

WATER AND AGRICULTURAL RESILIENCE IN THE FACE OF CLIMATE CHANGE

RÉSISTANCE DE L'EAU ET DE L'AGRICULTURE FACE AU CHANGEMENT CLIMATIQUE

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ABSTRACT

Climate change poses a profound global challenge, heightening vulnerability and exposure to risks that disrupt societies worldwide. It intensifies extreme weather events, exacerbating threats to water security and agricultural productivity through heat waves, prolonged droughts, erratic monsoons, floods, and cyclones. These phenomena aggravate water scarcity and crop failures, particularly in vulnerable regions like India, where agriculture consumes over 80% of freshwater resources yet loses up to 60% due to inefficient practices. The present study focuses on tackling the above issues via an integrated digital platform in the field of water with aquaWISE and agriculture with fieldWISE. This study proposes an integrated AI-enabled digital framework combining hydrological intelligence, remote sensing, IoT systems, and geospatial analytics to strengthen climate-resilient water and agricultural governance. It advances water security across the food-water-energy nexus, with deployments in over 8 cities serving around 1.3 million people. Flood monitoring covers 406 reservoirs and 35 river basins, while digital twins enable real-time oversight of 1,832 km of water conductor systems. Notable impacts include onboarding about 20 million farmers via fieldWISE, monitoring around 200,000 irrigation tanks, and reducing energy consumption by 8%. By leveraging satellite data integrated with AI/ML models, the fieldWISE platform enables periodical sowing progression monitoring, crop health assessment, crop classification, pictorial pest detection, agricultural monitoring, and climate-smart operations through field-level risk advisories. Together, these systems address risks from inadequate preparedness through timely alerts and early warnings, enabling informed decision-making. Demonstrated outcomes include advisories to around 12 million farmers, processing large amount of satellite data across 15.4 million hectares of farmland, a 10-15% potential yield increase, protection of around 800,000 hectares from pests. This paper outlines various impacts and applications using aquaWISE and fieldWISE by its innovative approaches, technical frameworks, demonstrated impacts, and scalable pathways for building climate-resilient water-agriculture systems.

Keywords: Climate resilience, AI irrigation, digital twins, aquaWISE, fieldWISE, aquaIRRIGATION, precision agriculture, water optimization, Water Security, remote sensing, Geospatial analysis

RESUME

Le sérieux défi posé par le changement climatique souligne la vulnérabilité et l'exposition aux risques susceptibles de perturber les sociétés globales. Il intensifie les événements météorologiques extrêmes, aggravant les menaces pesant sur la sécurité hydrique et la productivité agricole à travers des vagues de chaleur, des sécheresses prolongées, des moussons erratiques, des inondations et des cyclones. Ces phénomènes aggravent la pénurie d'eau et les mauvaises récoltes, en particulier dans des régions vulnérables comme l'Inde, où l'agriculture consomme plus de 80% des ressources en eau douce mais perd jusqu'à 60% en raison de pratiques inefficaces. La présente étude se concentre sur la résolution des problèmes ci-dessus grâce à une plateforme numérique intégrée - aquaWISE pour la gestion de l'eau et FieldWISE pour l'agriculture. Cette étude propose un cadre numérique intégré activé par

