DIC’s Terrace Farming Robot

Inter IIT Tech Meet 8.0

MaRS IIT ROORKEE

Team Members

Annushree

Avdesh Kumar Ranwa

Debaditya Barman

Dhruv Shehgal

Shashi Muchkund

Shubham Goyal

Visvash Attri

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Overview

MaRS IIT Roorkee has developed an autonomous bot to perform agricultural tasks for terrace farming. This bot can perform functionalities like seeding, watering, ploughing and harvesting of the crops. It is itself unique in a way that the bot can climb up and down the manmade steps in the terrace farming.

Project Motivation

The UN Food and Agriculture Organization predicts that we need to boost worldwide food production by 70 percent over the next several decades in order to feed the anticipated population of 2050. Many regions in India are hilly with sparse crop production, which with proper planning can be graded to better agricultural spots.

Terrace farming is widely practiced in India in the states of Meghalaya, Uttarakhand, Himachal Pradesh and Haryana. Among the 34 million people inhabitant in the Himalayan region, a large percentage of the population are dependent on hill farming. 15.8 percent of the total area of Himalayas i.e. 53.8 million Hectares are farmlands and 37 percent are sloping lands of various degrees. Being an integral part of the farming culture in India, the farmers are predominantly facing challenges in practicing the same. This project aims to provide a technical, cost-effective and reliable solution to the challenges faced by the farmers while practicing terrace farming.

The challenges faced in terrace farming are:

1) Narrow terraces make it difficult for the farmers to navigate. These also prevent the use of heavy machinery or animal power thus the farmers have to rely on locally made agricultural tools which are appropriate to narrow terraces. The use of improper tools and methods lead to poor yields.
2) Improper irrigation methods and shortage of watering systems hamper the growth of the crops.
3) Wider terraces demand the use of draft animals as a source of farm power. Sometimes farmers are compelled to use manual labour even for ploughing.
4) Steeper slopes make it difficult for the farmers to mobilise the farming tools. It drastically increases the labour demand and hence increasing the cost of production.

Products available in the market

The relevant existing solution which pertains to the autonomous implementation of the basic agricultural functionalities are:

1. **Naio Technologies**: Can automate weed detection, assist during hoe and harvesting.
2. **Energid Citrus picking system**: Automates harvesting of citrus fruits.
3. **Blue River LettuceBot 2**: Assists the farmer in cultivating lettuce crops. Has an inbuilt imaging system which helps in weed-detections.
4. **Vision Robotics**: Automates the process of seeding and harvesting.

None of the above machines is available in India. Neither any of the solution mentioned has the ability to climb the steps of the field cultivated by terrace farming. The existing solutions are customized to perform only limited tasks. Using a bot for a specific purpose will increase the cost of farming and is thus no economical. The solutions mentioned generally have very high cost of purchase and maintenance.

Field Visit - Village Bhatta Gaon

A survey and a field visit were conducted by our team in order to find the real challenges that the farmers face while practicing terrace farming. The field visit helped in getting a real live analysis of the dimensions of the terrace field, quality and moisture content of the soil.

The place of survey was Bhatta Gaon (30.4348° N, 78.0780° E). It is a small village in Uttarakhand located at an altitude of about 8000 meters above the sea level, about 94 kms from IIT Roorkee. The place for the study was decided by analyzing the terrain regions from Google maps. Our aim was to find the closest place from Roorkee where terrace farming is a mainstream occupation of the people and has a fair amount of connectivity.

Survey/Talking with Local Stakeholders

The family of Ram Jadwan depends on the terrace farming to fill their stomachs. He and his wife Mira Jadwan jointly run their ventures on their farm. We had the opportunity to ask a few questions to them.

Here is a conversation between Ram Jadwan (Local Farmer), Mira (his wife) and Debaditya (Team MaRS):

Debaditya: What is the actual problem faced by the farmers here?

Ram: Lands are dispersed, no roads to navigate, No equipment available, No irrigation.

Debaditya: What crops are mainly grown on the land?

Ram: Wheat, makki and jawar.

Debaditya: How do you navigate through steps?

Ram: Small kachcha road craven out though the steps.

Debaditya: What modern equipment are used by them to assist in their farming? Do you use tractors?

Ram: No modern equipment only hand driven tools.

Debaditya: What are the government schemes that tends to assist the farmers?

Ram: No government schemes. No help from them.

Debaditya: Is the yield of the products less? If yes then why? And how can it be increased?

Ram: Yes, it is very less. Land dispersion should be decreased. Poor quality seeds and no irrigation facility.

Debaditya: Will they be interested in the use of robot which can help them is terrace farming?

Ram: Yes, they will explore if the product yield increases.

Debaditya: Do you think technology can increase yield?

Ram: Yes, technology can increase yield.

Debaditya: Do you have a smartphone?

Ram: Not really but their son has one.

Debaditya: Are people migrating from mountains to cities? If yes then Why?

A glimpse from the survey: Debaditya having conversation with Ram and and his spouse Mira.

Debaditya: No money in farming. No money to feed the family for one month.

Ram: Yes.

Debaditya: What about water supply?

Ram: No water for irrigation.

Debaditya: How much land do you own? And what is the profit?

Ram: 8-10 Bigha. Very less profit. Mostly crops grown for family needs.

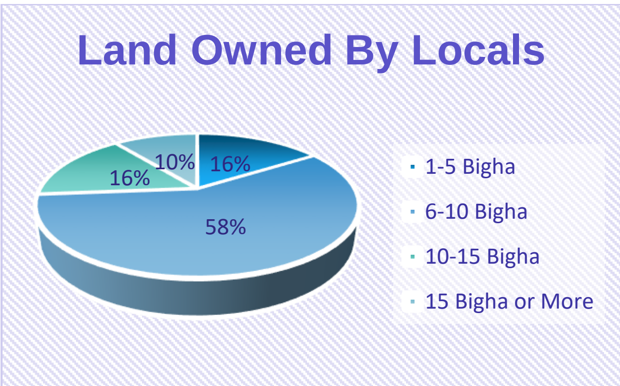
Debaditya: Is their home accessible by road?

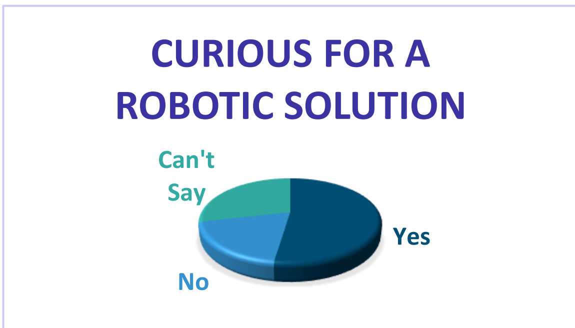
Ram: No.

