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Article

AGRICULTURAL AUTOMATION: DRONE AND ROBOTIC SYSTEMS WITH RURAL INTERNSHIP TRAINING MODELS

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Abstract: - Agricultural automation has emerged as a transformative force in modern farming, particularly in the context of food security and rural development in countries like India. Unmanned Aerial Vehicles (UAVs) and ground-based robotic platforms are now seen as practical tools for precision agriculture. Yet, their adoption in rural settings remains uneven, partly because technical capacity among farmers and agri-workers is limited. This paper examines the landscape of drone and robotic technologies used in agriculture, their operational advantages, and the barriers that slow their diffusion into rural areas. More importantly, it proposes a structured internship-based training model as a practical intervention to bridge this gap. Drawing on published literature, government policy documents, and field-based observations from agrarian communities in Rajasthan and Punjab, this review argues that technology alone is insufficient, it must be accompanied by accessible, hands-on training embedded in rural institutions. The proposed model integrates classroom instruction, field simulation, and mentored deployment into an eight-week training cycle suitable for agricultural colleges and Krishi Vigyan Kendras (KVKs). It is hoped that such a model, if adopted at scale, can democratize access to automation and support a new generation of technically equipped rural agri-preneurs.

Keywords: Agricultural Drones, Robotic Systems, Precision Agriculture, Rural Internship, Skill Development, India, UAV, Agri-Tech Training.

1. INTRODUCTION

India has over 140 million farm holdings, where majority are smallholder farms with limited access to any mechanization or modern agronomic inputs (FAO, 2022). In this context, sensors, unmanned systems, and machine learning are making precision agriculture more and more popular all around the world, both a challenge and an opportunity. The potential is in cutting production expenses, better yield prediction and less physical effort in farming. The problem is that the majority of these technologies come from settings that are quite different from Indian or South Asian farming environment.

In particular, agricultural communities have been interested in drones also known as UAVs or unmanned aircraft systems. The aerial survey capability of large areas in a short period of time with little agrochemical spray drift and the ability to create multispectral imagery for crop health assessment has been proven in trials in Andhra Pradesh, Maharashtra, and Haryana (ICAR, 2021). The ground robots, however, are starting to be used in selective harvesting, soil testing and weeding. These systems, combined, represent a change from the thinking of broad acre, input oriented farming to a more focused, data driven approach.

However, there is a disconnect. The very farmers best able to benefit from these systems may not be able to adopt them because of digital literacy or financial constraints or institutional capacity and support. Extension services are thinly spread. Agricultural universities are starting to adjust curricula, but limited experience with drone and robotic platforms. This is not just a problem in India; similar trends can be seen in parts of Latin America, Southeast Asia and sub-Saharan Africa (CGIAR, 2020).

This paper argues that skill development and in particular, the ability to develop skills through structured rural internship models is as critical as the technology itself. It provides an overview of the current scenario of agricultural automation, the important challenges to automation, and a practical training model based on the ground realities in rural India. The review is conceptual; however, it is based on empirical studies published in the literature and government initiatives like Sub-Mission on Agricultural Mechanization (SMAM) and Digital Agriculture Mission.

Research Objectives

To examine the role of drones and robotic systems in agricultural automation.

To identify major barriers affecting the adoption of agricultural automation in rural settings.

To analyse the importance of rural internship-based skill development models.

To propose a practical internship training framework for agricultural automation in rural India.

2. BACKGROUND AND MOTIVATION

2.1 Evolution of Agricultural Automation

Path of agricultural mechanisation has been similar to the pattern of overall technological progress. The first wave brought the tractors and mechanical harvesters, and the second wave added chemical inputs and irrigation management, and the model proposed in this paper is based on three design principles derived from the literature of adult learning and vocational training, autonomous machines and artificial intelligence (Fountas et al., 2020). This third wave is characterized by the level of detail in the information it produces, and how quickly that information can be used to inform on-farm decisions.

Around 2010, drones started to be used in agriculture in a significant manner for aerial photography and then for vegetation index mapping with normalized difference vegetation index (NDVI) analysis (Tsouros et al., 2019). In 2018, commercial manufacturers in China, the US, and Israel sold agricultural drones capable of transporting liquid payloads of 10–16 kg which had been certified for agricultural purposes. In India, the Directorate General of Civil Aviation (DGCA) published the Drone Rules 2021 which provided a more definite regulation framework for the drone operations in agriculture.

Theoretically, robotics in agriculture has been around for a little longer, but in the real world, applications in agriculture are slower to be deployed in the field because of the complexity of unstructured outdoor environments (Bac et al., 2014). Initially the systems were in the greenhouse to automate picking robots for tomato and cucumber, and have now been expanded to field systems. NAO robots that identify weeds and weed them independently (like the Naïo Oz and Tertill) and computer vision fruit pickers (which are currently under development) are two areas of active research, as are soil sampling robots that are controlled by GPS waypoints.