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l'intelligence artificielle (IA) combinant l'intelligence hydrologique, la télédétection, les systèmes IoT et l'analyse géo-spatiale afin de renforcer la gouvernance de l'eau et de l'agriculture résistante au climat. Elle fait progresser la sécurité hydrique à travers le lien entre alimentation-eau-énergie, avec des installations dans plus de 8 villes desservant environ 1,3 million de personnes. La surveillance des inondations couvre 406 réservoirs et 35 bassins versants, tandis que les jumeaux numériques permettent une surveillance en temps réel de 1 832 km de systèmes de distribution d'eau. Les impacts remarquables incluent l'intégration d'environ 20 millions d'agriculteurs via fieldWISE, la surveillance d'environ 200 000 réservoirs d'irrigation et une réduction de 8% de la consommation d'énergie. En exploitant les données satellitaires intégrées aux modèles d'IA et d'apprentissage automatique (ML), la plateforme fieldWISE permet une surveillance périodique de la progression des semis, une évaluation de la santé des cultures, une classification des cultures, une détection picturale des insectes nuisibles, une surveillance agricole et des exploitations climato-intelligentes grâce à des conseils sur les risques à l'échelle de la parcelle. Ensemble, ces systèmes traitent les risques liés à une préparation inadéquate à travers les alertes et les avertissements précoces en temps opportun, permettant ainsi une prise de décision éclairée. Les résultats démontrés comprennent des conseils à environ 12 millions d'agriculteurs, le traitement de grandes quantités de données satellitaires couvrant une superficie de 15,4 millions d'hectares de terres agricoles, une augmentation potentielle du rendement de 10 à 15% et une protection d'environ 800 000 hectares de terre contre les insectes nuisibles. Cet article souligne divers impacts et applications de l'aquaWISE et de l'fieldWISE en mettant en lumière leurs approches innovantes, leurs cadres techniques, leurs impacts démontrés et leurs voies évolutives permettant de construire des systèmes eau-agriculture résistants au climat.

Mots-clés : Résistance climatique; Irrigation par IA; Jumeaux numériques; AquaWISE; FieldWISE; AqualRIGATION; Agriculture de précision; Optimisation de l'eau; Sécurité de l'eau; Télédétection; Analyse géospatiale.

INTRODUCTION

India's agrarian economy is increasingly vulnerable to climate variability, diminished reservoir inflows due to reduction of glaciers, altered precipitation patterns, and significant canal conveyance losses (FAO 1989; CWC 2011; Kulkarni & Nagarajan 2019). Extreme climatic phenomena such as El Niño and La Niña further intensify droughts, floods, and monsoon variability, impacting agricultural productivity. Conventional flood-based irrigation exacerbates groundwater depletion and yield volatility, with wheat outputs projected to decline by 10–40% by 2050 (Bhattarai *et al.* 2023). Climate-Resilient Agriculture offers a pathway to sustainability through improved irrigation management, climate-smart cropping systems, geospatial intelligence, AI, remote sensing, IoT, and digital decision-support systems

LITERATURE REVIEW

Many studies are performed in the field of climate change, change in temperature, extreme conditions due to climate change, greenhouse effects, and climate resilient agriculture. In addition to this, human intervention by deforestation and industrialization has also added to long term changes in weather and temperature leading to modern climate change (Wilson and VanBuren 2022). This leads to an increase in carbon dioxide levels, which leads to an increase in greenhouse effects globally. This results in a rise in global temperatures by 2030-2052, posing risk to global food security and agricultural productivity mainly in low and middle -income nations (United Nations 2015; NOAA 2024; IPCC 6th Assessment ReportWG1 2021). Agriculture is the main backbone of the Indian rural economy. With an increase in climate change with extreme weather conditions the agricultural stability is greatly impacted (Singh *et al.* 2021). The staple crops of India for example rice and wheat also face a major threat with this diverse climate. It is estimated that by 2050 there exists a need for climate resilient agriculture across various climate zones (Shanabhoga *et al.* 2020 ; Srivastav *et al.* 2021). Climate Resilience Agriculture (CRA) is an important way for increasing resilience and productivity by integrating modern techniques and traditional knowledge (Singha *et al.* 2024). There are many studies which emphasize that CRA can improve water management and food security (Sekaran *et al.* 2021). With an increase in climate change, erratic rainfall, and changing levels of CO₂ in addition to pest infestations and diseases have

brought agricultural instability and huge economic losses (Mohapatra *et al.* 2022; Kumar and Gupta 2021). Hence there comes a need to empower the farmers for increasing the national food security to meet the demands of the projected population of India which is about to reach 1.7 billion by 2050 (United Nations 2015; Government of India 2014; Swaminathan and Bhavani 2013). Hence it becomes mandatory for adopting CRA in effective policy frameworks and good governance to meet the complex challenges. This gives way to integrate farming practices which will build food security and enhance sustainability (Aich *et al.* 2022). It is thus evident that despite significant advancements in climate-resilient agriculture, there remains limited integration between basin-scale water intelligence systems and farm-level digital advisory ecosystems which is taken care of, in the present work realising the importance of CRA practices for sustainability in Indian agriculture and food security.