Debaditya: Seeds used?

Ram: 10-12 kg for 8-10 bigha land.

Due to the time constraints, the survey could be completed with only 21 such families. Most of the families were having at least one smartphone in their family. A large section of them own less than 10 bigha land out of which most of it remains uncultivated. Some population of the farmers believe that the government should provide them with such technological solutions.





Attending the Gram Panchayat

Team Members also attended the Gram Panchayat and came across the various viewpoints of the people regarding terrace farming. Village Pradhan personally met the team and discussed about the problems of manual labor and less efficiency of yield. He also remarked about the role of the government and said that the government and the engineers of the country should come forward for providing these farmers with proper technology.

A glimpse from the Gram Panchayat meeting.

Discussing the problems with Rakesh Rawat, the Pradhan of village Bhatta Gaon.

Market

According to a survey conducted by **NCOF**, among the **34 million** people that inhabit the Himalayan region **80 percent** of the people are dependent on hill farming. **48 percent** among them practice farming on sloping lands i.e. terrace farming.

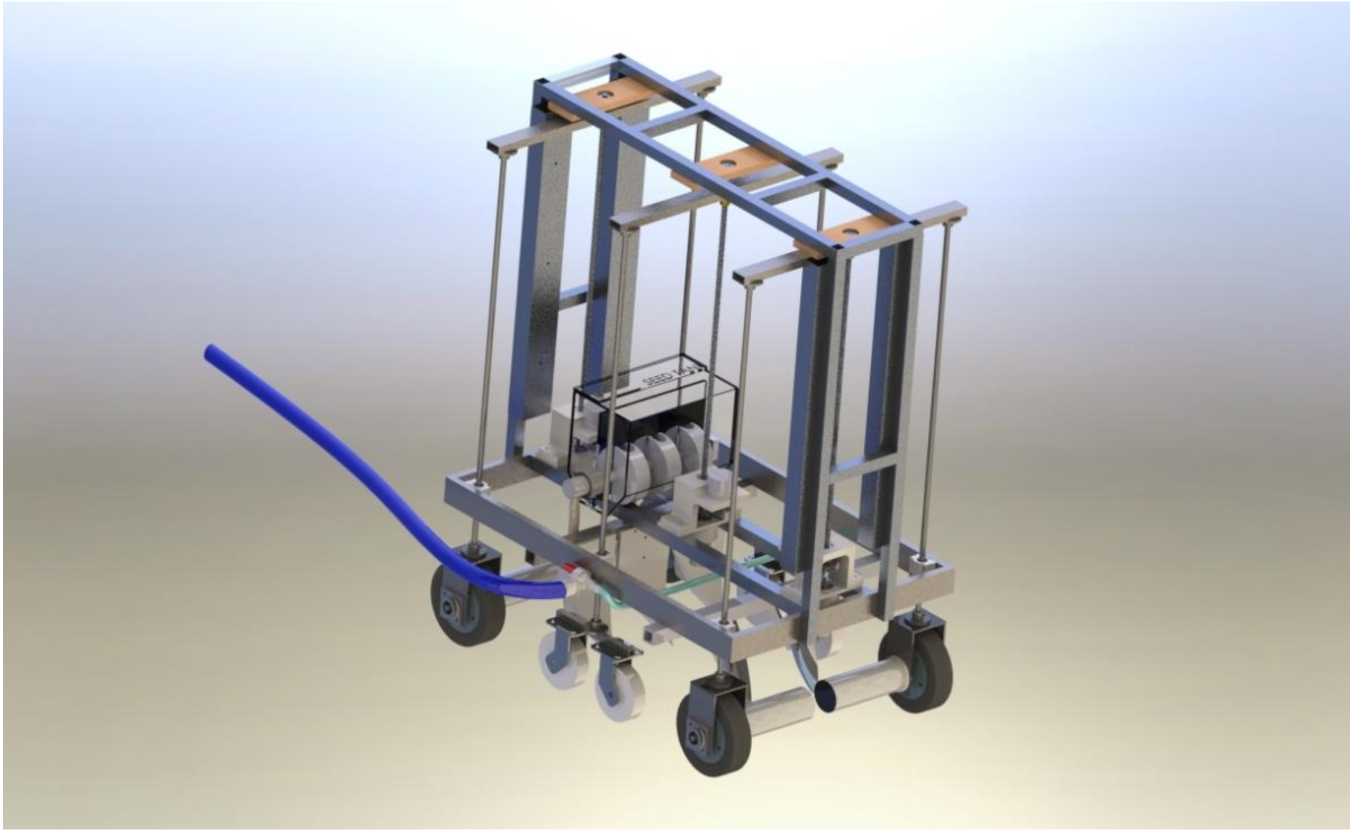
State (1)	Area (sq. kms) (2)	Population (No.) (3)	Rural (numbers) (4)	Population density (per sq.kms) (5)	Area under forests ('000 ha) (6)	Net cropped area ('000 ha) (7)	Net cropped area as per cent of total area (8)	Cropping intensity (per cent) (9)	Average size of holdings per family (10)
North Western Hill region									
Himachal Pradesh	55673	6077900	5482319	109	1094	551	12.16	174	1.16
Jammu &Kashmir	222236	10143700	7627062	46	2747	733	16.27	147	0.76
Uttaranchal	53483	8489349	6310275	159	3342	788	14.91	164	1.01
Total	331392	24,710,949	19419656	75	7183	2072	14.47	160	0.97
North Eastern Hill region									
Arunachal Pradesh	83743	1097968	870087	13	5154	166	3.02	159	3.31
Assam	78438	26655528	23216288	339	1930	2701	34.41	152	1.17
Manipur	22327	2388634	1818224	107	602	140	6.33	142	1.22
Meghalaya	22429	2318822	1864711	103	938	240	10.71	111	1.33
Mizoram	21081	888573	447567	42	1599	91	4.31	100	1.29
Nagaland	16579	1988636	1635815	119	875	261	16.73	113	4.82
Sikkim	7096	540851	480981	76	257	95	13.38	127	1.65
Tripura	10486	3199203	2653453	305	606	277	26.41	152	0.60
Total	262179	39,078,215	32987126	149	11961	3971	17.09	145	1.92
India	3,287,240	1028,830,774	742706609	312.98	69024	141231	46.15	134	1.41

Source: NCOF Vol. II. Report, 2005.

