AI-Driven Satellite Monitoring and Robotic Solutions for Sustainable Farming with Pest and Disease Management

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ABSTRACT

Traditional farming practices often struggle with efficient crop health monitoring and pest management, leading to resource wastage, increased costs, and environmental degradation. This project presents an innovative AI-driven solution combining satellite data, advanced analytics, and robotic systems to address these challenges.

The system provides segmentation and identification of intervention target areas through a suite of NDVI, GNDVI, and NDRE analyses of Sentinel-2 Multispectral Satellite data over extensive agricultural fields, thereby enabling the detection of significant pest outbreaks and associated diseases. An easy-to-use application designed for farmers offers two basic options for pest identification and disease detection. All that the farmer would need to do is take pictures of the affected plants, and this application will be able to identify the pests and diseases, thereafter advising chemical, organic, and natural management measures based on the crop and pest in question.

Conventional pest infestations are tackled by an autonomous robotic car designed with advanced technologies for sustainable pest management. A range of biological sprays, testing, and ultrasonic repellents are employed against flying pests, while ground-level pests are managed by using vacuum systems, traps, and fogging treatments. The integration of sensor data with real-time communication to enhance pest control efforts while minimizing adverse environmental impacts.

The artificial intelligence process analyzes sensor information for better pest detection accuracy and predicting impending infestations for proactive management. This integrated system allows the farmers to make decisions based on environment-friendly solutions to practice sustainable agriculture.and improving crop productivity.

INTRODUCTION

Farmers face challenges in monitoring crop health and pest infestations across large areas in an efficient manner due to the limitations of the conventional tools. Hence, they find themselves using resources inadequately, spending more money, and damaging the environment, as current methodologies miss the level of accuracy required in targeted solutions.

The objective is to build a system using AI for the detection of crop diseases and pests over larger areas, based on satellite data and plant images, with real-time advisories provided for the farmers on control measures (natural, organic, and others, separately) with regard to pest type and crop.

The solution applies satellite data, AI-based analysis, and robotic systems to create precise crop monitoring and sustainable pest control. Satellite software checks how crops are doing, maps areas that require intervention, and assists the farmer with allocation of resources and problem management in real time. The segmentation of large farms into smaller-sized areas allows for the provision of added insight into the specific needs of these areas for a more tailored approach to agricultural management.

It is possible for a farmer to download such applications on his/her mobile devices to upload images of wilting or diseased plants, granting diagnosis for the suffering condition and recommending different methods to manage it. Natural controls will usually first be suggested, which may be followed either by organic solutions or by chemical remedies, but only as a last resort. In case the infestation becomes very severe and long-lasting, an automated vehicle system will come into play for controlling pest insects. This advanced robotic pest control will apply biologicals, traps, and ultrasonic repellents for flying pests, followed by vacuum systems and fogging for control against ground-dwelling pests. AI analytics boosts pest detection efficiency, real-time monitoring, and foresight in modelling future outbreaks. This will empower a farmer through eco-friendly and insightful solutions for sustainable farming.

NEED FOR THE PROJECT

The motive behind the development of this system lies in the rising need for farmers to use advanced, sustainable tools for precise crop monitoring and pest management that minimize resource wastage and allow environmental health. Between 20% and 40% of crops are lost to pests and diseases on a global scale every year, according to the Food and Agriculture Organization. 3 billion kilograms of pesticides are used worldwide every year, with only 1% of all pesticides being used effectively against insect pests with target plants.

In India, crop diseases in major crops such as rice, wheat, sugarcane, cotton, and pulses inflict an annual loss of ₹50,000 to ₹60,000 crores.The global Precision farming market size is expected to grow at a CAGR of 10.7% from USD 9.7 billion in 2023 to USD 21.9 billion by 2031.