OBJECTIVES OF THE STUDY

Based on the above studies the following objectives are formulated as follows:

- To develop an integrated digital framework for climate-resilient water and agricultural management.
- To demonstrate the role of AI, ML, remote sensing, and IoT in supporting predictive water governance and precision agriculture.
- To evaluate the application of digital twins and geospatial intelligence for irrigation optimization, flood forecasting, and drought resilience.
- To assess the scalability and operational impact of integrated water–agriculture intelligence systems across Indian agro-climatic regions.
- To examine the contribution of digital climate resilience platforms toward sustainable development and food security. Unlike conventional CRA studies focusing on isolated interventions, this work integrates hydrological intelligence, irrigation management, digital agriculture, and disaster resilience into a unified operational ecosystem.

METHODOLOGY & METHODS

The present study addresses water and agriculture challenges under climate change through climate-resilient agriculture, sustainability, food security, improved farmer livelihoods, smart agriculture powered by fieldWISE, and water security through aquaWISE. It presents an integrated water and agricultural intelligence ecosystem developed by Vassar Labs, combining AI, ML, Remote Sensing, GIS, Hydrological and Hydraulic Modeling, IoT, and DPI. aquaWISE and fieldWISE support climate resilience through inflow forecasting, adaptive irrigation scheduling, cost monitoring, and pest identification with advisories, spanning the hydrological cycle from rainfall monitoring and water management to drought resilience.

aquaWISE serves as the flagship “Digital Public Infrastructure for Water,” integrating SCADA telemetry from 205+ reservoirs, 200K irrigation tanks, satellite imagery, weather APIs, and crowdsourced gauges into digital twins for forecasting and optimization (**Figure 1**). aquaWRIMS serves as a state scale water resources intelligence platform for unified water management using AI, satellite data and IoT to deliver real time insights, forecasting and decision support, aquaFLOOD provides flood risk assessments, early warnings, and AI-powered prediction models. aquaIRRIGATION delivers crop-water advisories using digital twins, satellite indices, soil IoT probes, CNNs, LSTMs, SAR/optical imagery, and ET estimation.

The framework includes aquaWISE integrating aquaWRIMS, aquaDROP, aquaLAKE, aquaWELL, aquaIRRIGATION, Water Budgeting Intelligence Systems, fieldWISE, aquaCITY, aquaFLOOD, and aquaDROUGHT, connecting water data across rainfall, surface water, groundwater, irrigation, agriculture, urban water, flood forecasting, and drought resilience. Vassar Labs’ solutions optimized 205 reservoirs, empowered 15M+ farmers, delivered 20–30% productivity gains and 25–40% water savings,

conserving billions of cubic meters annually. In Odisha, GOWATER monitors 13 major and 59 medium irrigation projects with real-time insights for efficient water distribution.



Figure 1. Architecture of aquaWISE

By integrating data from IoT sensors, SCADA systems, satellite observations, weather agencies, and hydrological models, it provides real-time visibility of reservoirs, canals, rivers, pumps, and irrigation networks. The platform supports flood forecasting, reservoir operations, irrigation planning, and drought assessment through dashboards and GIS-based visualization. AI and machine learning enhance predictive accuracy and decision-making, while alerts and advisories strengthen response during critical situations and support climate-resilient water management (Figure 2).

aquaDROP: The water cycle begins with rainfall, making rainfall intelligence essential for effective water resource management. Leveraging hydro-meteorological intelligence and climate analytics, Vassar Labs developed aquaDROP, an AI-powered platform integrating AWS, rain gauges, Doppler weather radar, IMD forecasts, global weather models, and satellite precipitation data for real-time rainfall monitoring, forecasting, rainfall-runoff estimation, reservoir inflow prediction, flood preparedness, drought monitoring, and decision support (Figure 3).

aquaLAKE and aquaWELL: Water storage systems are critical for long-term water security. Leveraging geospatial intelligence and water analytics, Vassar Labs developed aquaLAKE and aquaWELL to create digital twins of surface and subsurface water systems. Integrating satellite imagery, terrain models, IoT observations, and AI-driven analytics, the platforms monitor storage, sedimentation, groundwater, water quality, and support reservoir management, groundwater sustainability, climate resilience, and water accounting (Figure 4).