Going by the statistics shown in the table, the **population dependent on hill farming** in India will account to about **823,064,619.2** and the **population practising on sloping lands** will amount to about **395,071,071.216.**

Our solution targets the farmers who are **practicing farming on sloping lands** and identifies them as the primary user of the product. The method of deployment of the product can be different in different scenarios. The product can be deployed by the government as an aid to the farmers. In this case the government will be the customer. The product can be acquired by an individual farmer which makes him/her as the customer.

Our Solution



Features:

1. **Basic agricultural functionalities**: The bot can perform the basic agricultural functions for the farmers. The basic functions include.
    a. Ploughing
    b. Watering
    c. Seeding
    d. Harvesting
2. **Sensors**: Installed with advanced sensors like moisture, humidity, temperature etc. to get the data inputs.
3. **IOT enabled:** Display sensor data on a web page. The bot can be controlled as per user discretion.
4. **Alert System:** A centralized alert system governs the bot. It can alert the user in case of:
    1. Shortage of Seeds
    2. Low power
    3. Internal damage
5. **Solar powered:** The bot **can** be customized to run on solar powered panels.

Innovation

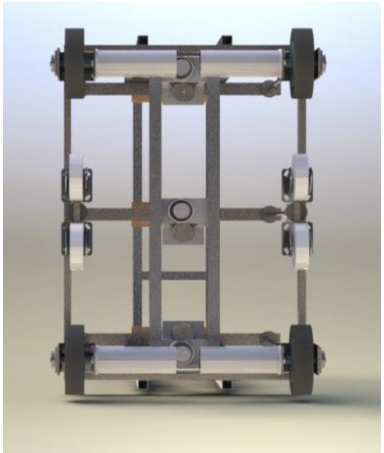
- **IOT enabled:** In the present age, farming in the western countries are heavily influenced by the modern technologies. They have adopted the principle of **smart farming**. Sensors are frequently used by them to check the soil and weather conditions and this helps them in taking important decisions. However, the farmers of India are way behind in this aspect.

  Our aim is to take the farmers in the loop. Making a bot which only completes the basic agriculture functions without any human interruptions will lead to ignorance of farmers towards the technologies. This particularly defeats the purpose of making the farmers smart. Also, the farmers lack inputs from their lands, Therefore the idea of implicating IOT in our bot is an important step taken towards making the farmers smart.

  Our bot is integrated with IOT. Three particular sensors are used to determine the soil moisture content, humidity and temperature. The detailed working of the IOT is discussed in later sections. The inputs from these sensors can help the farmer in determining: -
    - The region where irrigation is needed.
    - Amount of water needed for irrigation.
    - The temperature gradient in the farmland (generally terrace farm of each ranges to about 600m hence a difference in temperature gradient)

  Our bot is automated to water the fields according to the sensor readings. This functionality can be customized by the farmers according to their need.
- **Height Adjustable Chassis:** The chassis of the bot is supported by three lead screws which in turn is driven by three motors. This unique design of the bot helps to **uplift the entire chassis of the bot to the height desired** to perform a particular task. For e.g. **while watering the crops the chassis can be lifted above the height of crop**, this ensures that the crops are not hampered by the motion of the Agri tech bot as it moves forward. **4 start lead screw nuts have been used because they multiply the total effective power developed by a large factor**.

Mechanical Aspect of the bot.

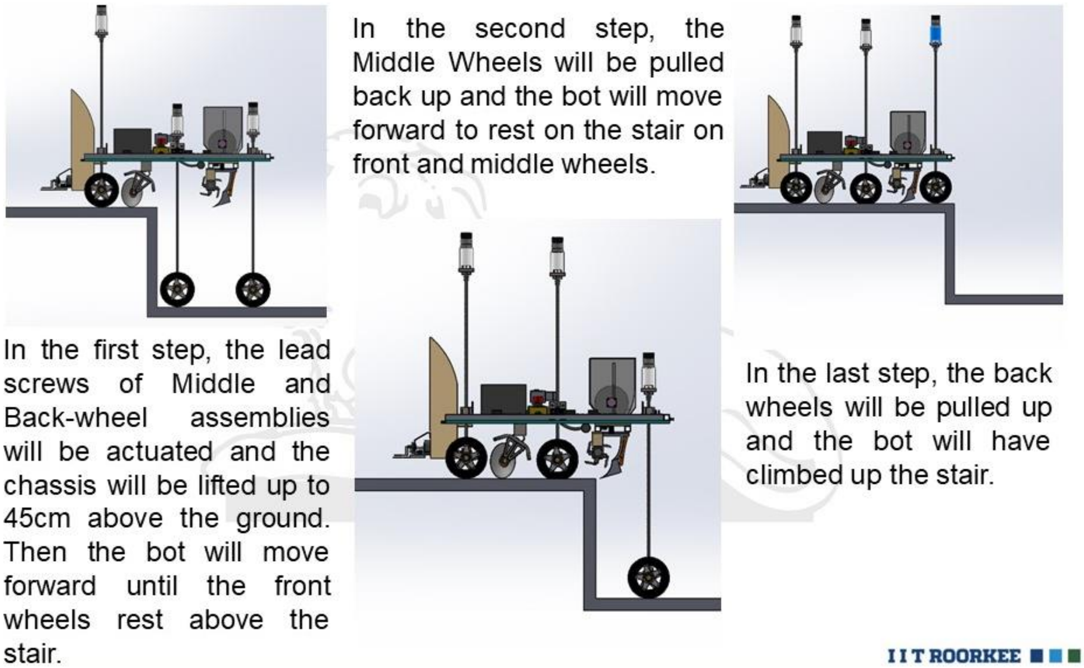


Traversal

- The bot uses 4-wheel differential drive to traverse on the soil surface. Two central idler wheels are provided for extra stability while climbing the steps and traversing on uneven surfaces.
- For this drive we are using Mega Torque Planetary DC geared motor of 300RPM and torque capacity of 92kg-cm, enough to carry out tasks like Ploughing and Seeding.
- The chassis of bot is made up of square steel pipes, arc welded together for rigidity.

