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Overview

Crop failure remains a major concern for farmers and agricultural economies, especially in developing countries like India. Traditional methods of monitoring are often reactive, inaccurate, or delayed. With the rise of AI and access to multivariate datasets (like weather, soil, crop, and satellite data), there is a growing opportunity to build smarter systems that can predict failure before it happens. This paper proposes a beginner-level AI framework that combines various data inputs to improve the prediction of crop failure, supporting farmers and policymakers with early alerts and insights.

Introduction

Agriculture is highly dependent on natural and environmental factors. Unpredictable rainfall, poor soil quality, excessive pesticide use, and emerging plant diseases can all contribute to crop failure. Although some AI solutions have been developed in this area, most are limited to one or two parameters — such as only using rainfall or NDVI values. This study aims to build a multivariate crop failure prediction system using weather, soil, satellite imagery, and plant health data. The model, trained with diverse data sources, will offer farmers and authorities a better way to anticipate failure risks and take early preventive measures

Agriculture is the backbone of India’s economy, employing nearly half of the population and contributing significantly to food security. Despite its importance, Indian farmers continue to face a wide range of problems that affect their productivity, income, and overall livelihood. These issues are both structural and socio-economic in nature, and they persist even after decades of policy interventions and technological progress.

[17] India is the second largest producer of wheat and rice, the world's major food staples. India is currently the world's second largest producer of several dry fruits, agriculture-based textile raw materials, roots and tuber crops, pulses, farmed fish, eggs, coconut, sugarcane and numerous vegetables.

About Major Crops in India [18]

- Various food and non-food crops are grown in different parts of the country depending upon the variations in soil, climate, and cultivation practices.
- Major crops grown in India are rice, wheat, millet, pulses, tea, coffee, sugarcane, oil seeds, cotton, jute, etc.

[19] **Top 10 Leading Agricultural States of India**

India is an agricultural powerhouse, with a diverse range of crops grown across its vast landscapes. Here are the top 10 leading agricultural states in India:

1. Punjab
2. Uttar Pradesh
3. Maharashtra
4. Madhya Pradesh
5. Rajasthan
6. Bihar
7. Andhra Pradesh
8. Karnataka
9. Tamil Nadu
10. West Bengal

Farmer Suicides [19]

The National Crime Records Bureau (NCRB) data reveals a grim picture of the agrarian crisis in India. Between 1995 and 2014, as many as 296,438 farmers ended their lives, highlighting the chronic distress within the agricultural community. The problem did not abate in the following decade. Between 2014 and 2022 alone, an additional 100,474 farmers died by suicide, indicating that structural challenges in Indian agriculture remain unresolved despite various policy interventions and relief measures.

In 2022, the NCRB report documented those 11,290 persons engaged in the farming sector died by suicide. Of these, 5,207 were cultivators (farmers owning or leasing land) and 6,083 were agricultural labourers, accounting for 6.6% of the total suicide deaths recorded in the country for that year. These figures underscore that both farmers and farm labourers—despite being at different levels of the agricultural value chain—continue to face immense economic and social hardships.

The causes behind these suicides are multifaceted. Farmers often struggle with crop failures due to erratic monsoons, pest attacks, or natural disasters, which severely reduce yields. Coupled with rising input costs (such as seeds, fertilizers, and pesticides) and low output prices, many farmers are unable to recover their investments. Dependence on informal credit at high interest rates, indebtedness, and lack of access to institutional financial support worsen their situation. For agricultural labourers, underemployment, seasonal work, low wages, and lack of social security contribute significantly to their vulnerability.

The rising trend of suicides also reflects psychological stress, social pressures, and a lack of adequate mental health support in rural areas. While governments at both the central and state levels have introduced loan waivers, crop insurance schemes, and income support programs,

the persistence of suicides indicates that these measures have not been sufficient in addressing the root causes of agrarian distress.

This crisis not only affects the lives of farming families but also has broader implications for food security, rural stability, and the socio-economic fabric of India, considering that nearly half of the country's workforce still depends on agriculture and allied activities for their livelihood.

Farmer Debt

According to [20], nearly **50 per cent of agricultural households in India were indebted in 2019**, highlighting the widespread financial stress in the farming sector. On average, each indebted household carried an outstanding loan of **₹74,121**, which indicates not only the high dependence of farmers on credit but also their vulnerability to debt traps. These loans often originate from both institutional sources (such as banks and cooperatives) and non-institutional sources (such as moneylenders), with the latter usually charging higher interest rates. The burden of debt, combined with fluctuating crop prices, rising input costs, and uncertain weather conditions, has made repayment extremely difficult for many farmers, thereby exacerbating the agrarian distress.