aquaIRRIGATION enables irrigation and canal water management through IoT-enabled canal sensors, SCADA systems, reservoir monitoring, satellite imagery, AI/ML, remote sensing, GIS supports flow monitoring, reservoir release planning, irrigation scheduling, soil moisture assessment, crop water demand estimation, and water allocation optimization. It optimizes releases based on soil moisture, crop stage, acreage, forecasts, reducing wastage up to 60% in Haryana, Andhra Pradesh, Telangana. It is implemented across 30 projects covering 120 million hectares, supporting 15 million farmers and 1,200 government officers (Vassar Labs 2025).

aquaFLOOD: aquaFLOOD is Vassar Labs' integrated flood forecasting and flood intelligence platform designed for proactive disaster preparedness and resilient water management. It combines real-time hydro-meteorological data, reservoir and river monitoring, satellite observations, IoT sensors,

hydrological and hydraulic models (HEC-HMS and HEC-RAS), and AI/ML analytics for flood forecasting and early warnings. It also predicts river and reservoir inflows and provides an interactive dashboard for stakeholders. By integrating rainfall forecasts, SCADA, gauge data, and geospatial intelligence, it enables real-time flood monitoring, risk analysis, inundation assessment, and decision support.



Figure 2. aquaWRIMS(representative purpose)

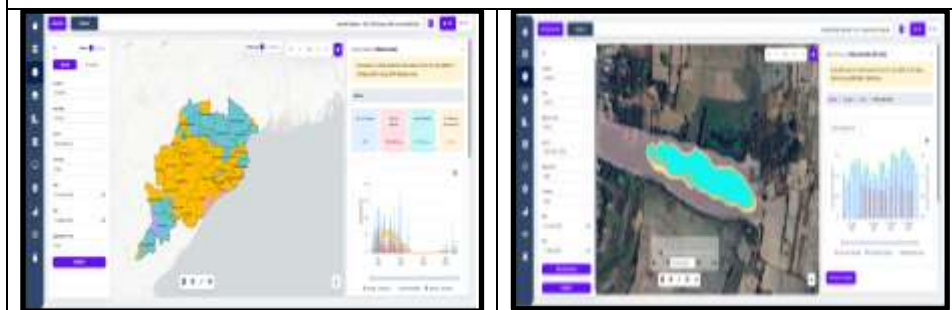


Figure 3. aquaDROP



Figure 4. aquaLAKE

Basin Scale water Budgeting and allocation intelligence Sustainable water governance requires understanding of basin inflows, reservoir storage, irrigation demand, groundwater interactions, and climate variability. Leveraging integrated water resource management, Vassar Labs has developed basin-scale water intelligence and allocation systems using hydrological modeling, geospatial analytics, remote sensing, IoT observations, and AI/ML forecasting. The platform integrates watershed analytics, reservoir monitoring, climate intelligence, and decision support for inflow forecasting, demand assessment, reservoir planning, and optimized water allocation.

aquaCITY: Urban areas increasingly face water stress due to rapid population growth, aging infrastructure, urban flooding, and climate variability. Leveraging its expertise in integrated water intelligence and smart governance systems, Vassar Labs developed aquaCITY to provide data-driven urban water management through smart distribution systems, stormwater analytics, groundwater monitoring, and urban flood intelligence. The platform integrates smart meters, IoT sensors, SCADA systems, and geospatial intelligence to support real-time monitoring, leak detection, flood preparedness, water distribution optimization, and sustainable urban water governance.