Climbing

- We divided bot into 3-wheel assemblies in which front and back are containing 2 wheels, 2 motors and a lead screw but the middle assembly contains 4 caster wheels and a lead screw so that the bot does not topple, while one of the front or back wheel assemblies is in the air.
- In the first step, the whole body will be lifted by actuating the lead screws of middle and rear wheel assemblies. Then the bot will move forward until the front wheels rest above the step.
- In the second step, the Middle Caster Wheels will be pulled back up and the bot will move forward by actuating the back wheels to rest on the stair on front and middle wheels.
- In the last step, the back wheels will be pulled up, this time the front wheels will be actuating and it will move the bot forward and the bot would have climbed up.
- **The bot also has an ability to lift itself above the crop for traversing in the field.**



Ploughing

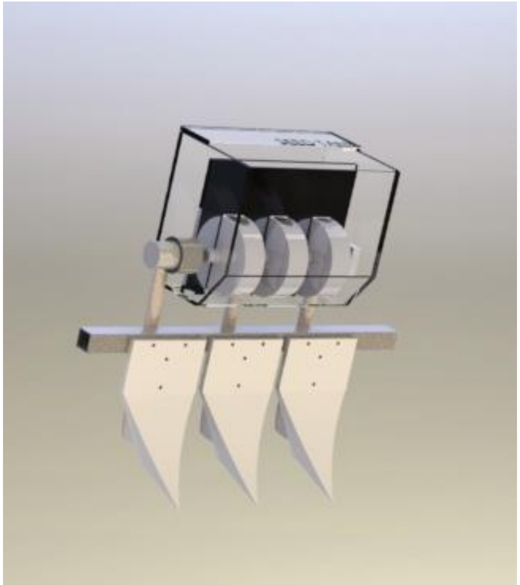
- After reading about different Ploughing mechanisms we used Disc Harrow mechanism instead of disc Plough. Because when we visited fields of “Bhatta Gaon”, we found out that the thickness of Topsoil for cultivation is less in comparison to that of plains and we can encounter stones while deep ploughing.
- Using a Disc Harrow mechanism for shallow ploughing would be more appropriate and will save the Tool from wear and tear. Simultaneously it will use less Power per unit area.
- A special concave disk having an angle of curvature of around 15-25 degrees has been used. This angle determines the ploughing depth. More the angle more is the depth of plough and more is the power to drive the operation.
- The discs also maintain an angle of 40-45 degrees with the direction of travel which helps it in rotation and opening of the soil by **scooping** it out simultaneously.

Watering

- Keeping in mind that a reservoir has already been provided, we are using a pipe with a pump that will water the crops using the sprinkle irrigation method close to the roots of the crops.
- The bot will have a solenoid-valve for electronically controlling the water given to the crops. The concept of the watering mechanism is designed so as to minimize the water consumption along with maintaining the net yield.

12V Solenoidal Valve

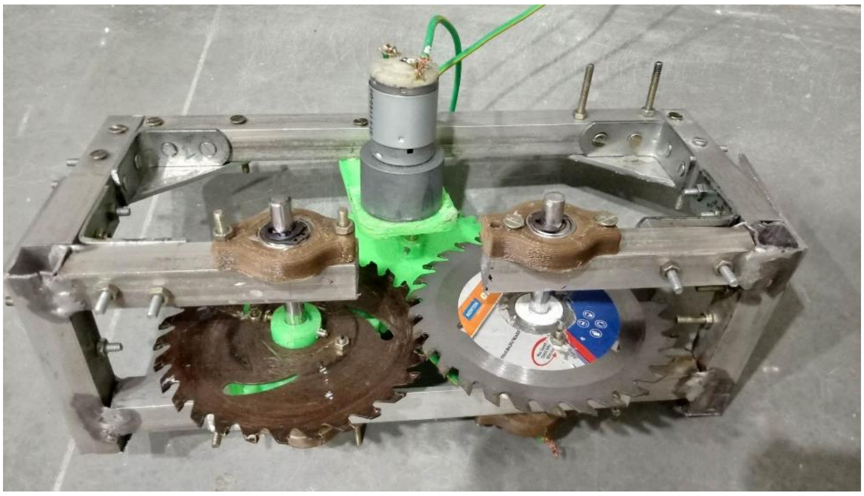
Seeding

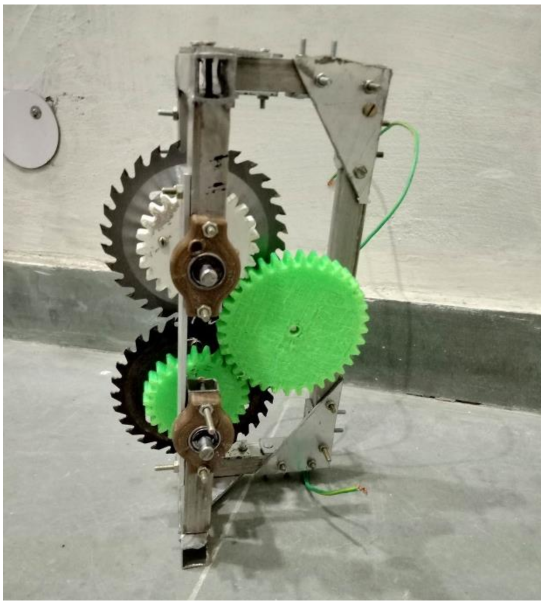


- For dropping the seeds, a seed tank is attached on the bot that directs the seeds to the outlet pipes using 3D printed discs controlled by Johnson type DC motor. The tank contains 3 circular disc-like structures with grooves in them. These discs are rotated by the motor.
- The tank is divided into two-compartments, one compartment contains the seed and the other compartment contains the outlet. When the motor rotates the disc, the seeds are trapped in the grooves and are transferred to the next compartment. The seeds then fall to the ground through the outlet.
- Cultivator is mounted at the bottom along with outlet pipes at their back so they easily drop off seeds in the tillage so formed.

Harvesting

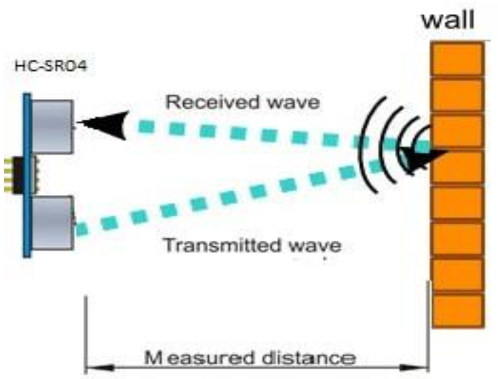
- Harvester consists of 2 cutting blade, operated by a geared DC motor using Spur Gears.
- Both the blades will rotate with the same speed but in opposite direction, the blades share a common cutting area which will ensure cutting of crop which comes in between them.
- The harvester can be detached and can be mounted on bot when required.