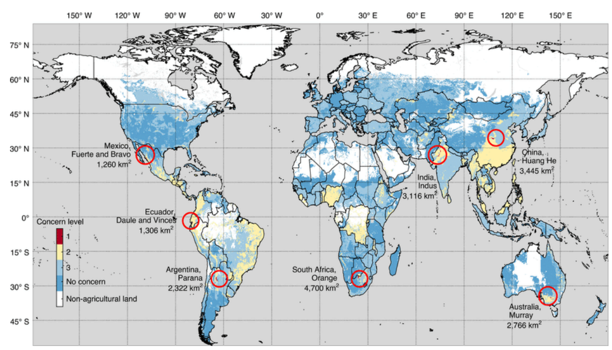


Fig.1 Global map of the regions of concern defined by pesticide pollution risk, water scarcity and biodiversity Regions of level 1 concern are areas of high pesticide pollution risk,and high biodiversity.

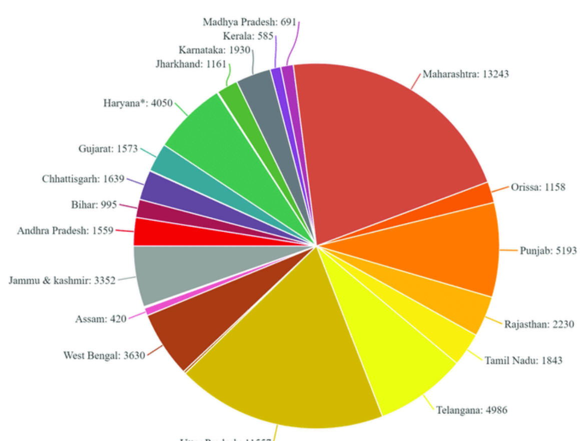


Fig.2 Pesticide use in India (2020-21), [Unit: Metric tons (M.T)].

RESOLVED CHALLENGES

Satellite data, Sentinel-2 multispectral images enables an in-depth analysis of wide agricultural areas divided into smaller sections for parameters calculation. These include NDVI, GNDVI, and NDRE.

The solution merges robotic systems, satellite information, AI-powered analysis for accuracy crop monitoring plus earth friendly pest control.The target sites are obtained after computing these parameters, providing critical insights into crop health and resource needs.

Farmers can access an app with two key features:

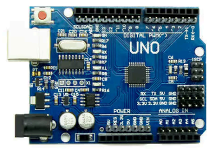
Disease Detection: When a plant image is uploaded, the app analyzes it for diseases and suggests appropriate remedies or medicines.

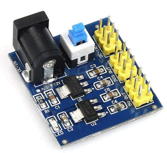
Pest Detection: Upon uploading an image, the app detects pest presence and recommends natural control methods as the first line of action.

If natural methods are insufficient, the system deploys a robotic car system for pest control.The car control system offers an eco-friendly way to deal with pests on farms. It uses technology that lets it move by itself and has special tools to help. For bugs that fly, there are sprays made from living things, as well as lights and sounds that scare them off. If there are bugs on the ground, the car can suck them up, catch them or cover an area in fog. By talking to each other all the time and sharing information about what they see, these cars work together to kill pests more efficiently – without causing as much harm to wildlife or the wider environment as current methods do.

COMPONENTS

IMAGE	NAME	DESCRIPTION
	Raspberry pi 5	The Raspberry Pi 5 is used in processing live feed, running AI algorithms for crop monitoring, and controlling robotic systems for eco-friendly pest control.

	Arduino Uno	It is used for taking inputs from raspberry and sending switching signals for relays, to turn on and off pest control devices.
	Esp32 Cam module	Used to send live feed on the app for the surveillance
	Wed Cam	used to capture high-resolution images of crops for disease and pest detection.
	TT Gear motor and Wheels	The TT Gear motor provides the necessary torque for movement, while the wheels enable the robot to navigate the farm autonomously
	Lm298 motor driver	The LM298 motor driver is used to control the TT gear motors in the robotic car system.
	4 wheels chassis	provides the structural foundation for the robotic car system. It supports the TT gear motors, wheels, and other components

	Computer fan	It represents the vacuum pump to suck the insects from plants
	Ring light	It represents the light trap to attract the insects by ligth
	Humidifier	It represents the fogger or the spraying natural pesticides
	Relay	It converts switching signals from arduino to electrical switching
	Power Module	Provides power to all components in the system with different voltages.

