pack and Implement mechanism which is common for all concepts (1)	

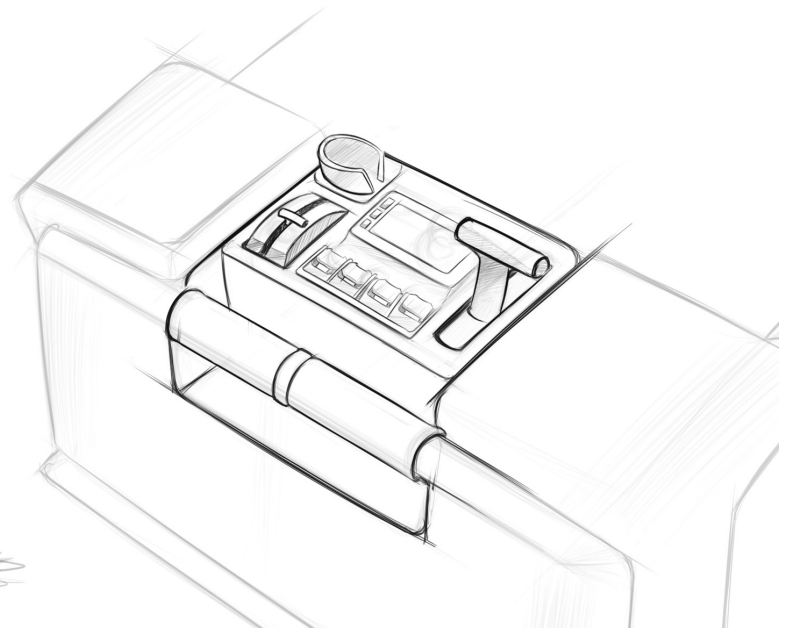
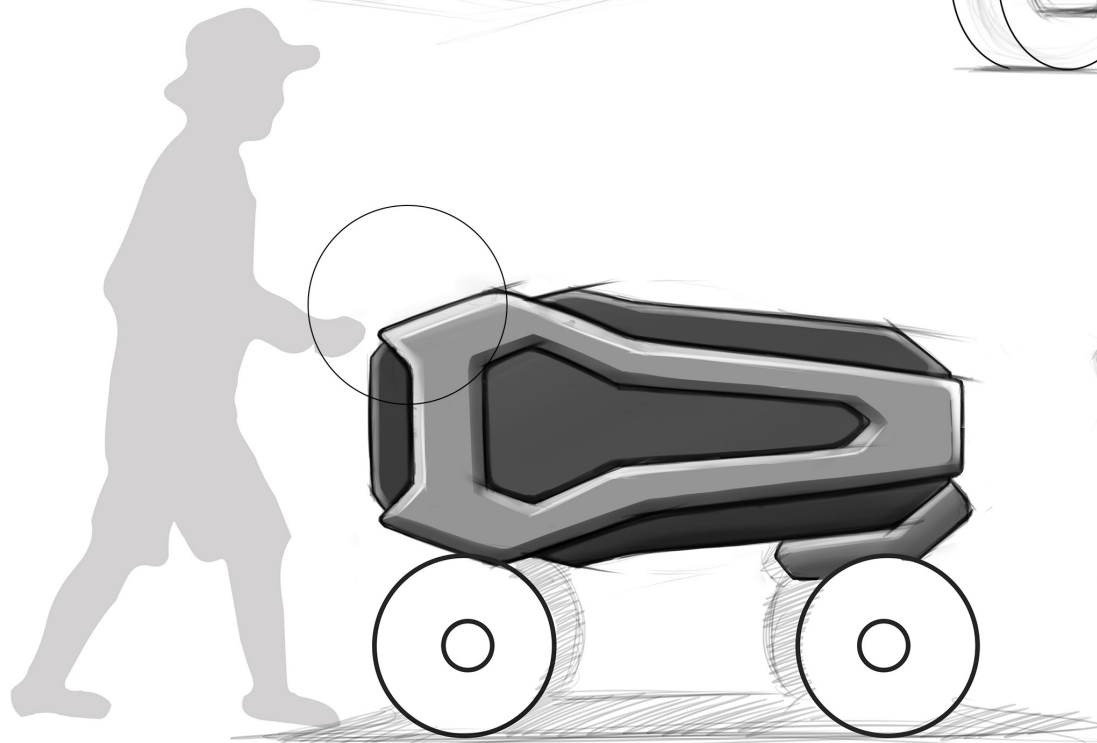
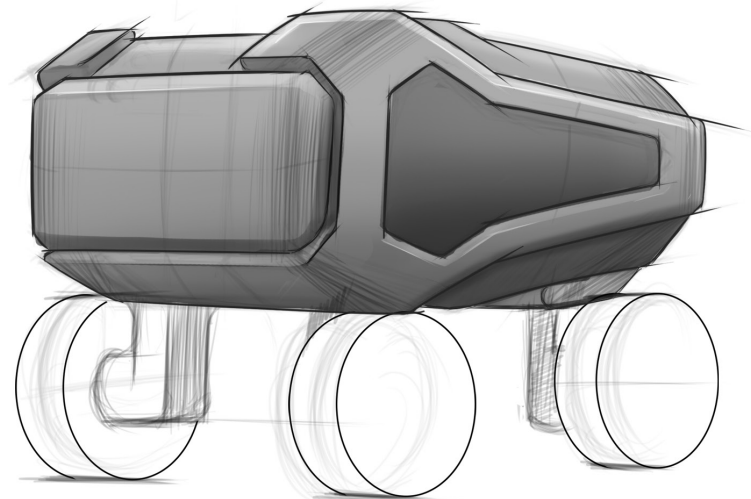
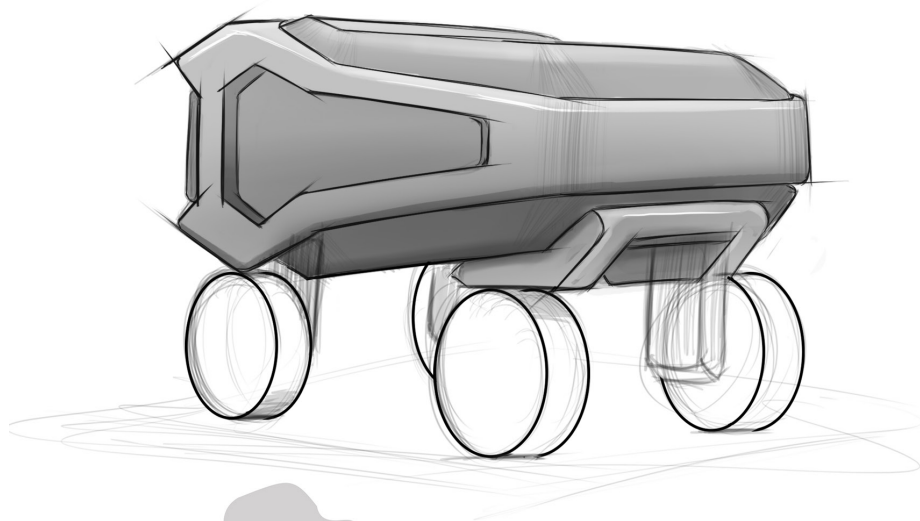
Direction 3.a and 3.b was not selected since it may increase the overall dimension of the vehicle. Further, based on comparison chart concept 2 was selected as final concept and developed further.