2.2 UAV Applications in Precision Agriculture

Crop monitoring using remote sensing is the most popular use of drones in Agriculture. Farmers and agronomists can make use of multispectral cameras mounted on a fixed wing or multi-rotor UAV to have an accurate map of biomass, chlorophyll content and water stress at a fraction of the cost of satellite imagery and with far greater temporal flexibility (Kondraju, 2025). It has been reported that application of nitrogen fertilizer on the basis of UAV-NDVI mapping of wheat and rice fields in Punjab saved 18-22% of fertilizer without any reduction in yield (Guan et al., 2019).

Spraying with pesticides and herbicides are also significant uses. Manual boom sprayers are typically used to spray agrochemicals that are applied uniformly across the field, resulting in over application in healthy areas and under application in stressed areas. Sprayers can be programmed using real-time crop maps for what researchers call variable rate applications (VRA) and UAV sprayers can vary the amount of spray produced by the nozzle. A field experiment conducted in Telangana state between conventional spraying and VRA using drone showed that the latter was able to achieve almost 30% less use of pesticides and still maintained the same pest control (Balaji et al., 2022).

In addition to spray and sensing functions, there are various other applications of drones in farming such as sowing of seeds in paddy fields with submerged water, support in pollination in orchards, monitoring of livestock in rangeland systems, etc. The payload, software and skills requirements for each application are different, making the training design challenge discussed later difficult.

2.3 Ground-Based Robotic Systems

Ground robots used in agriculture come in all shapes and sizes and perform a variety of tasks. Wheeled platforms are appropriate for row crops which have enough row space to permit autonomous navigation such as soybean, cotton and sunflower. Tracked vehicles perform better in soft sand, but are mechanically more complex. More recently, legged robots — like those developed at Boston Dynamics' Spot — are being tested at orchards where the terrain is very rough and it is difficult to use wheels.

The most commercially developed ground robots are for autonomous transplanting and harvesting in high value crops. Examples of what is technically possible are the Berry5 strawberry-picking robot, developed by Fieldwork Robotics, and the different asparagus-harvesting systems being developed in Europe. The Central Institute of Agricultural Engineering (CIAE), Bhopal has created prototype robots for sugarcane and maize cultivation, albeit their implementation at the field level is limited (ICAR-CIAE Annual Report Bhopal, 2024).

The importance of robot navigation in crop and weed classification, ripe fruit detection, diseased leaf detection and the use of computer vision and machine learning for robot navigation path planning is an important cross-cutting theme in the robotics literature. There are practical implications for training programs for rural populations in different agro-climatic zones, because models trained on one agro-climatic zone have been found to do poorly in another. There is a generalization problem with models trained on one agro-climatic zone and then tested in another, which has practical implications for training programs targeting rural populations across different agro-climatic zones.

2.4 Barriers to Adoption in Rural Settings

There are several obstacles to adoption in rural areas. There are some challenges to adoption in rural communities.

In agricultural systems involving smallholders or rural farmers, there are several groups of barriers that have been consistently found in the literature. Several clusters of barriers have been consistently identified in the literature for agricultural systems involving smallholders or rural farmers. These are the economic constraints, which are very common: A commercial agricultural drone costs INR 4 lakh to INR 15 lakh, and a capable ground robot can cost several times more. Even after subsidies given under schemes like SMAM, it becomes difficult for small and marginal farmers to invest in the initial stage (Chand, 2020).

Economic problems are exacerbated by infrastructural problems. Advanced machines have limited practical applications in remote areas due to factors such as the quality of GPS signals in hilly areas, intermittent power supply for powering up the machine, and the lack of local repair and maintenance facilities. No service center within 200 km. can destroy the drone more than if it didn't exist in the first place (Rahimi et. al. 2022).

Last but not least, policy and regulatory constraints continue to be an issue. Drone Rules 2021 streamlined the previous rules, but for certain missions, like night flights, or flying near sensitive areas, additional permissions still require cumbersome administrative procedures that deter small operators.

While a few studies have been concerned with the concepts of precision agriculture and UAV applications, little has been studied on well-structured rural internship programs that combine drone and robotic technologies with on-field agricultural education. This paper tries to fill this gap by suggesting a model for the practical implementation of internship to be deployed in the context of rural India.

