Concept Name: MicroFarm Rover

A compact, solar-assisted, battery-powered autonomous rover with interchangeable tool modules for soil preparation, seed planting, precision fertilizing, and targeted insecticide application.

The design should not copy a full tractor. That would make it too expensive, heavy, fuel-dependent, and hard to repair. The better design is a lightweight modular field robot that performs narrow-row operations slowly and precisely.

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1. Design Philosophy

The machine should be:

Low-cost: Use commodity parts, standard motors, off-the-shelf batteries, open-source electronics where possible.

Modular: One base vehicle, multiple tool heads.

Repairable locally: Steel tube frame, bolted parts, bicycle/motorcycle-style wheels, standard bearings, replaceable nozzles, simple wiring.

Eco-friendly: Electric drive, solar charging, reduced soil compaction, precision input application.

Autonomous but supervised: It can drive rows and perform tasks automatically, but chemical application should require human approval and geofenced operating limits.

FAO emphasizes that sustainable mechanization for smallholder farmers must fit local needs and should be environmentally responsible, not simply miniaturized large-farm machinery. (FAOHome)

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2. Core Machine Architecture

```
                    Solar Panel Canopy
                             │
          ┌──────────────────────────────┐
          │ Battery + Power Controller   │
          └──────────────────────────────┘
                             │
    ┌────────────────────────┼──────────────────────┐
    │                        │                      │
Drive Motors     Control Computer       Tool Controller
    │                        │                      │
Wheels/Tracks     GPS/IMU/Cameras       Seeder / Tiller /
                                     Fertilizer / Sprayer
```

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3. Physical Platform

Recommended Base

Four-wheel rover with high-clearance frame

Better than tracks for first version because wheels are cheaper, easier to maintain, and easier to source. Tracks improve traction but add cost, complexity, and maintenance.

Suggested dimensions

Item	Target
Width	0.8–1.2 meters
Length	1.2–1.8 meters
Ground clearance	30–50 cm
Weight	75–150 kg
Speed	Slow: 0.5–2 km/h
Working width	1 row or 2 narrow rows
Power	24V or 48V battery-electric
Charging	Plug-in + removable solar panel assist

The machine should be light enough that two or three people can move it manually if it fails.

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4. Tool Modules

The most important design decision is to make the machine tool-swappable.

Module A — Soil Tilling / Soil Preparation

For eco-friendly farming, avoid deep full-field tillage where possible. Use strip-tilling or shallow rotary cultivation only where seeds will be planted. Deep aggressive tillage burns energy, damages soil structure, and increases erosion.

Tool design

Component	Function
Shallow rotary tiller	Loosens planting strip
Adjustable tines	Set till depth
Depth wheel	Keeps consistent soil depth
Motorized lift	Raises tool at row ends
Soil moisture sensor	Prevents tilling when soil is too wet

Recommended approach

Use a narrow 10–25 cm strip tiller, not a full-width tiller.

This reduces power demand and soil disruption. Sustainable agricultural mechanization literature connects smallholder mechanization with conservation agriculture and lower-impact soil management rather than heavy conventional tillage. (MDPI)

Module B — Seed Planting

Use a precision seed metering system.

The machine should know row spacing, seed spacing, depth, and seed count. It should plant slowly but accurately.

Seeder design

Component	Function
Seed hopper	Holds crop seed
Seed metering wheel or vacuum disk	Releases one seed at a time

Component	Function
Furrow opener	Opens soil slot
Drop tube	Places seed
Press wheel	Covers and firms soil
Encoder	Tracks wheel distance
Seed sensor	Confirms seed drop

FarmBot is a useful reference point because it uses open-source robotic farming concepts with tool heads for seeding, watering, soil sensing, and other small-scale operations. (FarmBot Genesis Documentation)

Crops to support first

Start with common row crops:

Crop	Notes
Maize/corn	Good first crop because seed is large
Beans	Good mechanical seeding candidate
Sorghum	Useful in dry regions
Groundnut/peanut	Possible with larger seed metering
Vegetables	Later phase due to higher precision needs

Do not start with tiny seeds like carrot or onion unless you have a very accurate metering mechanism.

Module C — Fertilizer Application

The fertilizer system should be micro-dose capable.

Instead of broadcasting fertilizer across the whole field, the robot applies small amounts near the plant row or seed location.

Fertilizer options

Type	Best use
Granular fertilizer	Low-cost, simple, common
Liquid fertilizer	More precise, but requires clean water and pump
Compost pellet / organic pellet	Better eco-profile if locally available

Recommended design

Use a small auger-based granular dispenser.