Real World Problems: -

1. Droughts

Many regions, such as Maharashtra and Rajasthan, face recurring droughts due to low rainfall. Droughts reduce soil moisture, damage standing crops, and limit the availability of drinking water for both people and livestock. This leads to massive crop losses and farmer distress. According to [10] In six years (2015-21), the country lost 33.9 million hectares of the cropped area due to floods and excess rains and 35 million hectares due to drought, which are likely to intensify as various studies predict.

2. Floods

Seasonal floods in states like Bihar, Assam, and Uttar Pradesh submerge farmlands for weeks. Standing crops are destroyed, fertile soil gets washed away, and farmers lose both food and income. Floods also increase the spread of crop diseases. According to [9] on an average every year, 75 lakh hectares of land is affected, 1600 lives are lost and the damage caused to crops, houses and public utilities is Rs.1805 crores due to floods.

3. Unseasonal Rainfall

Sometimes rainfall occurs during harvesting periods, damaging crops like wheat, onions, and pulses. The quality of produce reduces drastically, and farmers are forced to sell at very low prices. Unseasonal rain has become more common in recent years due to climate change. According to [8] Unseasonal rain damaged crops on 30,000 hectares across state.

4. Declining Soil Fertility

Overuse of chemical fertilizers and pesticides has reduced the natural fertility of soil. Continuous monocropping without proper crop rotation depletes essential nutrients. As a result, yields fall despite higher investment in inputs. According to [7] Punjab and Telangana report NPK consumption rates of 74.50% and 94.78%, respectively — levels that threaten soil health and long-term agricultural sustainability.

5. Salinity and Alkalinity of Soil

In coastal regions and irrigated areas with poor drainage, salt accumulation in soil is a major problem. High salinity reduces crop growth and lowers productivity. Alkaline soils are also unsuitable for many food grains and vegetables. Around 6.727 million ha area in India, which is around 2.1% of geographical area of the country, is salt-affected, of which 2.956 million ha is saline and the rest 3.771 million ha is sodic [6]

6. Pest Infestations

Farmers often suffer from large-scale pest attacks such as locust swarms. These insects can destroy entire fields within hours. Without timely support, farmers lose their crops and incur huge financial losses. According to [3] Over 200,000 hectares crops lost to locust attacks since 2019

7. Crop Diseases

Fungal, bacterial, and viral diseases frequently affect crops like rice, wheat, and cotton. These diseases spread quickly, especially under humid or changing climatic conditions. Farmers often lack proper guidance to control outbreaks effectively. The global damage to rice, wheat, and maize by the fungi accounts for $60 billion each year. [5]

8. Climate Change

Global warming has led to unpredictable seasons and changing weather patterns. Crops that were once suited to a region may no longer grow properly there. This creates long-term challenges for farmers who rely on traditional practices. According to [4] absence of adoption of adaptation measures, rainfed rice yields in India are projected to reduce by 20% in 2050 and 47% in 2080 scenarios.

9. Extreme Weather Events

Farmers increasingly face extreme weather events such as cyclones, hailstorms, and heatwaves. These events cause sudden and massive crop destruction. With limited resources, farmers struggle to recover from such unexpected disasters. According to [2] India has faced extreme weather events on 93 per cent of the days in the year's first nine months -- 255 out of 274 days -- marked by heat and cold waves, cyclones, lightning, heavy rain, floods and landslides.

10. Lack of Education and Awareness

Many farmers are unaware of modern farming techniques, government schemes, crop insurance, and financial support systems. Limited access to digital tools and training widens the knowledge gap. According to [1] there are around 70% farmers in India who are unaware of modern farming techniques that is ~77 million

How are we going to help farmers to deal with these problems: -

🌦 **1. Hyperlocal Weather & Agromet Alerts *(Dependence on Monsoons)***

- Deliver field-specific forecasts (via push notifications, SMS, and voice calls) in the local language.
- Include rainfall probability, expected intensity, and temperature range to guide farmers on irrigation, sowing, and harvesting.
- Provide dynamic sowing and harvest advisories based on weather windows, helping farmers decide the safest time to plant or reap.
- Share seasonal trend warnings (delayed monsoon, above-normal rainfall, or extended dry spells) with simple do's and don'ts for preparedness)

💧 **2. Drought Early-Warning & Water-Storage Planner *(Droughts)***

- Real-time alerts about impending dry spells using satellite and weather data.
- Interactive water-budget calculator to show farmers how much water they have stored and how long it will last for their fields.
- DIY guided designs for small farm ponds, check-dams, or rooftop harvesting with step-by-step instructions.
- Suggestions on low-water requirement crops and alternate sowing practices when drought risk is high.