3. OVERVIEW TO KEY TECHNOLOGIES IN AGRICULTURAL AUTOMATION

The table 1 provides a summary of some of the primary categories of drones and robotic systems currently available/being developed for agricultural uses. This isn't an exhaustive list and is meant as a guideline to understanding what there is to consider when designing a training program that will need to cover the diversity of platforms. The table 1 provides a summary of important drone and robot platforms that are being used in agriculture

Table 1: Comparison of Key Drone and Robotic Platforms in Agricultural Automation

Technology	Primary Application	Key Advantage	Limitation

Fixed-Wing UAV	Crop monitoring, large farm aerial survey	Long range, fuel-efficient	Cannot hover; requires runway
Multi-Rotor Drone	Precision spraying, seed dispersal	Hovering capability, easy control	Short battery life (~25 min)
Ground Robot (Wheeled)	Soil sampling, weeding, harvest assist	High payload, stable	Limited to flat terrain
Legged Robot	Uneven terrain navigation, scouting	Terrain adaptability	High cost, complex control
Autonomous Tractor	Ploughing, sowing, harvesting	GPS-guided, proven tech	High initial investment

Indeed, most deployment scenarios in the real world are not a one-platform solution, but a mix of these platforms. The workflow of precision agriculture could start with a fixed-wing UAV for a broad area survey, followed by a multi-rotor drone for targeted spraying in stress-identified areas, and a network of sensors on the ground to deliver real-time soil moisture information. This integrated workflow is an important point of pedagogical design in training programmes, not machines.

4. PROPOSED RURAL INTERNSHIP TRAINING MODEL

4.1 Rationale and Design Principles

The course begins by examining the principles and rationale behind the design of software.

Agricultural training in India is largely supply oriented, that is, faculty and equipment determines the content of the course, rather than farmers' needs and field realities. This results in the graduate being aware of the theory of remote sensing but never having flown a drone, or a Krishi Vigyan Kendra with a demonstration drone which remains unused due to the lack of anyone in the staff who is certified to fly the drone.

The model presented here is based on three design principles taken from the literature on adult learning and vocational training. Learning should start based on realistic tasks the trainees should use real equipment, operate in real field conditions as early as possible in the program. Second, training should be modular and stackable short, verifiable competency units enable people who are unable to attend longer programmes to obtain partial qualifications. Third, the training ecosystem needs to be locally rooted: Partnerships with the local Panchayat Raj institutions, farmer producer organizations (FPOs), and district level agriculture departments are key to sustainability.

4.2 Program Structure

The internship is proposed to be conducted for eight weeks in any agricultural diploma college, Krishi Vigyan Kendras or government agricultural polytechnic. They require two multi-rotor agricultural drones, one of which needs to be GPS-enabled, a ground rover equipped with the GPS, and access to a minimum ten-acre demonstration farm. The following table 2 specifies the phases. The proposed 8-weeks Rural Internship Training Framework is presented in this table.

Table 2: Proposed Eight-Week Rural Internship Training Framework

Phase	Duration	Training Activities	Assessment
Phase 1	Weeks 1–2	Classroom & simulation — drone basics, sensor types, safety protocols	Pre-test, quiz
Phase 2	Weeks 3–4	Field observation — supervised UAV flight, data logging exercises	Field report
Phase 3	Weeks 5–7	Hands-on operation — solo spraying missions, robot calibration drills	Performance rubric

Phase 4	Week 8	Capstone project — full farm audit using integrated drone + robot system	Mentor evaluation

4.3 Target Participants and Selection Criteria

The following groups are targeted by the project and the selection criteria:

The main target group for this training model are young agricultural graduates or diploma holders ages 18-30, preferably from farming families or with previous experience of farm machines. The modular design, however, also enables adaptation to:

Experienced farmers or farm managers who want to acquire new knowledge and skills

In the communities where women are playing a pivotal role in the care of crops, the members of the women self-help groups (SHG) are included.In the communities where women play a pivotal role in the care of crops, members of the women SHG are included.

Agricultural extension officers working under the state government or NGOs

Staff members from FPO to oversee shared equipment pools

The competition for selection into the full 8 weeks programme should be based on a brief interview and a simple numeracy and digital literacy test. This is not to say that rural participants are not welcome, rather to ensure that trainees have the necessary competencies to participate in the technical content.

4.4 Institutional Partnerships and Funding

Equipment, field space, and qualified instructors are essential for any training program. In the Indian scenario, the three institutional pillars are most promising. The first one is the network of Krishi Vigyan Kendras which has more than 700 Krishi Vigyan Kendaras across the country, the objective for which is to transfer the technology in an applied manner. The second is the agricultural universities and their outreach and extension departments. The third is the private sector drone manufacturers and Agri-tech companies with a commercial interest in growing the number of users of their products.