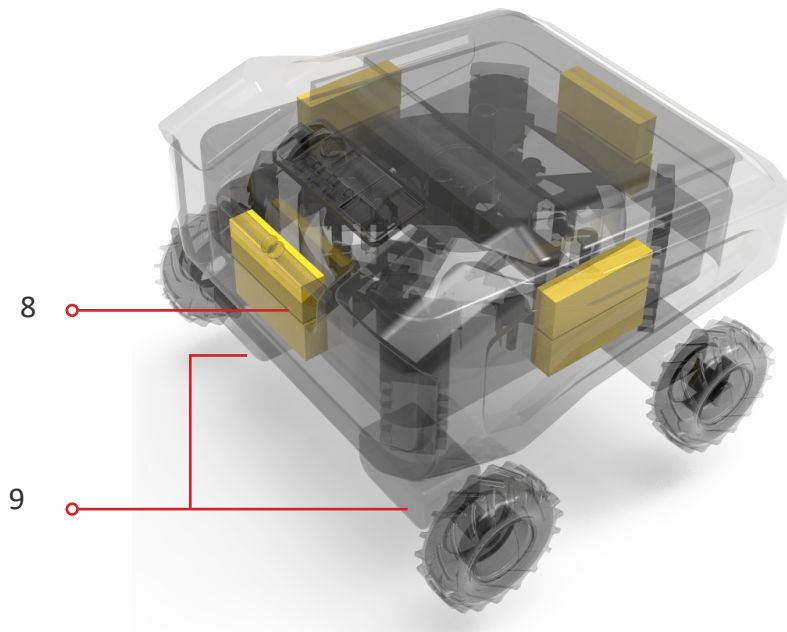
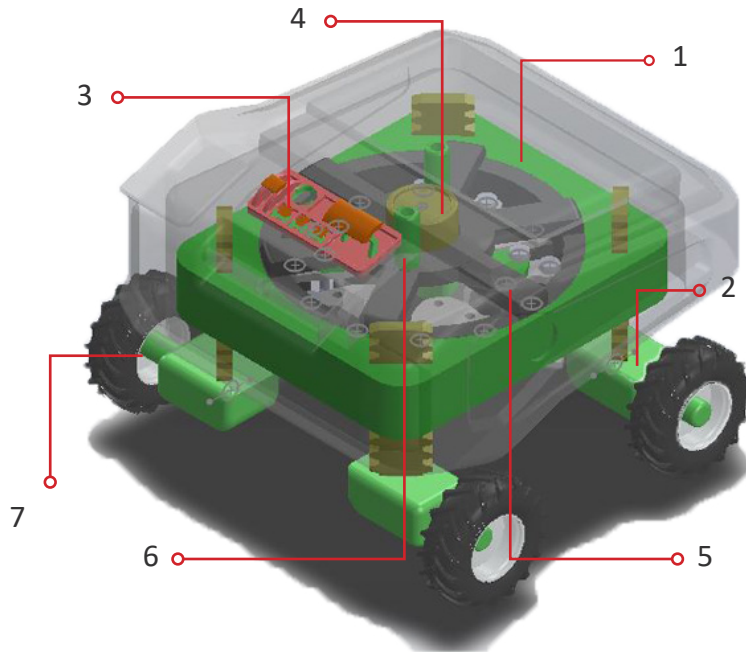
Form Ideation