🌊 **3. Flood Alerts & Post-Flood Recovery Checklist *(Floods)***

- Early-warning system with push/SMS alerts on flood or cyclone risks, localized to the farmer's GPS location.
- Evacuation guidance (livestock, seeds, machinery, and family safety measures) with reminders.
- Crop and grain storage safety steps (elevated platforms, waterproof bags, drying methods).
- Photo-based damage reporting tool so farmers can upload field pictures for insurance claims or government relief.
- A step-by-step recovery checklist (soil cleaning, crop replanting, pest prevention) after floods.

🌧 **4. Harvest-Time & Unseasonal-Rain Notifications *(Unseasonal Rainfall)***

- Alerts when sudden rain is predicted during harvest periods.
- Instant advisory on how to quickly dry crops, cover harvested produce, or move it to safer storage.
- Safe storage guidelines (moisture-free bags, ventilated rooms, drying machines).
- Information on market alternatives and pricing trends, reducing chances of distress sales due to weather shocks.

🌱 **5. Soil-Conservation How-to Toolkit *(Soil Erosion)***

- Simple step-by-step tutorials (infographics, short videos, voice instructions) on soil conservation practices.
- Localized techniques like contour ploughing, terracing, vegetative barriers, and cover cropping demonstrated visually.
- Live demo schedules by local Agri-extension officers or NGOs, notified through the app.
- Region-specific suggestions based on soil slope, rainfall intensity, and crop type.

🌾 **6. Soil Health Report & Nutrient Plan *(Declining Soil Fertility)***

- DIY soil testing integration (farmers can enter data from low-cost soil kits or upload lab results).
- Automated NPK and pH analysis with clear, farmer-friendly recommendations.
- Fertilizer schedule generator balancing organic (compost, green manure, biofertilizers) and chemical inputs.
- Crop rotation and intercropping plans tailored to restore fertility while ensuring yield.

🧂 **7. Salinity/Alkalinity Diagnosis & Reclamation Guide *(Soil Salinity and Alkalinity)***

- Option to input soil pH/EC test values or use soil-color/photo-based diagnosis.
- Gypsum/lime dosage calculator for affected fields with clear mixing and application steps.
- Leaching schedules using available irrigation water to flush salts from root zones.
- Suggestions for salt-tolerant crop varieties suited to the farmer’ s soil condition.
- Drainage improvement tips with low-cost field layouts (e.g., shallow drains, raised beds).

🐛 **8. Pest Swarm Alerts & Community Response *(Pest Infestations)***

- Real-time pest outbreak warnings (e.g., locust swarms) via geo-tracking and government alerts.
- Farmers can report pest sightings by uploading field photos to alert nearby communities.
- Integrated Pest Management (IPM) kits with cultural, mechanical, biological, and chemical options.
- Emergency low-toxicity pesticide guides for immediate damage control.
- Community coordination tools (bulk spraying drives, joint defense efforts).

9. Crop Disease Diagnosis + Treatment Protocols *(Crop Diseases)*

- Farmers can upload photos of diseased crops, with AI-assisted diagnosis returning disease name + severity.
- Step-by-step treatment guides (biological solutions, approved chemical sprays, dosage instructions).
- Automatic reminders for follow-up treatments (e.g., second spray after 10 days).
- Direct expert contact option (nearest agri-university/extension officer) for severe or unknown cases.

10. Climate-Smart Cropping Advisor *(Climate Change)*

- Long-term crop planning using climate projections for the region.
- Suggestions for climate-resilient crop varieties (drought-tolerant, flood-resistant, heat-resilient).
- Dynamic crop calendar shifts based on rainfall/temperature predictions.
- Risk scoring system for crops under changing climate, helping farmers diversify income.

11. Extreme-Event Preparedness Toolkit *(Extreme Weather Events)*

- Cyclone/heatwave/hailstorm safety protocols for crops, livestock, and families.
- Resilient storage locator (map of warehouses, silos, shelters nearby).
- Instant before/after event checklist: e.g., tying down polyhouses, moving livestock, covering irrigation pumps.
- Post-event insurance claim guidance (what proofs, documents, and steps are required).

12. Multilingual Learning + Voice-IVR Tips *(Lack of Education & Awareness)*

- Short visual explainers (comics, stepwise pictorial guides, GIFs) for low-literacy farmers.
- Voice call/IVR advisories in local dialects, accessible even on basic phones.
- Audio-video FAQs linked to each alert/test result (e.g., Your soil needs gypsum here is how to apply it).
- Offline accessibility so content can be saved once and viewed later without internet.

Subsidies and Policies for Farmers [11] :-

a) Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) [12]

Launched in 2019, the Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) is a flagship direct income support scheme of the Government of India aimed at providing financial relief to small and marginal farmers. Under this program, every eligible farming family receives ₹6,000 annually, disbursed in three equal instalments of ₹2,000 each, directly credited to their bank accounts through Direct Benefit Transfer (DBT). This ensures transparency, reduces leakages, and guarantees that the money reaches the intended beneficiaries without middlemen.