Electronics aspect of the bot

Sensors Used



1. **ULTRASONIC SENSOR**: 5 such sensors are used. Mainly used to maintain constant distance from wall while traversing.
2. **SOIL MOISTURE SENSOR**: 1 moisture sensor is used to take data inputs from the cultivated land.
3. **TEMPERATURE SENSOR**: 1 temperature sensor is used to get the temperature data from the field.
4. **ROTARY ENCODER**: 3 rotary encoders is used to keep track of the lead screws during their operation. The DC motors used for the traversing of the bot has inbuilt encoders.
5. **MPU 9250:** 1 such sensor is used. It contains gyroscope, accelerometer and magnetometer. It is used to maintain the orientation of the bot.
6. **BUMP SENSOR**: 4 bump sensors are used to determine the state of the bot in certain manoeuvres.
7. **HALL SENSOR**: Hall sensor is used to measure the distance travelled by the bot. Encoder cannot be used on the ground wheels as the wheel can slip on the ground which will result in wrong measurements.

Micro-Controller

The microcontroller of the bot is the brain of the bot. Each and every function and maneuverer of the bot is controlled by a microcontroller. It also helps the bot take decisions and decides the further course of action. We have used Arduino Mega microcontroller board which depends on AT Mega microcontroller.

It includes digital input/output pins-54, where 16 pins are analogue inputs, 14 are used like PWM outputs hardware serial ports **(UARTs)** – 4, a crystal oscillator-16 MHz, an ICSP header, a power jack, a USB connection, as well as a RST button. This board mainly includes everything which is essential for supporting the microcontroller. So, the power supply of this board can be done by connecting it to a PC using a USB cable, or battery or an AC-DC adapter. This board can be protected from the unexpected electrical discharge by placing a base plate.

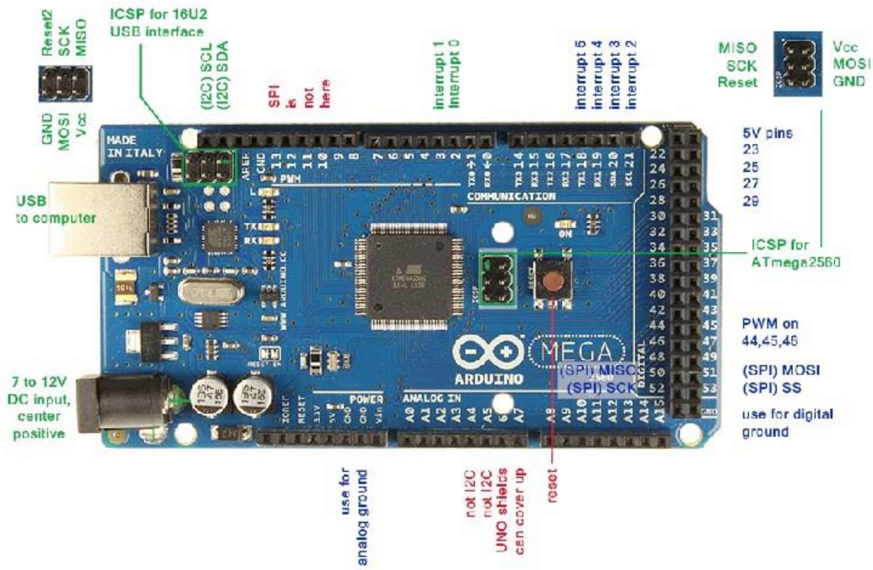
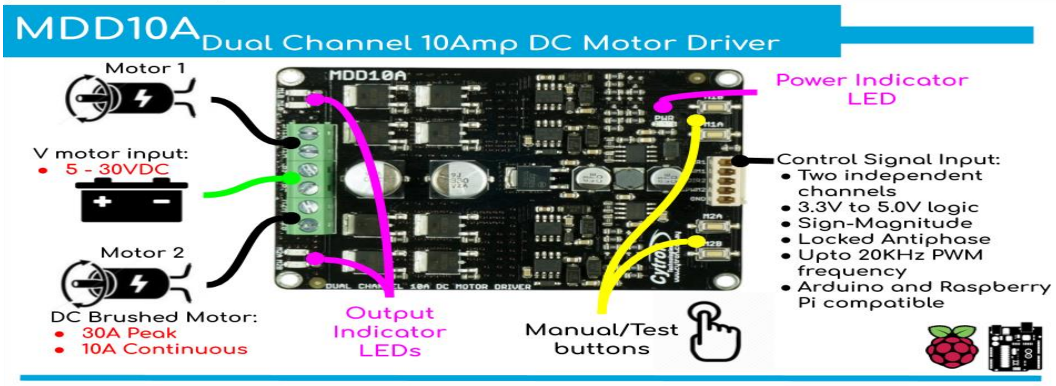


Fig Arduino AT MEGA

Motor Driver

The DC motors used in the bot are being controlled by the microcontroller through a motor driver. A motor driver enables the Arduino to control over the speed, direction and PWM of the motors.

We have used the Cytron MDD10A which is a dual-channel version of the MDD10C. Like MD10C, MDD10A also supports locked-antiphase and sign-magnitude PWM signal. It uses full solid-state components that offers faster response time and eliminates the wear and tear of the mechanical relay. It can support V-motor from 5V to 30VDC. With the pre soldered terminals, and on-board manual/test buttons, you can get started even without any microcontroller.



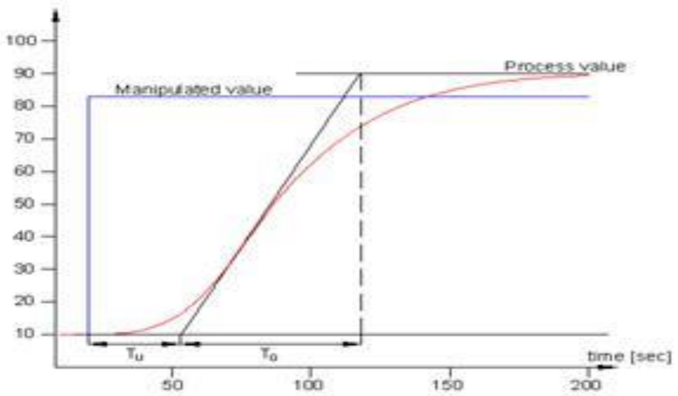
The Implication of PID

PID is short for proportional, integral and derivative. The name comes from the methods on how such controller deals with disturbances in the system. However, such a controller is only in **feedback systems.** The PID is used to correct the error of the bot while traversing.

Trial and Error Method: It is a simple method of PID controller tuning. While the system or controller is working, we can tune the controller. In this method, first, we have to set Ki and Kd values to zero and increase the proportional term (Kp) until the system reaches to oscillating behaviour. Once it is oscillating, adjust Ki (Integral term) so that oscillations stop and finally adjust D to get a fast response.