Power House:

Implement Power: 3 kw electric motor

Driving Power: 2 kw electric motor

Steering, Linear actuator, vertical feed power: 1 kw electric motor

Overall power required: 6 kw

Battery pack: Lithium Ion (24 V / 200 Ah)

Total battery run time: 2 to 3 hr

Overall:

Length: 130 cm

Width: 110 cm

Operation Width: 80 cm

Height: 100 cm

Handle Height: 85 cm

Ground Clearance: 20 cm

Speed: 10 to 15 kmph

1. Main frame with vertical feed mechanism

2. Steering Mechanism

3. Control Panel

4. Electric Motor for implement

5. Implement Holder

6. Linear Actuator

7. Hub motor at rear wheel

8. Battery Packs

9. Backup Battery Packs

I. Forward, Reverse, Neutral throttle

II. Steering switch

III. Kill Switch

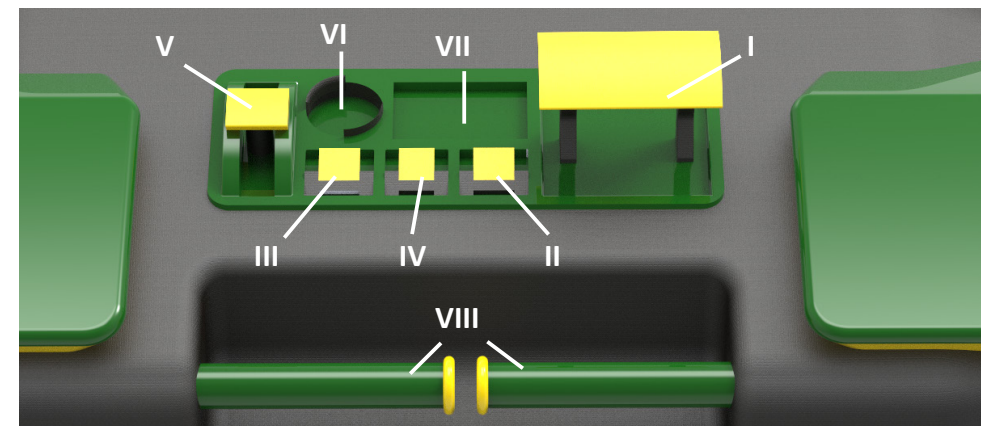
IV: Implement change switch

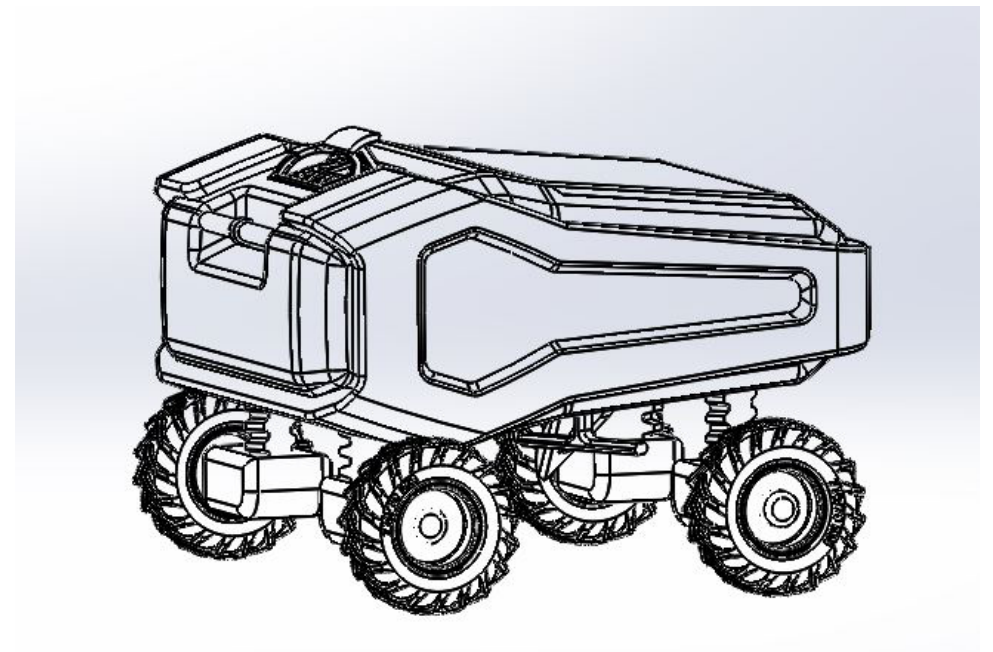
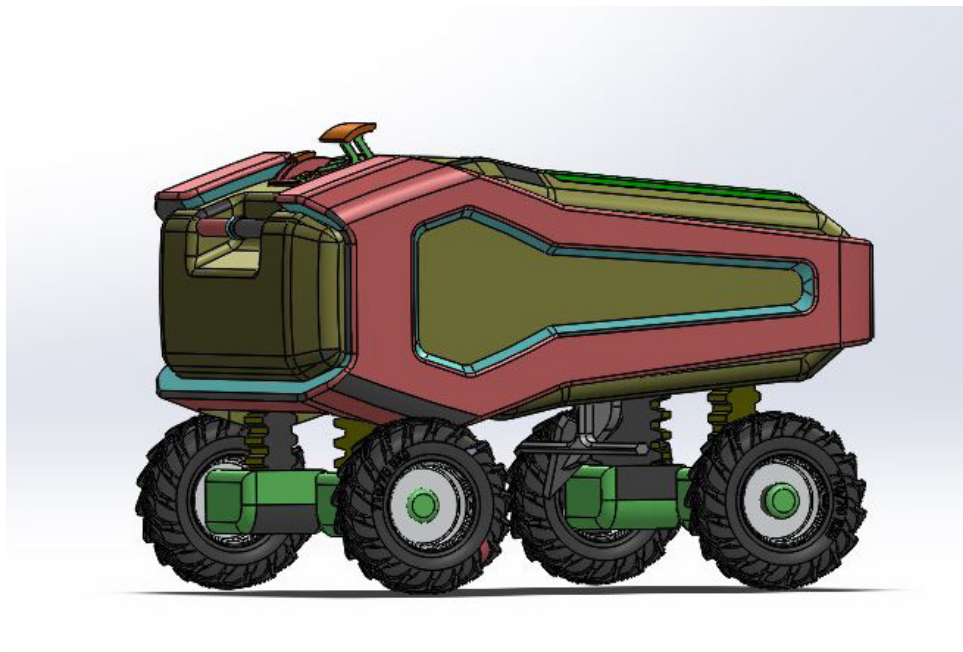
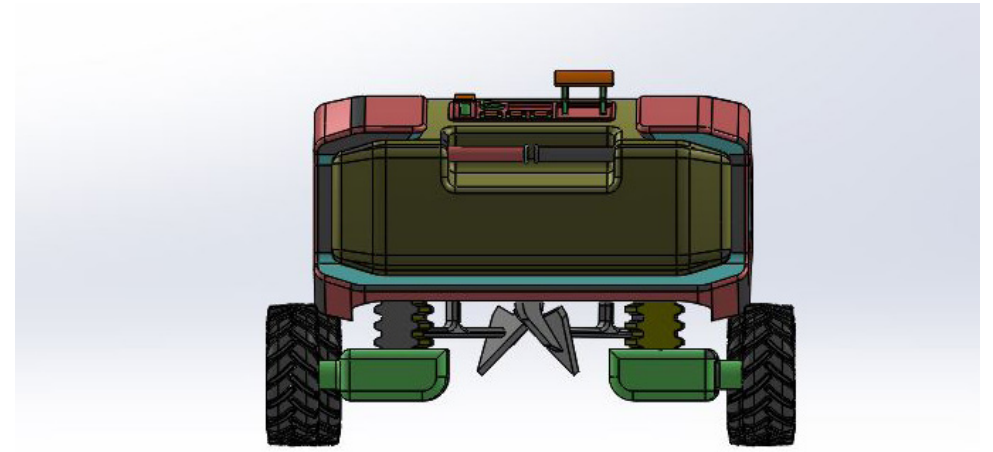
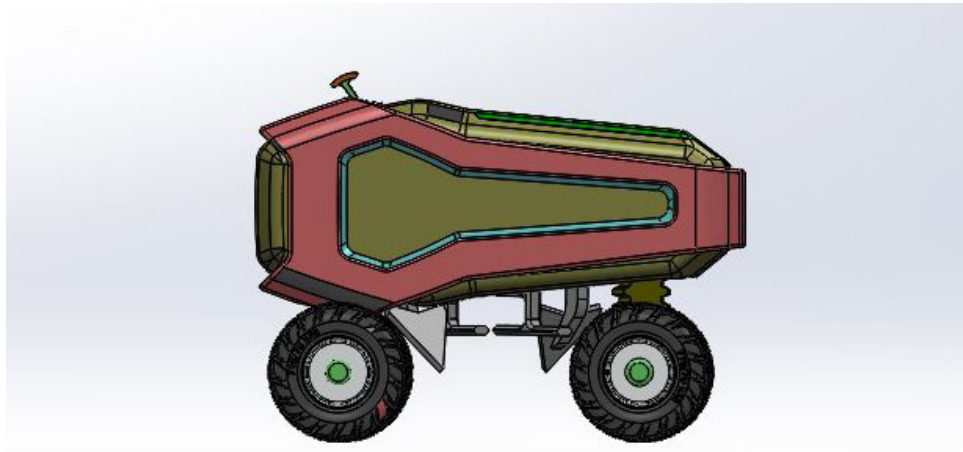
V: Implement handling throttle