FIELDWISE

fieldWISE is a first-of-its-kind, state-wide integrated digital agriculture, remote sensing and AI DPI designed to unify farmer, land, crop, soil, weather, market, and government systems intelligence within a single platform. This is deployed in Kerala as KATHIR, in Andhra Pradesh as APAIMS. The present study operationalizes Climate Resilient Agriculture (CRA) through the scalable and data-driven fieldWISE framework across the agricultural ecosystems of Andhra Pradesh, and Kerala. The framework enables advanced applications such as dynamic AI-assisted field mapping, crop health monitoring, crop classification, pest detection, phenology assessment, and wetness indexing. These capabilities are

achieved through automated field boundary delineation and real-time crop and pest monitoring using AI models integrated with multisource datasets, including remote sensing–based optical and microwave satellite data from Sentinel, Landsat, and Planet Scope constellations, among others. The description of each of these systems is provided below. Developed with a field-centric approach, fieldWISE addresses real-world agricultural challenges at the farm level. The platform incorporates AI and ML capabilities for farm boundary delineation, crop advisories, disease and pest alerts, crop loss assessment, and an AI-powered assistant. By leveraging integrated real-time data, it enables timely, location-specific advisories and supports officials through digitized workflows, real-time monitoring, and intelligent decision-support systems (**Figure 5**).



FIGURE 5. Architecture of fieldWISE

FIELDWISE IN KERALA:

The primary beneficiaries include farmers, agricultural officers, vendors, and allied stakeholders. fieldWISE has strengthened service delivery efficiency, enhanced transparency, and positioned Kerala as a leading model for an AI-driven platform for agriculture. Acting as a DPI for agriculture, fieldWISE empowers farmers and supports the supply chain from sowing to market. It integrates remote sensing, GIS, AI deployment, multilingual mobile-first design, and human-in-loop validations. The platform links crop-sown data from farm to state level, supports harvest assessment, soil health insights, and fertilizer recommendations. The localized advisories, early warnings for pest forewarning and extreme weather help in risk reduction, increase efficiency and dependence on intermediaries. Regular health monitoring helps in long term resilience under variable climatic conditions. fieldWISE dashboard has been divided into three phases as as unified agriculture database, agro-advisory services and soil moisture-based irrigation and as integration with e-market place.

fieldWISE has been applied successfully at Kerala agriculture system delivering over 13.2 lakh+ farmers registered and 1.5 lakh+ mobile app downloads where the platform shows a strong adoption, enabling seamless access to farm-linked services. More than 9 lakh farmers have applied for digital farmer ID cards, with 3.5 lakh IDs already issued. Over 4,000 agriculture officers have actively streamlined farmer verification, plant doctor consultations, and agro-advisories across more than 185 crops. Integration with 35+ soil testing laboratories across the state has enabled data-driven Soil Health Cards and precise fertilizer recommendations. Powered by AI/ML and remote sensing, fieldWISE has geo-tagged over 1.6 million farm boundaries, 35.36 million plantation trees beyond survey and sub-survey levels, while classifying more than 1.1 million hectares of major crops to deliver accurate crop intelligence.

Routine AI/ML assessments of 180,000+ paddy farms support production planning and policy formulation, augmented by 800,000+ daily personalized advisories on weather, crop stress, pests, irrigation, and nutrients. Real-time monitoring of 800,000+ farm plots boost transparency, climate resilience, and farmer empowerment. Additional features like farm mechanization services, farm input (fertilizer, pesticide and seeds) stock availability proximate to plots and an integrated eMarketplace linking FPOs and agribusinesses streamline input access and foster direct market connections, ultimately enhancing income and efficiency throughout the agricultural value chain (Figure 6,7).



Figure 6: Webinterface for statelevel officers



Figure 7. Mobile APP for Farmer and their services

FIELDWISE IN ANDHRA PRADESH:

fieldWISE is a unified portal implemented during 2017–18 for Andhra Pradesh to promote sustainable agriculture at mandal, district, and state levels while addressing climate change challenges. It supports cultivators and the agriculture department through a digital agriculture ecosystem aimed at enhancing income, improving agricultural GVA, and enabling data-driven decisions via real-time monitoring. It enables planning, policy, resource optimization, climate-resilient operations, and end-to-end services across pest management, financial planning, irrigation advisories, and market trends. It empowers cultivators with schemes, advisories, training, and capacity building through a mobile app with Sowing Advisory, Crop Planning, Pest Advisory, and AI Assistant.