BLOCK DIAGRAM & METHODOLOGY USED

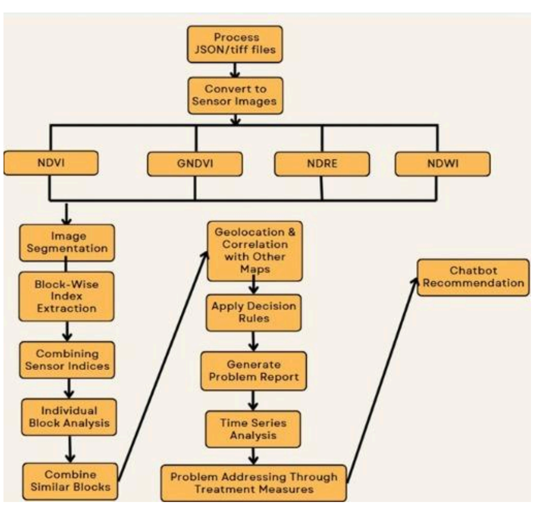


Fig.3 Satellite Data processing Flow

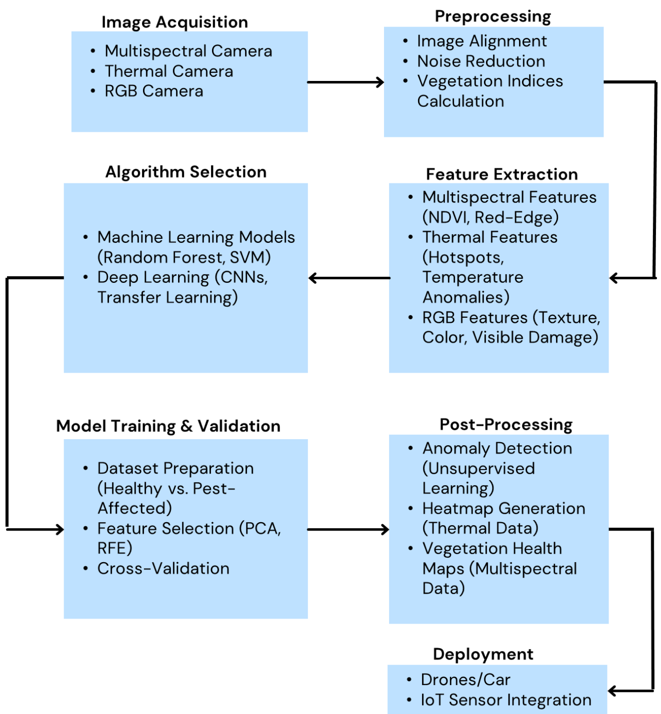


Fig.4 Image processing flow

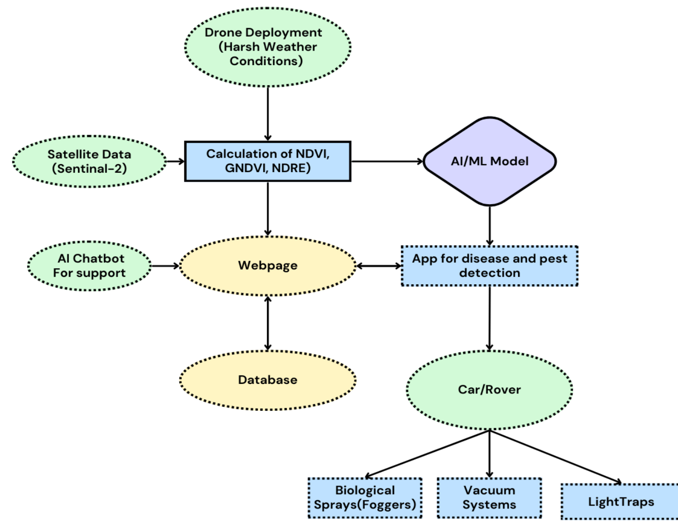


Fig.5 Robotic car working flow