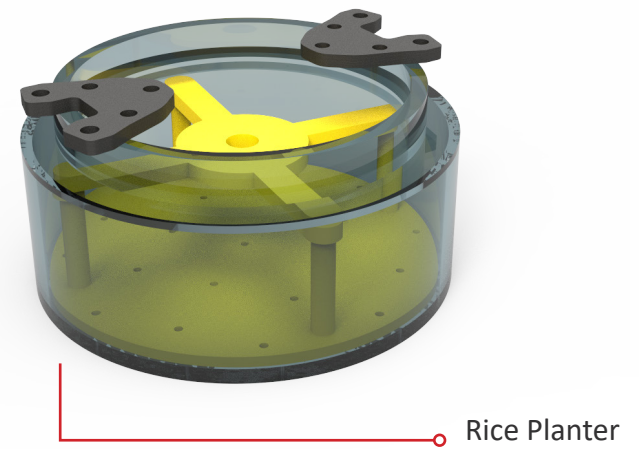
VI: Bottle Holder

VII: Information Display Holder

VIII: Steering control cum Handle





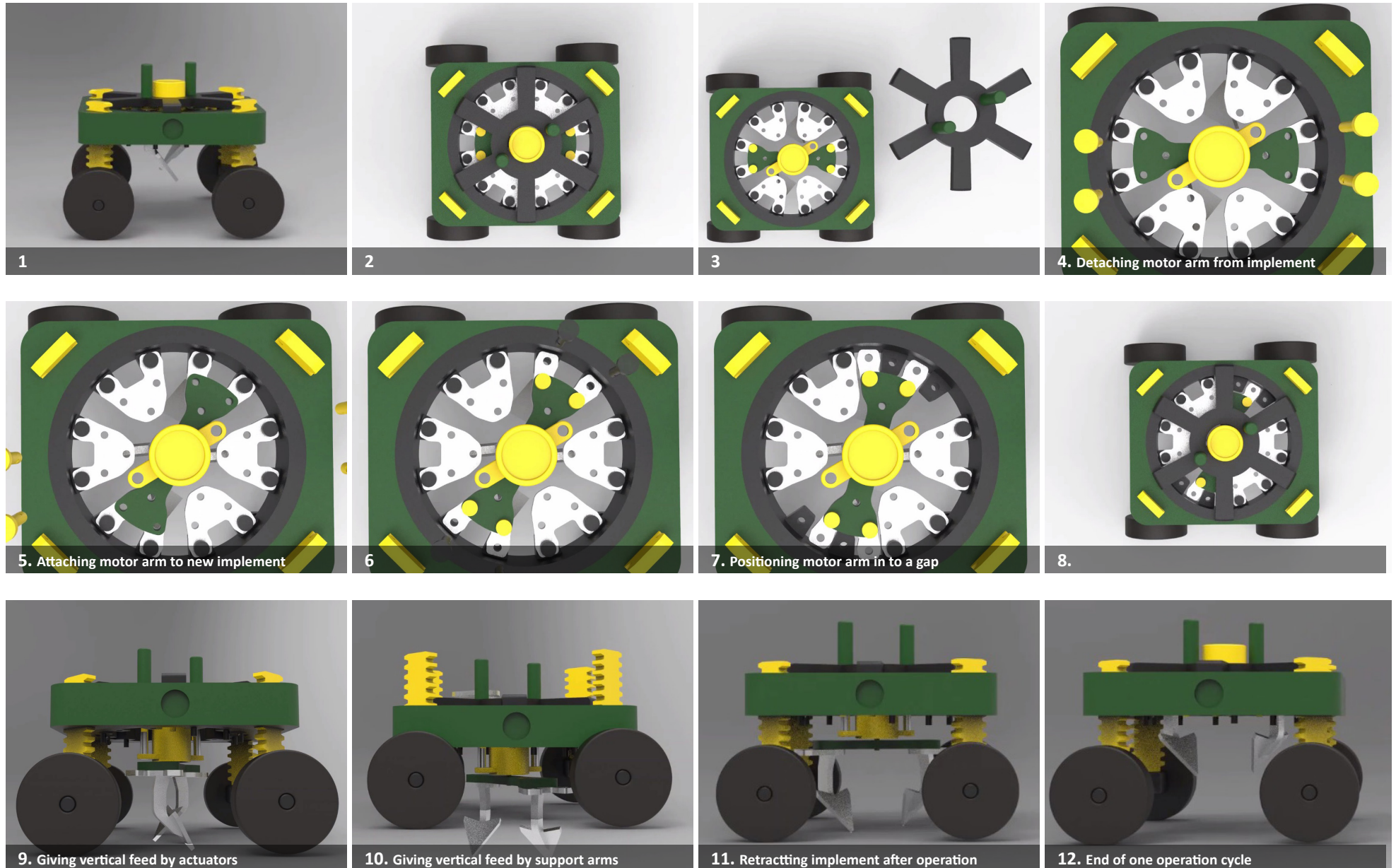






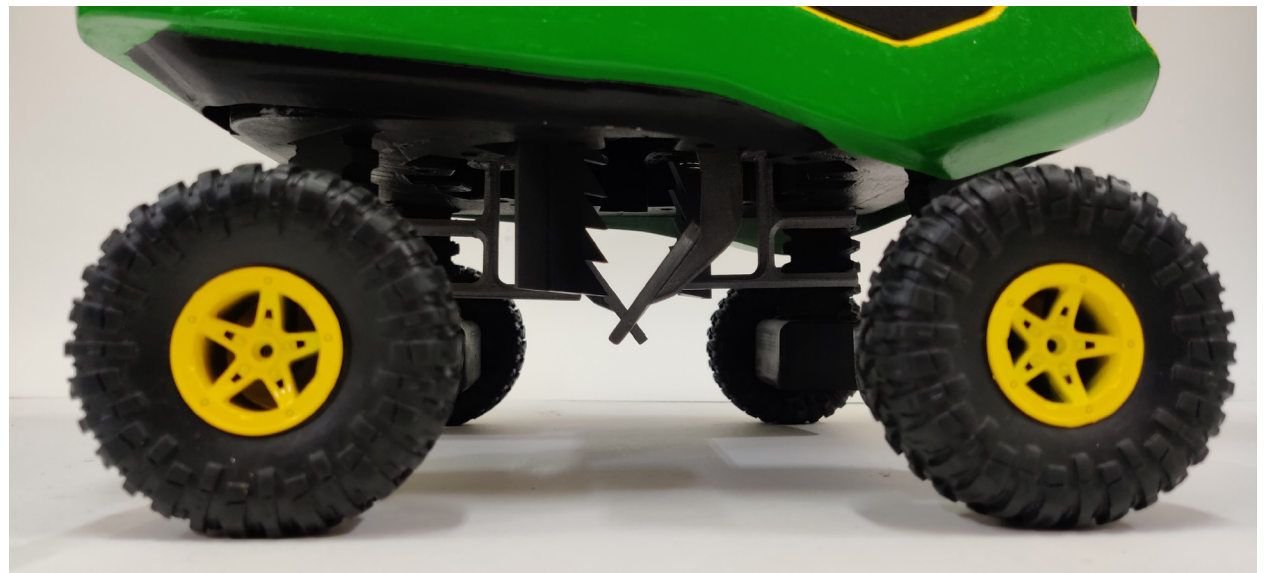


Activity flow of the new mechanism



Physical Scale Model





Conclusion

Conclusion

India has millions of small and marginal farms. The project focused on providing aid to the farming operations like ploughing, tilling, puddling and harvesting, etc. The new design has a new way of doing these operations. Current machines operate implements by pulling them while the designed vehicle does the same activities circularly. The new vehicle is small and compact, which is more suitable for small and marginal farms, which has uneven shapes. This concept is in the segment of power tiller (walk behind tractors), which has better ergonomics and handling compare to power tiller.