Process reaction curve technique: It is an open-loop tuning technique. It produces a response when a step input is applied to the system. Initially, we have to apply some control output to the system manually and have to record the response curve.After that, we need to calculate slope, dead time, the rise time of the curve and finally substitute these values in P, I and D equations to get the gain values of PID terms.

Process reaction curve



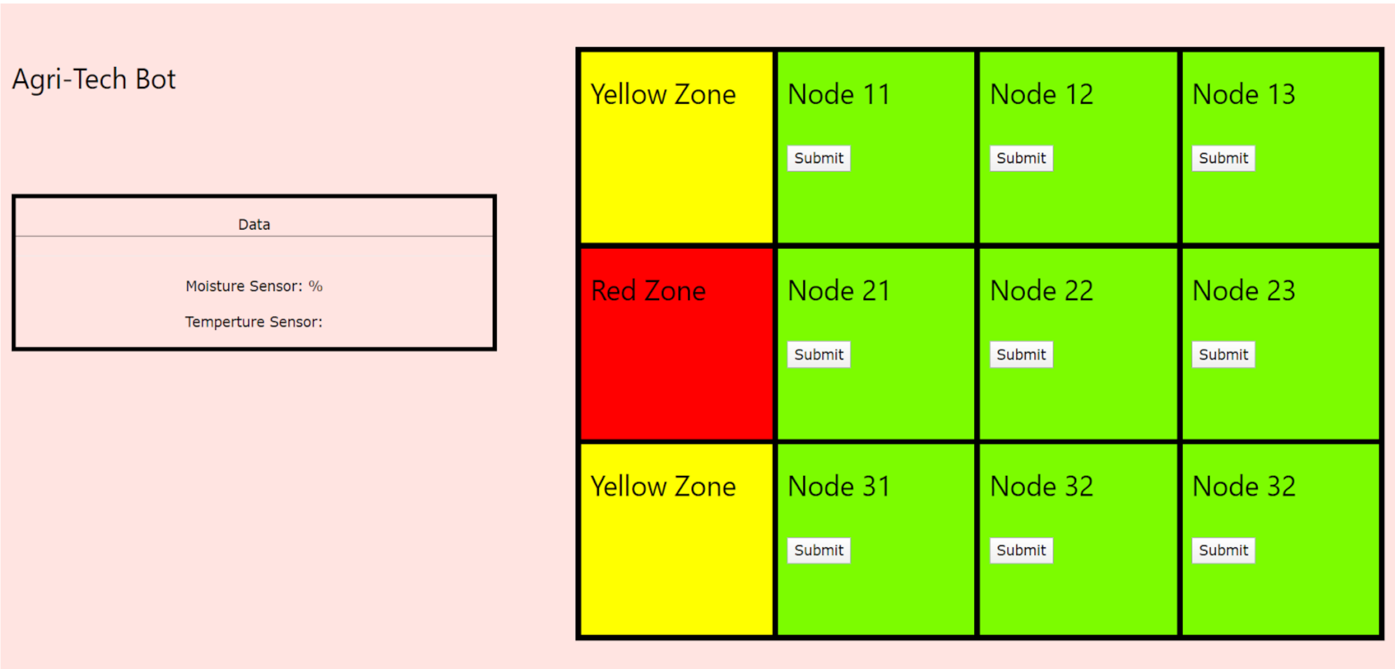
Working of the IOT (Web Page)

One of the problems faced by the farmers in terrace farming is the lack of data from the land but this feature of the Agritech bot is the solution to the problem faced. The Agritech robot is envisioned to make the farmers smart, robust and decrease the human dependency.

The readings from the different types of sensors (moisture, humidity, temperature etc) will be taken by a microcontroller and transferred wirelessly to a database. The readings will be stored in the database using file handling. The files with the reading will be sorted according to the nodes present on field. A **node** is a region/area on the actual cultivated land whose details can be obtained in order to analyse the condition of the soil and the crops.

All the sensors are connected to the **Arduino AT Mega** microcontroller, which will be responsible for registering the input data from the sensors. Since Arduino AT-Mega does not have a in-built Wi-Fi or Bluetooth system, so a **ESP-8266 NODE-MCU** can be used to transfer the data wirelessly to the database. The transfer of data from Arduino to the esp8266 can take place through interrupt pins, then the esp8266 will create a local server, another python script will run on a device having the database which will read the data from the esp8266 and store it in a database using file handling. The micro-header named **ESP_MICRO.h** is a very important header file needed for the esp8266 to transfer the data.

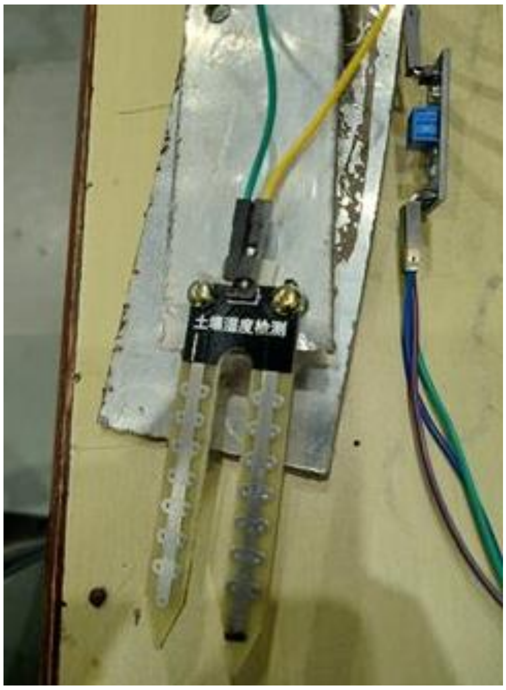
After the data is stored in the database in a sorted manner, we will need to render the files to the web page which will display the data to the user. The **web page** is thus an essential entity here. The web page contains a responsive replica of the land under cultivation. A basic snapshot of the web page looks like the picture as shown below.