APP DEMONSTRATION

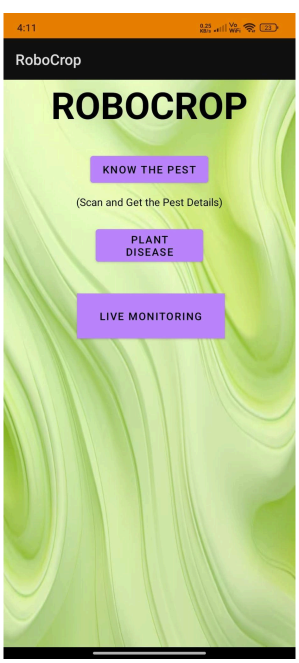


Fig.6a App Home page

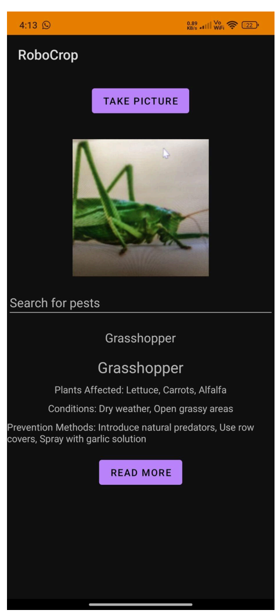


Fig.6b Know the pest

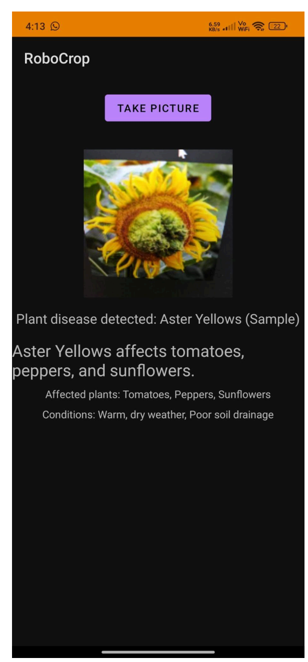
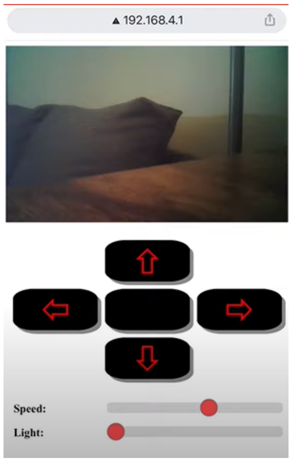