Although the new concept has benefits like it can perform various operation in one go without the need to implement change, it has certain shortcomings; it uses a battery pack as a power source. Current batteries have low ampere hour; so, a machine can only run up to two to three hours after that charging is needed. Since the new concept operates the implement circularly the speed of the one operation cycle is less compare to power tiller.

Annexure

Tulsiram / 51 years / 8 people		Farming and Young Brother is Forest Guard	
Plain fields. 8 bigha (4+2+1+1 bigha) (2 ha.)			
Conventional Farming		Organic farming has less yield and there is not reachable market for produce	
Rice	Ragi Adud Tuvar	None	None
How they perform Farming Operation			
Animal (Own Two Bulls) Ploughing (In farm nearby home) Puddling (In farm nearby home)	Labor Transplanting (Hire) Spraying (Self) Harvesting (Hire) Threshing (Hire) Transportation of Cattle food (Self)		Machines Ploughing (Rent Tractor) Puddling (Rent Tractor) Irrigation (Owns Water Pump) Crop Transportation (Rent tractor)
Do not want to invest in big costly machine. Due to lack of irrigation can only take two crops a year.		Machine suitable for small farms, specially for puddling and transplanting	



Rakesh / 28 years / 6 people		Farming, Govt. Job, Dairy Business	
Hilly fields. 6.5 bigha (4+2.5 bigha) (1.5 ha.)			
Conventional Farming		Organic farming has less yield and there is not reachable market for produce also, it is easy to control pesticides using chemical	
Rice	Ragi Adud Tuvar	None	None
How they perform Farming Operation			
Animal (Owns Seven Cattle) Ploughing (Ox on rent in 2.5 bigha) Puddling (Ox on rent 2.5 bigha) Cattle for dairy business	Labor Transplanting (Hire) Spraying (Self) Harvesting (Hire) Threshing (Hire)		Machines Ploughing (Rent Tractor) Puddling (Rent Tractor) Irrigation (Owns Water Pump) Crop Transportation (Rent tractor, Pick up truck)
Do not want to invest in big costly machine. Due to lack of irrigation can only take two crops a year.		Machine suitable for small farms, specially for puddling and transplanting	



Dineshbhai / 53 years / 6 people		Farming, Tractor rental	
Plain fields. 12 bigha (4+3+3+2 bigha) (3 ha.)			
Conventional Farming		Lack of resources for Organic Farming and post marketing	
Rice, Sugarcane	Tuvar	None	Vegetables
How they perform Farming Operation			
Animal None	Labor Transplanting (Hire) Spraying (Self) Harvesting (Hire) Threshing (Hire)	Machines Ploughing (Own Tractor) Puddling (Own Tractor) Irrigation (Owns Water Pump) Crop Transportation (Own tractor and personal bike)	
Tractors are hard for ploughing in small farms, we have the big farms but not all the people has		Current tractors are less comfortable keeping in mind Indian climate condition	



Balubhai / 57 years / 6 people		Farming, Construction and Dairy	
Plain fields. 6 bigha (3+3 bigha) (1.5 ha.)			
Conventional Farming		We have to put more effort and time in organic farming	
Rice	Bhindi Bringle	None	Mangoes Grass for cattle
How they perform Farming Operation			
Animal (3 cattles) None	Labor Transplanting (Hire) Spraying (Self) Harvesting (Hire) Threshing (Hire)	Machines Ploughing (Rent Power tiller) Puddling (Rent Power tiller) Irrigation (Owns Water Pump) Crop Transportation (rent pick up trucks, modified bikes)	
Want to buy Powertiller		Ox are high to maintain, it will be great to have machine for ploughing, tilling, puddling etc	



Gamanbhai / 55 years / 7 people		Farming and Dairy	
Plain fields. 7.5 bigha (3.5+2.5+1.5 bigha) (1.75 ha.)			
Conventional Farming		It doesn't have good return. Although, they grew vegetables for home organically	
Rice Sugarcane	Bhindi Bringle	None	Mangoes Grass for cattle
How they perform Farming Operation			
Animal (6 cattles) Ploughing (Ox on rent)	Labor Transplanting (Hire) Spraying (Self) Harvesting (Hire) Threshing (Hire)	Machines Ploughing (Rent Power tiller) Puddling (Rent Power tiller) Irrigation (Owns Water Pump) Crop Transportation (rent pick up trucks, modified bikes)	
Want to buy Powertiller. Powertillers are not comfortable to use and need so much effort during deep ploughing		Ploughing, Tilling and Puddling required the machines most	