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Fertilizer Hopper → Auger Meter → Drop Tube → Soil Placement
```

Sensors

Sensor	Purpose
Hopper level sensor	Warns when fertilizer is low
Auger rotation sensor	Confirms dispensing
Soil moisture sensor	Prevents wasteful application
GPS/row map	Applies only where needed

Precision agriculture technologies can reduce fertilizer runoff and improve profitability, but adoption is often blocked by cost and complexity. That is exactly why the design should be simple, modular, and low-cost rather than a premium robotic tractor. (GAO)

Module D — Insecticide Application

This is the most sensitive module. The machine should not blanket-spray insecticide by default. That defeats the eco-friendly goal.

The design should use targeted, low-volume application guided by crop-stage, scouting, human approval, and eventually computer vision.

Recommended insecticide module

Component	Function
Small chemical tank	5–15 liters
Low-pressure pump	Reduces drift
Solenoid-controlled nozzles	Sprays only when commanded
Shielded spray hood	Prevents drift
Flow meter	Measures actual chemical use
Camera	Detects plant/pest/disease signs
Wind sensor	Prevents spraying in unsafe conditions
Operator approval button	Required before spraying

FAO’s Integrated Pest Management guidance emphasizes reduced pesticide use, ecosystem balance, natural pest control, and lower production cost. The robot should support that philosophy rather than simply automate chemical spraying. (FAOHome)

Precision spot-spraying systems use cameras and AI to distinguish weeds or targets from crops, allowing targeted application instead of blanket spraying. (agresearch.montana.edu) Research and field reporting also show that precision and robotic spraying can reduce chemical usage, though adoption is constrained by cost, regulation, and farmer economics. (ScienceDirect)

Hard rule

For insecticide, the first version should require:

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Human confirms chemical → Robot verifies weather → Robot sprays only mapped zones
```

No autonomous unsupervised chemical spraying in version 1.

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5. Autonomy Stack

Navigation

Use a tiered approach:

Version 1 — Low-cost autonomy

Component	Function
GPS	Basic position
IMU	Heading and tilt
Wheel encoders	Distance tracking
Row-following camera	Keeps machine aligned
Physical row markers	Backup guidance

This is lower cost but less precise.

Version 2 — Higher precision

Component	Function
RTK GPS	Centimeter-level field navigation
Stereo camera or depth camera	Obstacle detection
AI vision	Plant, weed, pest, and crop-row detection
Field map	Repeatable operations

Commercial field robots such as FarmDroid use high-precision RTK and seed-location memory to enable precise seeding and later weeding or plant protection. (FarmDroid)

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6. Power System

Recommended setup

Component	Recommendation
Battery	24V or 48V $LiFePO_4$
Solar	200–600W panel canopy or charging station
Motor drive	Brushless DC or geared DC motors
Runtime target	4–8 hours per charge
Charging	Solar dock + wall/grid/generator backup

Solar on the rover helps, but be realistic: solar alone may not power heavy tilling continuously. Use solar as an extender and charger, not the only energy source.

FarmDroid is a good proof point that solar-assisted agricultural robots can support seeding and plant-protection operations, but your machine should be smaller and lower-cost for smallholder markets. (FarmDroid)

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7. Control System

Hardware

Layer	Suggested component
Main computer	Raspberry Pi / Jetson Nano-class board
Real-time controller	Arduino / ESP32 / STM32
Motor control	DC motor controllers
Communications	Wi-Fi, Bluetooth, optional LoRa
User interface	Android phone app
Emergency stop	Physical button + wireless kill switch

Software

Function	Software behavior
Field mapping	Farmer walks boundary once
Row planning	App generates row paths
Task planning	Select till / plant / fertilize / spray
Autonomy	Robot follows row
Logging	Records seed count, fertilizer, spray volume
Safety	Stops for humans, animals, obstacles

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8. Operating Workflow

Step 1 — Field Setup

Farmer uses phone app to define:

```
Field boundary
Crop type
Row spacing
Seed spacing
Fertilizer rate
No-spray zones
Water source / charging location
```

Step 2 — Soil Preparation

Robot performs shallow strip tilling.

```
Follow row → Lower tiller → Till planting strip → Raise tool at turn
```

Step 3 — Planting

Robot plants seeds based on crop spacing.

```
Open furrow → Drop seed → Confirm seed drop → Cover seed → Log location
```

Step 4 — Fertilizing

Robot applies fertilizer near the seed or plant row.

```
Move to mapped row → Dispense micro-dose → Confirm flow → Log amount
```

Step 5 — Insecticide

Robot performs targeted spray only after approval.

```
Scan crop → Identify problem zone → Ask approval → Check wind → Spot spray
```

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9. Safety Requirements

This machine must be designed like farm equipment, not like a toy robot.