Farmer Digital Connect and Precision Advisory

The platform integrates farm records, crop planning, irrigation guidance, pest-disease alerts, fertilizer recommendations, and market intelligence into unified digital ecosystem. . By leveraging Soil Health Card data, crop stage information, farm history, weather forecasts, irrigation conditions, satellite observations, and agronomic knowledge systems, the AI Assistant generates precision advisories tailored to individual farms.

Hyper-Local Advisory and Crop Risk Forewarning

Hyper-Local Advisory and Crop Risk Forewarning delivers advisories to village, mandal, and farm-level recommendations using GPS-tagged locations, satellite imagery, weather grids, soil variability, and crop patterns, with early alerts for drought, pests, diseases, cyclones, heatwaves, and unseasonal rainfall.

Conversational AI and Government Scheme Integration

The AI Assistant is a multilingual conversational platform on Farmer App and WhatsApp, enabling voice or text interaction in Telugu and English. It supports queries on crops, weather, pests, fertilizers,

markets, and scheme eligibility. It integrates Farmer Registry, PM-KISAN, land records, and departmental systems for scheme identification, tracking, reminders, and subsidy access.

Data Ecosystem and Technology Architecture

fieldWISE is powered by a multi-source data ecosystem integrating national and state datasets, weather observations, land and agricultural records, field-level systems, scientific recommendations, ECMWF forecasts, and satellite imagery. Hosted within the State Data Centre, it uses sovereign AI architecture, specialized AI agents, RAG, vector databases, and a hybrid LLM infrastructure combining Google Gemini and open-source LLMs for secure, contextual, and intelligent response generation.

AI for Monitoring – Sowing and Crop Status at Farm Level

fieldWISE implements a large-scale AI-enabled crop monitoring framework for near real-time assessment of sowing activity and crop status across Andhra Pradesh. It integrates satellite remote sensing, geospatial analytics, and machine learning to generate parcel-level insights across 1.44 crore agricultural parcels covering 82 lakh acres. Sowing progression uses multi-temporal optical and SAR satellite data. AI/ML geospatial workflows enable assessment of sowing status, crop growth stages, and spatial distribution, supporting planning, resource allocation, policy interventions, climate-resilient agriculture (**Figure 8**)

AI for Climate Resilience – Crop Health Monitoring

fieldWISE incorporates AI-driven crop health monitoring systems to identify vegetation stress and productivity anomalies at parcel level. It combines satellite-derived vegetation indices, historical crop signatures, weather observations, and anomaly detection algorithms to generate near real-time crop health intelligence. The system uses Sentinel-2 multispectral imagery deriving NDVI, LSWI, and SASI, analyzed temporally to detect deviations from expected growth. Historical 5–7 year datasets are used to establish crop-specific seasonal baselines and phenological patterns. ML-based anomaly detection identifies chlorophyll stress, water stress, and delayed growth, supporting irrigation planning, climate adaptation, and targeted advisories.

AI for Monitoring – Crop Acreage at Farm Level

The framework uses Sentinel-1 SAR, Sentinel-2 multispectral optical imagery, and high-resolution Planet Scope imagery. Sentinel-1 SAR supports monsoon monitoring via cloud penetration and crop structure sensitivity. Crop classification uses CNNs and LSTM with temporal features, combining radar backscatter and optical signatures. It identifies paddy, maize, cotton, black gram, red gram, and groundnut and integrates outputs with registries, parcels, crop booking, subsidies, and insurance via geospatial infra.

AI for Monitoring – Horticulture at Tree Level

fieldWISE has developed a tree-level horticulture intelligence system using ultra-high-resolution satellite imagery and deep learning-based object detection to estimate plantation extent, tree density, and horticulture distribution for planning. Using 0.3-meter imagery, crowns via multi-headed CNNs using YOLO and Mask R-CNN, classifying coconut, oil palm, and mixed plantations. It has mapped 3.77 coconut crore and palm trees across Andhra Pradesh and extended to mango, lime, and cashew, supporting census, yield estimation, subsidy targeting, climate resilience, and monitoring.