Umeshbhai / 48 years / 4 people		Farming, Laboring and Dairy	
Plain fields. 3 bigha (2+1 bigha) (0.75 ha.)			
Conventional Farming		Wants to do organic farming but yield and profit is less	
Sugarcane	None	None	Grass for cattle
How they perform Farming Operation			
Animal (6 cattles) NA	Labor Transplanting (Hire) Spraying (Self) Harvesting (Hire) Threshing (Hire)	Machines Ploughing (Rent Power tiller) Puddling (Rent Power tiller) Irrigation (Owns Water Pump) Crop Transportation (rent pick up trucks, bicycle and bike)	
None		Interested in dairy business, growing cattle grass doesnt require much effort as agriculture	



Nareshbhai / 40 years / 8 people		Farming and Dairy	
Plain fields. 7.5 bigha (4+3.5 bigha) (2 ha.)			
Conventional Farming		Wants to do organic farming but yield and profit is less and demand is also less	
Rice Sugarcane	Bhindi	None	Grass for cattle
How they perform Farming Operation			
Animal (13 cattles) NA	Labor Transplanting (Hire) Spraying (Self) Harvesting (Hire) Threshing (Hire)	Machines Ploughing (Rent Tractor/Power tiller) Puddling (Rent Tractor/ Power tiller) Irrigation (Owns Water Pump) Crop Transportation (rent pick up trucks, modified bike)	
Wants to buy powertiller		Transporting cattle food, ploughing and puddling requires machine the most	



Subhash / 45 years / (Dindori Nasik)		Farming	
Hilly fields. 4 acre (1.6 ha.)			
Organic Farming		NA	
NA	Moong	Soybeans	Cabbage, Cauliflower, Ladiesfinger
How they perform Farming Operation			
Animal (2 Ox) Ploughing (Own Ox)	Labor Planting (Hire/Self) Spraying (Self) Harvesting (Hire) Threshing (Hire)		Machines Irrigation (Pond, Water pump) Crop Transportation (Rent pick up trucks)
Doesnt want to buy diesel operated machine, belives in sustainable farming		If electric machines are there he will like to go with it	

Sunil / 55 years / (Nasik)		Farming	
Hilly fields. 3 acre (1.2 ha.)			
Conventional Farming		Not good market for organic produce, less yield and low profit	
NA	Wheat, Maze,	Soybeans	Cabbage and Tomatoes
How they perform Farming Operation			
Animal NA	Labor Planting (Hire/Self) Spraying (Self) Harvesting (Hire) Threshing (Hire)	Machines Ploughing (Rent tractor) Irrigation (Water pump) Crop Transportation (Rent pick up trucks)	
Dont want to own any machine, since he is planning to sell is land		If he has a choice to buy he will go for powertiller	

Kiran / 42 years / (Pune)		Farming	
Plain fields. 5 acre (2 ha.)			
Conventional Farming		Not good market for organic produce, less yield and low profit	
NA	Wheat,	Soybeans	Onion
How they perform Farming Operation			
Animal NA	Labor Planting (Hire/Self) Spraying (Self) Harvesting (Hire) Threshing (Hire)	Machines Ploughing (Rent tractor) Irrigation (Water pump) Crop Transportation (Rent pick up trucks)	
Have not use tractor by himself so cant say anything about problem he might have using tractor		Wants to buy power-tiller, specially for ploughing, tilling and harvesting	

Ramdas / 65 years / (Kalavi, Nashik)		Farming	
Plain fields. 4 acre (1.6 ha.)			
Conventional Farming		Not good market for organic produce, less yield, low profit and less biomass	
NA	Wheat, Maze	Soybeans	Garlic Onion
How they perform Farming Operation			
Animal NA	Labor Planting (Hire/Self) Spraying (Self) Harvesting (Hire) Threshing (Hire)	Machines Ploughing (Rent tractor) Irrigation (Water pump) Crop Transportation (Rent pick up trucks)	
Have used powertiller but is tiring and cant go beyond certain depth during ploughing		Wants to buy power-tiller	

Different Implements and Machines used by Farmers



Image 26. Small weeder cum power-tiller



Image 27. Power-tiller



Image 28. Power-tiller wheel during puddling



Image 29. Small Power-tiller



Image 30. Weeder for Paddy field



Image 31. Seeder



Image 32. Fan for Dehusking



Image 33. Community place for Threshing



Image 34. Bike Trailer for crop transportation



Image 35. Wooden Platform on bike for crop transportation



Image 36. Mahindra Tractor

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