Fig6c plant disease detection



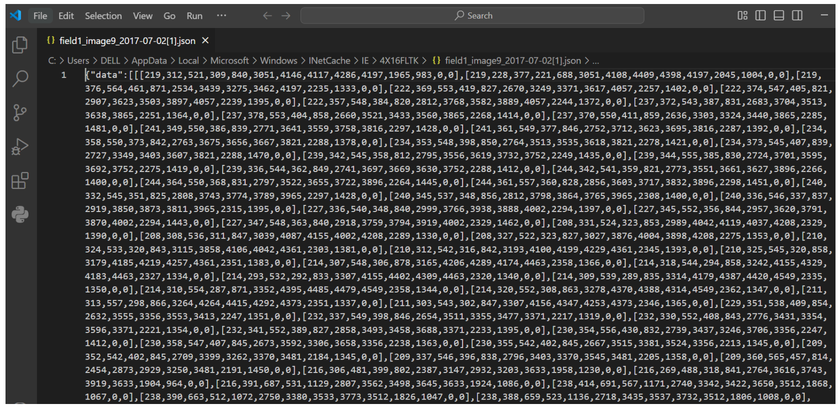


Fig.6d Live monitoring and control of car

Fig.7 Multispectral data from sentinel v2 satellite

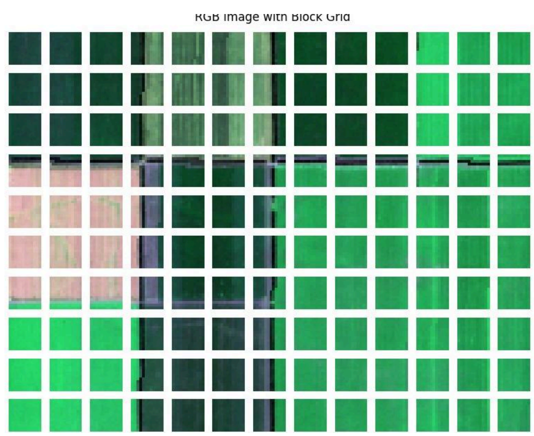


Fig.8 Converting total plot(field) into blocks

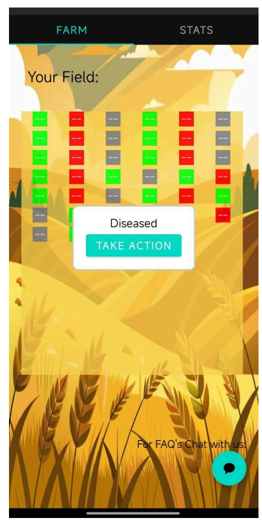


Fig.9 Health status of Block

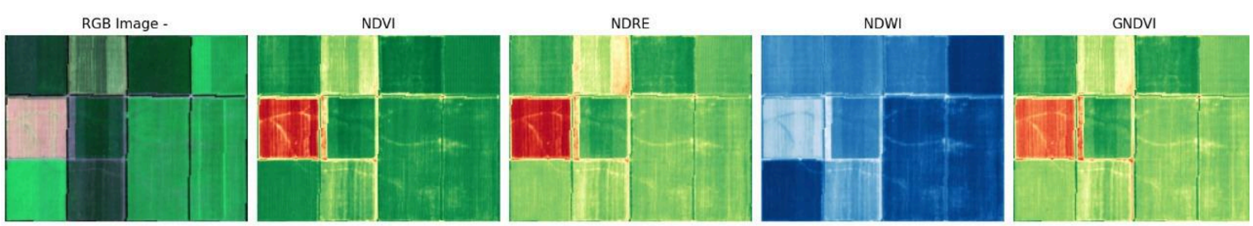


Fig.10 Different parametric images of field

PROTOTYPE

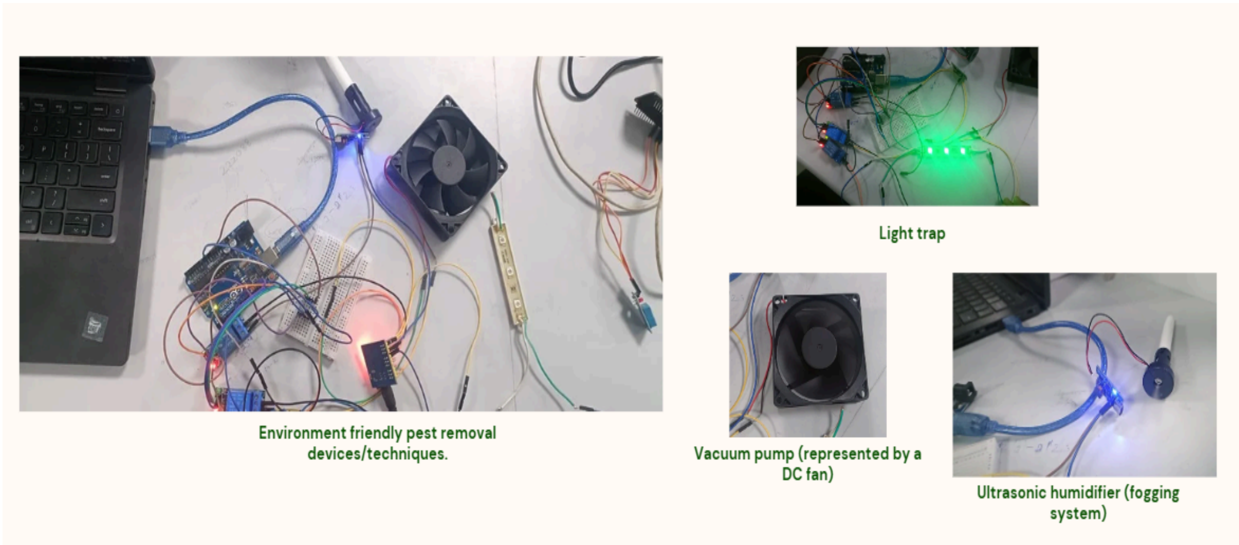


Fig.11 Individual working before attaching to robot (Tested with different pests)