The Web page Interface

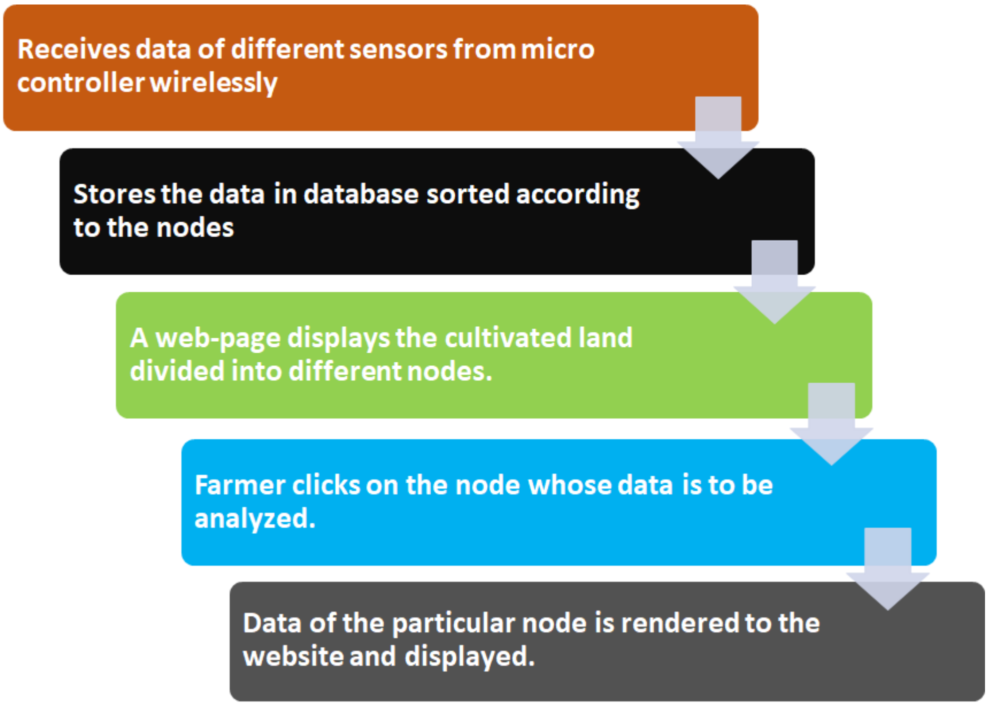
The table on the right-hand side is the replica of the cultivated land and in our case is the arena for the problem statement. The table is **responsive** and will respond to the click of the user. Each step is divided into different **nodes**. It is the region where the Agritech bot will take the readings from the sensors.

The user has to click on the **submit button** on the nodes whose conditions/readings he wants to analyse. The details of the sensor reading will be displayed on the box present on the right-hand side of the web page. The data from the database will be rendered to the website using flask. A **note/message** can be delivered regarding what can be expected of the readings.



Soil moisture sensor

A simplified flow-chart of the process:



Sample Esp8266 code

This sample code will run on esp8266. The code creates a local server and hosts the sensor data to the same local server. Another python script which connects to the same local server will be able to read the data hosted on the local server and simultaneously create a text file for each node with data for the respective node.

```
#include "ESP_MICRO.h" //Include the micro library
int testvariable = 0;
String str= "48 49 50 51";
void setup(){
  Serial.begin(115200); // Starting serial port for seeing details
  start("deboasus","12345678");  // EnAIt will connect to your wifi with given details
}
void loop(){
  waitUntilNewReq();  //Waits until a new request from python come
  /* increases index when a new request came*/
  testvariable += 1;
  //returnThisInt(testvariable); //Returns the data to python
  returnThisStr(str);
}
```

Python Script on receiving end

The sensor data sent by the Esp8266 to the local host needs to transferred to a database. In our case we have used laptop as a database for the storage of the sensor data. The process of reading the data from the local host and writing it to a database is done by a python script that runs on the same computer where the database is located. The snippets of the code are explained below.

`import urllib.request` (*This is the library that needs to be imported. This library enables the code to link to the url as defined in the next line.*

`url = "http://192.168.137.161/"` *# ESP's url, (Esp serial prints it when connected to wifi, This is obtained by the code run on esp as explained in the previous section)*

`n = urllib.request.urlopen(url).read()` *# get the raw html data in bytes (sends request and warn our esp8266)*

`n = n.decode("utf-8")` *# convert raw html bytes format to string :3*

`data = n.split()` *#split data we got. (if you programmed it to send more than one value) It splits them into separate list elements.*

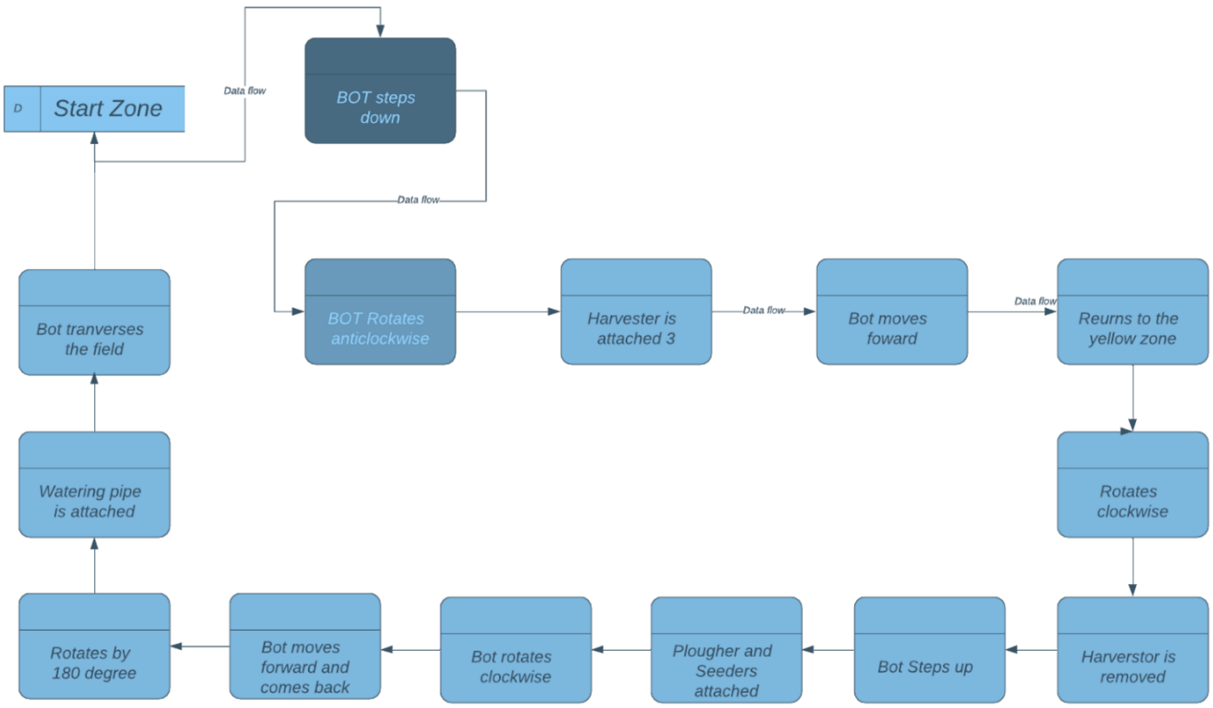
The variable “**data**” contains the data read from the ESP. After achieving this task, we can write the data in a text file using the **write** function in python.