Risk	Required control
Human injury	Emergency stop, low speed, bump sensors
Animal collision	Camera + ultrasonic detection
Chemical exposure	Human approval, shielded nozzle, wind lockout
Crop damage	Row-following camera, low-speed mode
Battery fire	$LiFePO_4$ battery, fuse, BMS
Theft	GPS tracking, lockout code
Software failure	Manual override

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10. Suggested Prototype Roadmap

Phase 1 — Manual electric rover

Build the base platform first.

Goal: Move reliably in soil.

Deliverables:

```
Electric chassis
Battery system
Remote control
Emergency stop
Basic tool lift
```

Do not add AI yet.

Phase 2 — Seeder module

Add seed planting first.

Why: Seeding is easier and safer than insecticide.

Deliverables:

```
Seed hopper
Metering wheel
Drop sensor
Furrow opener
Press wheel
Seed count log
```

Phase 3 — Fertilizer module

Add micro-dose fertilizer.

Deliverables:

```
Granular hopper
Auger dispenser
Rate calibration
Application log
```

Phase 4 — Soil strip-till module

Add shallow tilling.

Deliverables:

```
Rotary strip tiller
Depth control
Lift actuator
Current/load monitoring
```

Phase 5 — Targeted spray module

Add insecticide last.

Deliverables:

```
Low-pressure pump
```

```
Shielded nozzle
Flow meter
Wind lockout
Human approval workflow
Spray log
```

Phase 6 — Autonomy

Add row-following, GPS, and field mapping.

Deliverables:

```
GPS/RTK option
Camera row detection
Obstacle stop
Phone app
Task scheduling
```

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11. Rough Bill of Materials

Subsystem	Major components
Frame	Welded steel tube, aluminum panels, tool rail
Drive	2–4 geared motors, wheels, motor controllers
Power	$LiFePO_4$ battery, BMS, solar charge controller, solar panel
Compute	Raspberry Pi/Jetson-class computer, ESP32/STM32 controller
Sensors	GPS, IMU, encoders, camera, ultrasonic sensors, soil moisture
Seeder	Hopper, metering disk, seed tube, furrow opener, press wheel
Fertilizer	Hopper, auger, motor, flow/rotation sensor
Tiller	Rotary tine head, gearbox/motor, depth wheel
Sprayer	Tank, pump, solenoid nozzles, flow meter, spray shield
Safety	E-stop, bump rail, kill switch, warning light
Interface	Android app, local web dashboard, manual joystick mode

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12. Recommended MVP Configuration

For a real MVP, do not build all four functions at once.

Build this first:

```
Electric rover
+ autonomous row following
+ seed planting
+ fertilizer micro-dosing
+ manual/assisted strip tilling
```

Then add insecticide as a controlled module later.

The most valuable first product is probably:

Autonomous planter + fertilizer micro-doser

That gives immediate farmer value, reduces labor, improves spacing, and avoids the regulatory and safety complexity of autonomous pesticide spraying.

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13. Key Design Tradeoffs

Decision	Recommendation	Reason
Wheels vs tracks	Wheels first	Cheaper and easier to repair
Full till vs strip till	Strip till	Lower energy, better soil protection
Gas vs electric	Electric	Lower operating cost, solar compatible
Full autonomy vs supervised	Supervised autonomy	Safer and more realistic
Blanket spray vs spot spray	Spot spray only	Eco-friendly and lower chemical cost
RTK GPS now vs later	Later option	Cost-sensitive MVP
AI vision now vs later	Later	Start with row-following and logging

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14. Practical Machine Summary

MicroFarm Rover should be a small electric autonomous farm assistant, not a miniature tractor. It should use a modular tool system to perform:

1. Shallow strip tilling
2. Precision seed planting

3. Micro-dose fertilizing
4. Targeted, human-approved insecticide application

The smartest design path is to start with planting and fertilizing, because those are high-value, measurable, and safer. Add tilling next, then add insecticide only after the machine has reliable navigation, logging, safety controls, and farmer approval workflows.

The core value proposition:

A low-cost autonomous farming rover that helps small farmers increase yield, reduce manual labor, reduce chemical waste, protect soil health, and operate without dependence on large tractors or diesel fuel.