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Smart Kanda: Assessing Challenges Faced by Farmers and Optimizing Onion Farmer Profits in Maharashtra State

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Abstract:

This research develops a comprehensive data-driven framework to enhance onion marketing decisions for farmers in Maharashtra, focusing on profit maximization through improved price forecasting, profitable market allocation, fraud detection and transportation logistics. The study combines time-series analysis, statistical modelling, operations research techniques, data visualization and building recommendation engine to address real-world challenges faced by farmers. The study uses AGMARKNET onion market data, containing arrival quantity and price information across multiple APMC markets in Maharashtra.

The study employs a mixed-methods approach: quantitative analysis of over 72,000 historical records from multiple APMC markets using linear regression for price sensitivity, SARIMAX for forecasting, and linear programming for optimization; complemented by a descriptive survey of 150 farmers (100 from Ahilyanagar/Ahmednagar district and 50 from Satara district) to capture real-world farmer's issues. achieving an average MAPE of 17.73%, MAE of 188.51 /quintal, and RMSE of $212.95/quintal$ across 84 markets, evaluated via 4-week rolling back testing. Data visualization (bar plots, moving average charts) was employed to visualize the issues faced by farmers. Successful estimation of price sensitivity (a) in 101 markets revealing a generally negative relationship between arrivals and prices. Transportation costs were modelled using a tyre-based cost table, comparing Full Load Transport (FLT: cost per km) and Partial Load Transport (PLT: flat cost per ton). For each allocated market, the minimum-cost option was selected.

Additionally, a transportation problem was solved using Operations Research techniques: the initial basic feasible solution was obtained via the Vogel's Approximation Method (VAM), followed by optimal solution through the Modified Distribution (MODI) method. This analysis calculated and proved that there is the net profit advantage of selling produce to distant high-price markets (e.g., Pune and Mumbai) compared to local markets (e.g., Ahilyanagar). The Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) is applied to model the onion supply chain timeline identifying critical activities and estimating project duration under uncertainty. Overall, all of the Descriptive Analytics, Diagnostic Analytics, Predictive Analytics and Prescriptive Analytics is done by using Python. Limitations include reliance on historical data without real-time external factors (weather, policy) and assumptions in capacity and cost models. Agriculture is highly dependent on market prices, transportation costs, and demand fluctuations across different regions. Farmers often sell their produce in nearby markets without analysing whether distant markets could provide better returns. This research proposes a data-driven framework to forecast agricultural commodity prices and optimize selling locations to maximize farmer profit.

Keywords: APMC, AGMARKNET, Recommendation engine, Time-series forecasting, Backtesting (MAPE, MAE, RMSE), SARIMAX model, Price sensitivity analysis, Profit maximization, Market allocation optimization, Linear programming, Transportation problem, Vogel's Approximation Method (VAM), Modified Distribution (MODI) method, Full Load Transport (FLT), Partial Load Transport (PLT), Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), Diagnostic Analytics, Predictive Analytics, Prescriptive Analytics, Python.

Introduction:

India is primarily an agricultural country often described as the backbone of its economy, with over 50-60% of its population relying on farming for their livelihood. It is a global leader in production, ranking as the second-largest producer of rice, wheat, cotton, sugar, and fruits. Agriculture contributes significantly to India's GDP (roughly 20.2%) and is a major source of raw materials for various industries. The country has a vast, fertile area and diverse climatic conditions, allowing for a wide variety of crops to be grown, including food grains, oilseeds, and plantation crops but farmers frequently face financial losses due to market price fluctuations, lack of price and government scheme information, and inefficient market selection. In many cases farmers sell their crops in the nearest Agricultural Produce Market Committee (APMC) market without evaluating whether better prices exist in other markets. The absence of real-time price forecasting and profit analysis leads to suboptimal selling decisions. At the same time, the Government of India provides price information through platforms like AGMARKNET, but raw data alone does not directly help farmers make decisions. Statistical and machine learning techniques can transform this data into actionable insights. This research proposes a data-driven system for market selection and price forecasting using statistical analysis, time series forecasting, and optimization methods.

The objectives:

1. To identify various issues faced by farmers through field survey.
2. To analyse agricultural market price data.
3. To forecast future prices of commodities using time series models.
4. To estimate transportation cost based on distance.
5. To reduce the total transportation cost.
6. To determine the optimal distribution of produce across markets.
7. To maximize farmer profit using optimization techniques.

Literature Review:

Several studies have been conducted in India to understand the challenges faced by farmers and the behaviour of agricultural commodity prices. Reports published by the Indian Council of Agricultural Research and highlight that farmers in India face multiple constraints including lack of storage facilities, limited market information, price fluctuations, transportation problems, and dependence on intermediaries in agricultural markets. These issues significantly affect farmers' income and market participation. Studies based on data from AGMARKNET have been widely used to analyse agricultural price movements across Indian markets. Researchers have applied time series techniques such as ARIMA, seasonal ARIMA, and exponential smoothing models to forecast prices of commodities like onion, potato, and tomato. Research supported by the Indian Agricultural Statistics Research Institute has also demonstrated the usefulness of statistical and machine learning models in agricultural price forecasting. overall, the literature suggests that combining market information systems with statistical forecasting models can improve price prediction and support farmers in making informed decisions about selling their produce across different markets.