The funding can be potentially tapped from the various streams such as the Sub-Mission on Agricultural Mechanization (SMAM) under the Ministry of Agriculture and Farmers Welfare, the Skill India Mission under NSDC partnership, CSR of agri-input companies and various schemes launched by the state government for youth employment in agriculture. A combination of public and private funds will be more sustainable than relying on one government program.

5. EXISTING INITIATIVES AND EVIDENCE

The model presented here is unique in combining drone and robotic training with pedagogy of rural internship, but there are some precedents that can be noted. Since 2020, ICAR-Central Research Institute for Dryland Agriculture (CRIDA) has been conducting short duration drone trainings for farm women in Telangana with good adoption rates, which are observed post-series (CRIDA, 2022). With the support of the government, the Garuda Aerospace startup has already trained more than 500 drone pilots, among which about 40% are rural youths. The partnership between PAU (Punjab Agricultural University) and the private drone service providers has resulted in a model in which trained pilots operate drones as per custom-hire basis that is an Agri-drone service economy in Punjab.

The FarmHack network in the Netherlands and the AgTech Rural Training Initiative in Kenya offer similar examples at the international level of using open-source hardware and community-led pedagogy to speed the uptake of rural technology. The Kenyan case is especially relevant as it happens in a smallholder context, with less infrastructure and heavy donor engagement all of which are also common in many Indian districts.

The above cases indicate that agricultural automation training in the rural areas is possible and that it can create enduring changes in farmer practice and productivity provided support is provided for market access to the skills developed. Someone who isn't capable of employment or custom hiring, and has no career pathway to maintain or deploy skills, is less likely to do so. That is why the proposed model places greater emphasis on enabling training and the development of institutional settings (FPOs, custom hiring centers, and service start-ups) within which trained people can apply their skills in the economy.

6. CHALLENGES, LIMITATIONS AND FUTURE DIRECTIONS

This paper argued the inculcation of drone and robotic technology training into rural internship systems. However, it would be uneducated not to recognize the shortcomings of this argument and the hurdles that would arise in the real world.

The first is that the training model idea is so complex that its implementation is hard to sustain in the Indian bureaucracy. KVKs, agricultural universities, district administrations and private companies are not necessarily on the same page or on the same schedule. Creating and sustaining effective multi-institutional partnerships is challenging, and typically not highlighted in policy documents, but is essential for programme success.

Secondly, there is a fast pace of change in technology in this area. Current drone hardware and software platforms may be replaced in 3-5 years. If training programs are developed for the specific platforms instead of concepts and skills, they may become obsolete very fast. This is a call for a more principles-based approach to curriculum design with regular updates to the modules as well as access to manufacturer training resources.

Thirdly, the gender aspect of agricultural technology uptake needs to be given a larger consideration than this paper does. In India, crops require more agricultural labor than other tasks, especially from women, who are doing a large share of labour, especially in the tasks where robots could be most beneficial, such as care, weeding, and post-harvest handling of crops. However, technology training programs, if not intentionally designed to be inclusive, often cater to a mainly male clientele base. This is a challenge that needs to be tackled through pro-active marketing initiatives, flexibilities in schedules, and considerations of safety and social norms related to women's transport.

Then of course, there's the data question. The more detailed data that drones and robots gather at the farm level, the more questions are raised about ownership, access to and commercial uses of that data. They are real problems faced by precision agriculture today, around the world. No training programme can neglect data rights and digital literacy as fundamental elements will leave farmers inadequately prepared to participate in the new agri-data economy.

7. CONCLUSION

Drones and robotic technologies represent a truly viable and proven way to make agriculture more productive, cut crap waste of inputs and alleviate some of the physical workload in the rural sector. The body of evidence on these benefits is emerging, but is sufficiently robust to warrant policy and investment focus.

Technological is the less pressing limitation, this paper suggests, because the more important one is human. Rural India and similar regions lack the skills necessary to deploy, maintain and make decisions from farm systems, where automation is used. To close this divide, a planned and ongoing investment in "on the ground" training is necessary, not just classroom-based learning, not just demonstrations but a planned programme of internships where rural youth have multiple supervised opportunities to engage with working systems in actual farm settings.

The proposed 8 weeks rural internship model is one that can be followed. It is not a unique structure, but one that will need to be adapted to local contexts, availability of equipment and institutional capacity. However, it is a beginning point and a framework that is aligned with the principles of adult learning and has been found, at least in part, to be effective in the context of what has been done in India, and elsewhere.

Hopefully it is reasonable to believe that once agricultural automation can be scaled up through the training of capacity through KVKs, agricultural colleges and public-private partnerships, then it will be taken up. The technology is available. The challenge is to whether rural training can catch up..

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