Using Flask

Flask is a **micro web framework** written in python. Flask has been used in this project to render the web pages to a local host which can be accessed by the farmer. The sensor data stored in a local system cannot be directly read in the front end by any web pages and hence the necessity to read the data and render it to a local host. The flask reads the data of the particular node from the database and renders the data to the web page hosted on a local server.

Solving the Problem Statement

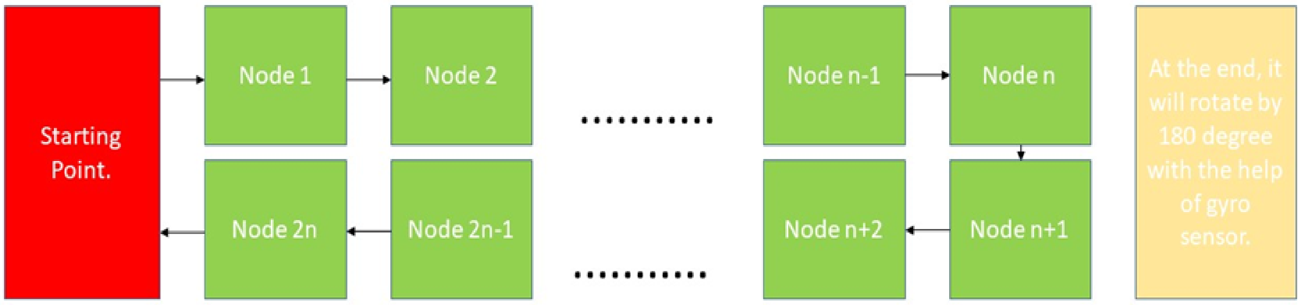
Task flow for the navigation of the bot



Traversing

- Traversing occurs with the help of ultrasonic sensors. Which is used to maintain a constant distance from the wall.
- After starting, the bot will stop successively after a fixed distance and take readings of various sensors and water the zone accordingly.
- **Ploughing** will occur automatically as the bot moves.
- After detecting the end of the arena, the bot will take a 180 degree turn in the clockwise direction and move back to the respective starting zone.
- After detecting red or yellow region, bot will do the required action i.e. climbing up or down the steps.

TRAVERSING



- After starting it will stop at different nodes and take data of moisture in soil and do irrigation.
- Traversing is done with the help of ultrasonic sensors.
- Data taken will be send to web server.

Step Up Manoeuvre

- For climbing mechanism, 3 lead screws are actuated using 3 DC motors, which lift the whole body in 3 steps.
- In the first step, the whole body will be lifted by actuating the lead screws of middle and rear wheel assemblies. Then the bot will move forward until the front wheels rest above the step. A bump sensor will detect that the front wheels have touched the ground. The front colour sensor will detect the change in the zone for the prior part of the bot (yellow to red).
- In the second step, the Middle Wheels will be pulled back up and the bot will move forward to rest on the stair on front and middle wheels.
- In the last step, the back wheels will be pulled up and the bot would have climbed up.
- The step-down manoeuvre is the opposite of the step up manoeuvre.
- The bot also has an ability to lift itself above the crop for traversing in the field.

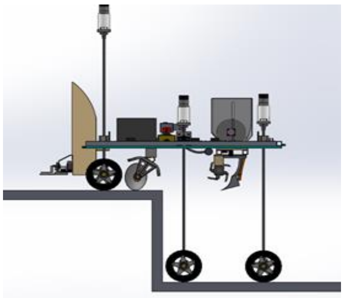


Fig.2: First step

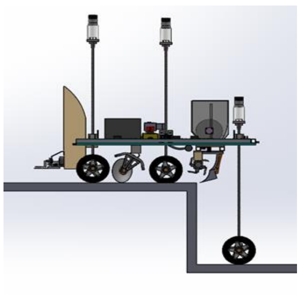


Fig.3: Second step

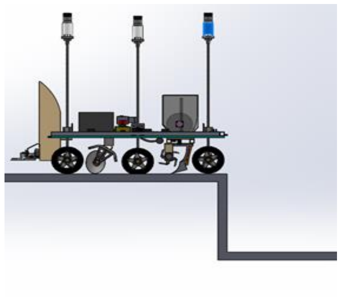


Fig.4: third step

Cost Structure

Component	Number used	Cost INR
Planetary Geared Motor	4	19,996
Arduino Mega 2560	1	800
Node MCU Esp8266	1	260
Motor Driver	6	15,000
Battery	3	4997
Heavy Duty Wheels	4	900
Caster Wheels	4	200
Johnson motor	5	1996
Rotary Encoder	3	4497
Ultrasonic Sensor	5	900
Mpu9250	1	190
Dht11 temperature	1	108
Soil Moisture Sensor	1	75
Bump Sensor	4	400
Lead screw	3	2397
Material for Body	----	4000
Manufacturing	----	3500
		Total Cost- 60,216

Proposal for real life solution

Apart from the technical solution as proposed in this report, there are some other serious measurements that needs to be undertaken by the government in order to ensure the smooth deployment of the bot.

1. A case study on Japan shows that in 1998 the country faced a steep decline in the percentage of hill farming, over 3.8 percent of the nation's farming land was abandoned by 1998. This was due to the years of neglect and bias against the hill agriculture. The Japan government was able to realise the gravity of the solution and imposed strict measures to reverse the trend.
2. What has happened in Japan, carries a very important message for the future of hill agriculture in India. Looking deep inside the Uttarakhand hills, one finds that similar conditions is developing in several areas of the Indian Himalayas and that hill agriculture in India faces a similar situation sooner than later.
3. The government should impose a strategic turn around in its agricultural policies to revive the already declining hill farming. They should also provide subsidies on technological solution which tends to assist them. Our product also falls under this category. Surveys from Bhatta Gaon proves that farmers are willing to use modern equipment but they are incapable of affording the such solutions due to their already less income.

One of the key findings of the survey of Bhatta Gaon is that the height of the steps is very high ranging from 350cm to 480cm. The vertical surface of the steps is irregular and also slanted at an angle of about 5-10 degrees from the perpendicular. These conditions make it very difficult for any logical bot to navigate between the steps. The degree of manipulation in the bot to climb such high and irregular steps will decrease the overall efficiency and performance of the bot in performing other agricultural functions. The problem can be solved by customizing the steps of some degree so that the bot can perform efficiently that is to say that the steps can be modified to smaller height and regular terrain on the vertical wall.