Data and Methods:

- **Primary data:** From google form questionnaire
- **Secondary data:** From various agricultural websites and from GeoJSON containing village-level boundaries for the entire state of Maharashtra.
- **Sample size:** 150 respondents (100 from Ahilyanagar district and 50 from Satara district)

Conclusions from Graphs and Survey:

- With change in climate use of inorganic pesticides is increased. Showing no flexibility.
- Though comparing with education level farmers don't get information about government schemes on time.
- Most of the farmers sell their produce to middleman.
- On average organic fertilizers are used only 30% as compared to inorganic fertilizers.
- No enthusiasm is shown in testing soil.
- Most of the people say that farming is a good career opportunity.
- The main barrier in getting benefit of government schemes is lack of information which is not received on time.
- People are benefited by PM-Kisan yojna the most.
- No enthusiasm is shown for using agricultural mobile apps and websites.
- The 7-day and 14-day simple moving averages (SMA) closely tracked short-term fluctuations and reacted quickly to price changes, making them suitable for weekly decision-making by farmers and traders.
- Holt-Winters additive provided the closest fit to the actual price movements, successfully tracking both the medium-term trend and the recurring seasonal-like cycles of spikes and troughs throughout 2024 and into 2025. Holt's linear and simple exponential smoothing captured the overall upward and downward trends reasonably well.

Methodology:

1) LPP model [linear programming problem]

Farmer no. 32

Land: 10 acres

Crops: Wheat, Chickpea, Onion

Decision variables: x1 = acres of Wheat, x2 = acres of Chickpea, x3 = acres of Onion

Objective: Maximize profit

Onion gives no profit, so x3=0, x1=10 acres, x2=0

Wheat has high profit allocate more land within budget, labor, and water constraints.

Maximum Profit: Rs 4,80,000

Interpretation: All land should be allocated to Wheat to maximize profit under budget, labor, and water constraints. Onion is not profitable, and Chickpea is limited by labor and water.

2) PERT and CPM:

Critical path (zero slack): A1 -> A3 -> A4 -> A5 -> A7 -> A9 -> A10

Sum of TE durations along these paths = 91.84 days (project expected duration).
Project standard deviation: ~4.19 days.
Fraud Detection:
P.M. Kisan: Taxpayers and Professionals: 4 + 3 = 7 fraud farmers
Pradhan Mantri Fasal Vima Yojna: Fake Crop Sowing: 18 fraud Farmers (the crops they actually take and the crops for which they were benefitted by government are different)
Transportation for max price on 16-02-26
Ahilyanagar, Pune, Mumbai, Nashik.
Total profit: Z = 3011100

Comparison:

- Farmer 1 if sells their produce to other cities instead of Ahilyanagar then he gains Rs. 3,66,300
- Farmer 2 if sells their produce to other cities instead of Ahilyanagar then he gains Rs. 3,64,760
- Farmer 3 if sells their produce to other cities instead of Ahilyanagar then he gains Rs. 11,39,600

Similarly, even considering the minimum price on 16-02-26 we get the following results by following same procedure:

- Farmer 1 if sells their produce to other cities instead of Ahilyanagar then he gains Rs. 5,01,300
- Farmer 2 if sells their produce to other cities instead of Ahilyanagar then he gains Rs. 2,14,760
- Farmer 3 if sells their produce to other cities instead of Ahilyanagar then he gains Rs. 15,59,600

Forecasting and Recommendation Engine:
Dataset rows after cleaning: 72,209
Arrival sensitivity (a) estimated for 101 markets
Markets with 2200 records: 84
Forecasts generated for 84 markets
Evaluation metrics computed for 84 markets
FORECAST ACCURACY (last 4 weeks backtest)
Average across evaluated markets:
MAE: 188.51
RMSE: 212.95
MAPE: 17.73

Conclusion:

The Recommendation Engine suggest best market to sell, and it also suggest what quantity to sell where according to the arrival quantity of the market. It further suggests the best transportation possible and which tier vehicle to prefer after selecting minimum transportation cost.

Future Scope of the study:

1) The accuracy of forecasting can be increased by using various ML techniques
2) Recommendation engine can be developed for many other commodities too other than onion.
3) Recommendation engine can also be developed for other states though market optimization will be more flexible.

Limitations:

1) The research is limited for onion commodity for only Maharashtra state.
2) Any spelling error in village name or district name will not proceed for forecasting and optimization.
3) The dataset is limited up to 150 farmers from only two districts to detect farmer's actual problems.
4) The cost of labour and tolls isn't subtracted from net profit though actual values where not known yet.

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