AI for Climate Resilience – Crop Health Monitoring

fieldWISE incorporates AI-driven crop health monitoring to identify parcel-level vegetation stress and productivity anomalies. The framework combines satellite-derived vegetation indices, historical crop signatures, weather observations, and anomaly detection algorithms to generate near real-time crop

health intelligence. Machine learning models detect nutrient stress, water stress, disease impacts, and delayed growth, while crop health intelligence system supports scientific irrigation planning, climate adaptation, and targeted agricultural advisories (**Figure 9**)

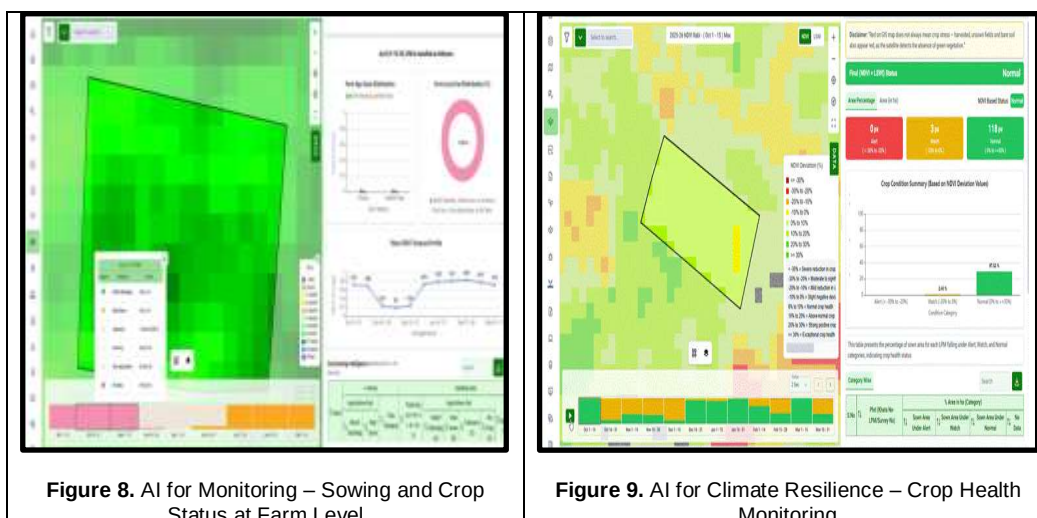


Figure 22 AI

AI for Climate Resilience – Pest Precision Management

fieldWISE integrates AI-based pest and disease forewarning systems to support predictive crop protection strategies by combining meteorological variables, crop stage information, historical pest incidence data, and computer vision models. Supervised machine learning algorithms, time-series forecasting, and probabilistic risk scoring identify high-risk zones and generate preventive advisories. The platform also supports mobile-based pest diagnosis, where farmers upload crop images for automated symptom classification using CNN-based models. The AI engine identifies probable infestations and recommends remedial measures based on agronomic protocols, improving extension service accessibility and reducing indiscriminate pesticide usage.

Conclusion

It can be inferred from the above given frameworks and case studies that Vassar Labs advances in state-scale water resource management using advanced technology, flood simulations, smart irrigation, AI for groundwater revival, nowcast, cloud top temperature and inventory of models positioning India as a global blueprint for AI-water **DPI**. Scalability hurdles, data sparsity in remote areas, farmer digital literacy, and model generalization amid non-stationarity are tackled via data-agnostic adapters, multilingual GenAI, and federated learning. The platforms support real-time monitoring, predictive analytics, flood forecasting, irrigation optimization, crop intelligence, pest forewarning, and field-level advisories within a unified decision-support ecosystem. Case studies from Andhra Pradesh, Telangana, Odisha and Kerala highlight their practical scalability and contribution toward improved water-use efficiency, agricultural productivity, and evidence-based governance. By transforming water and agricultural systems into continuously monitored digital ecosystems, these frameworks enable proactive planning and sustainable resource management. Overall, aquaWISE and fieldWISE present a scalable model for climate-resilient governance, sustainable agriculture, enhanced water security, and long-term food security in climate-vulnerable regions. Future trajectories emphasize multi-hazard digital twins coupling water-energy-food nexuses. Keeping this in view, Vassar Labs makes geospatial intelligence accessible to all. This strengthens water and agriculture resilience, sparks sustainable development, and safeguards food security too.

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