The scheme initially targeted only small and marginal farmers owning up to 2 hectares of cultivable land, but later it was expanded to cover all farmer families, irrespective of landholding size, with certain exclusions such as institutional landholders and high-income earners.

The objective of PM-KISAN is to provide farmers with timely income support to meet their expenses for procurement of inputs such as seeds, fertilizers, and equipment, as well as to cover day-to-day household needs. By offering a steady financial cushion, the scheme aims to reduce farmers' dependence on informal credit sources, thereby lowering their debt burden.

As of recent years, PM-KISAN has become one of the largest direct cash transfer schemes in the world, benefitting over 11 crore farmer families across India. The program also forms a part of the government's larger vision of ensuring farmer welfare, financial inclusion, and rural prosperity.

Benefits: This financial aid helps farmers meet their expenses during critical periods of the agricultural cycle. It also provides some level of economic security, enabling them to invest in their crops.

b) Pradhan Mantri Fasal Bima Yojana (PMFBY) [15]

The Pradhan Mantri Fasal Bima Yojana (PMFBY), launched in 2016, is one of the most significant crop insurance schemes for farmers in India. It aims to provide comprehensive risk coverage against crop losses due to natural calamities, pests, and diseases. By safeguarding farmers from unpredictable risks, the scheme helps reduce their financial vulnerability and ensures income stability.

Under PMFBY, farmers pay only a nominal premium rate—2% of the sum insured for Kharif crops, 1.5% for Rabi crops, and 5% for commercial/horticultural crops. The remaining premium is subsidized by the central and state governments, making it affordable for farmers.

Benefits: The scheme ensures that farmers receive compensation for their losses, reducing their financial burden. Premium rates for farmers are kept low, making it accessible to all. At Kshema General Insurance, we are proud to offer crop insurance policies under PMFBY to safeguard farmers' livelihoods.

c) Kisan Credit Card (KCC) Scheme [16]

The Kisan Credit Card (KCC) scheme, introduced in 1998 by the Government of India in collaboration with the Reserve Bank of India (RBI) and NABARD, is one of the most important rural credit initiatives. Its primary aim is to provide farmers with timely and affordable short-term credit to meet their cultivation and other agricultural needs.

Under the scheme, farmers are issued a credit card–like passbook or a smart card linked to their bank account, which allows them to withdraw funds easily and use them whenever required. This ensures quick access to working capital without the need for lengthy loan approval processes every season.

Benefits: KCC offers timely financial support and flexible repayment options, reducing the need for farmers to rely on high-interest informal loans. The scheme also covers allied activities like animal husbandry and fisheries.

d) Soil Health Card Scheme [14]

The Soil Health Card (SHC) Scheme, launched in 2015, is a major government initiative aimed at promoting scientific management of soil resources and ensuring sustainable farming practices. Under this program, farmers are provided with a soil health card that contains a comprehensive analysis of their soil's condition. The card gives detailed information about key parameters such as pH, organic carbon, and levels of essential nutrients (Nitrogen, Phosphorus, Potassium, Micronutrients, etc.).

By receiving this personalized soil report, farmers can make informed decisions on the appropriate type and quantity of fertilizers, manures, and soil amendments required for their fields. This not only helps in improving crop productivity and soil fertility but also prevents the overuse or imbalance of chemical fertilizers, which has been a major cause of soil degradation in India.

The scheme operates through a network of soil testing laboratories set up across the country, where soil samples are collected from farmers' fields and analysed scientifically. Based on the test results, soil health cards are issued once every two years to all farmers.

Benefits: Proper soil management improves crop yields and reduces input costs. By maintaining soil health, farmers can enhance their productivity and reduce environmental degradation.

e) Paramparagat Krishi Vikas Yojana (PKVY) [13]

The objective is to produce agricultural products free from chemicals and pesticides residues by adopting eco- friendly, low- cost technologies. Key Thrust areas of PKVY in promoting organic farming include the following:

- Promote organic farming among rural youth/ farmers/ consumers/ traders
- Disseminate latest technologies in organic farming
- Utilize the services of experts from public agricultural research system in India
- Organize a minimum of one cluster demonstration in a village

Benefits: Farmers receive financial aid to cover the cost of certification, training, and inputs for organic farming. The scheme encourages sustainable agricultural practices, which can lead to higher market prices for organic produce.

How can the farmers access these schemes

Registration: Farmers need to register themselves with their respective State Agriculture Departments or authorized agencies to avail the benefits under specific schemes.

Required Documentation: Most schemes require basic documentation, including Aadhaar numbers, bank account details, and land records. Ensuring these documents are in order simplifies the application process.

Awareness Programs: The government frequently organises workshops, training sessions, and awareness programs to inform farmers about available schemes. Farmers can actively participate to stay updated.

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