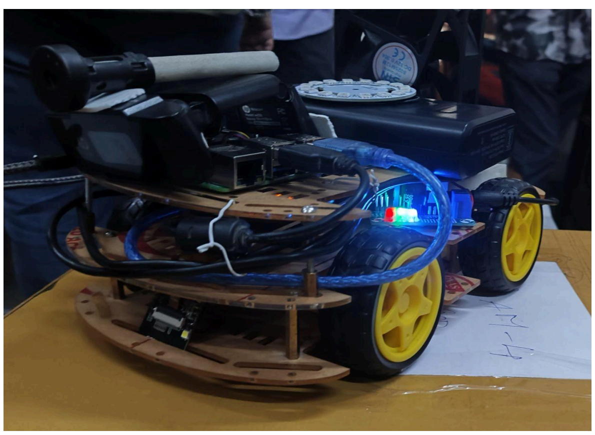


Fig.12 Functional Robot

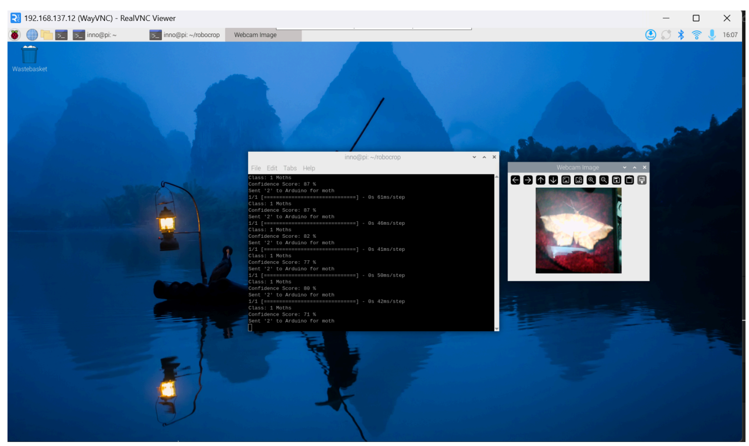


Fig.13 ML model prediction in raspberry pi

CONCLUSION

The **AI-driven satellite monitoring and robotic solution for sustainable farming** offers a groundbreaking approach to modern agriculture. By integrating **AI, robotics, and satellite imagery**, this project enhances **real-time monitoring**, reduces **pesticide overuse**, and improves **overall crop health**. The **precision farming approach** not only helps **farmers maximize yield** but also contributes to **environmental sustainability** by promoting **responsible resource utilization**.

By leveraging **real-time data**, farmers can make **informed decisions**, optimize **resource allocation**, and reduce dependency on **harmful chemicals**. The project emphasizes **natural pest control** methods, which help maintain **ecological balance** while increasing **farm productivity**.

Furthermore, the adoption of **AI-powered automation** in agriculture supports **sustainable farming practices** by reducing **land degradation** and **minimizing environmental impact**. As advancements in **AI and robotics** continue to evolve, this system has the potential to **redefine the future of agriculture**, making farming more **efficient, productive, and environmentally conscious**.

FUTURE SCOPE

There is a lot that can still be done to make this project even better for the environment and for farmers—it has a great deal of potential. One idea we are working on is to add sensors that measure humidity and temperature: if we can fit these into our system, they will take constant readings on things like how damp or dry the air is. We would then use specially designed computer programs that can learn for themselves (artificial intelligence) to decide if there might soon be a problem with bugs eating crops or a plant illness spreading. If the sensors issue a warning early enough, farmers will have time to do things which stop the threat becoming serious – such as using chemicals more carefully or changing the way their machines work.

In addition, we think it could be possible to teach the robots new tricks so that they need less help from human beings while at work and can cover bigger fields or do more things each day. One machine alone does not currently have very long range for talking to others (for instance to say ‘I need help’ or ‘I’ve found some bugs’) but this might change if we upgrade their software. Should such improvements become reality, there could also be scope for incorporating additional devices into our networked robotic workforce: further ahead still they might make use of highly advanced “deep learning” algorithms enabling them to provide extremely detailed crop assessments continuously alongside up-to-the-minute environmental reports.