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Shetigram - Building a Digital Bridge between Farmers and Consumers

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Abstract- Transparency, cutting out middlemen, and fair trade have become essential focuses in agriculture. This paper proposes an innovative e-commerce platform that facilitates direct trans- actions between farmers and end-consumers using Ethereum blockchain smart contracts, leveraging the Elliptic Curve Dig- ital Signature Algorithm (ECDSA) for secure and transparent transactions. ECDSA enhances security by providing robust authentication, ensuring that all transactions are irrefutable and trustworthy. The platform has a hybrid recommendation system, which uses the Bidirectional Encoder Representations from Transformers (BERT) algorithm for delivering personalized product recommendations that fit each customer's personalized settings. This enables the software to work on natural lan- guage processing and this technique captures subtle feelings and contexts, thereby enhancing recommendation accuracy and diversification. Besides ARIMA, XGBoost algorithm, one of the machine learning methods, is applied to predict agricultural commodity prices and the demand, in this way by considering the internal, external, and seasonal factors that can create credit for each commodity provides much more accurate predictions and decision-making insights. XGBoost is a non-linear algorithm that wins in the comparison of MAE, RMSE, and MAPE as it continued to improve by capturing more factors and patterns associated with changes in the models. The platform aims to solve the problem of farmers being disadvantaged due to the lack of access to smartphones and internet connectivity. It will be done by integration of USSD-based interface that enables wide participation with basic mobile devices.

Index Terms—Elliptic Curve Digital Signature Algorithm (ECDSA), Bidirectional Encoder Representations from Trans- formers (BERT), Price and Demand Forecasting,Extreme Gra- dient Boosting(XGBoost) Unstructured Supplementary Service Data(USSD) Interface.

I. Introduction

Agriculture is an important sector of the Indian economy, and 85% of farmers operate on less than five acres of land and smallholder farmers produce 51% of agricultural output but most of them live in rural areas and have no access to information about market and market trends. According to a 2023 survey, 40% of consumers bought groceries online through e-commerce platforms in 2022, and expected to reach 70% by 2025. This study shows a promising future for e- commerce platforms in the agriculture domain.

In the traditional supply chain, both farmers and consumers face challenges. One of the major challenge for farmers is the market accessibility. Farmers especially in rural areas have limited market knowledge about the price range and demand of products which results into wastage of commodities. [6]Small- scale farmers struggle with the transportation of goods and they usually end up getting small income and do not receive fair prices for their products. On the other hand, consumers face problems regarding transparency and the quality of products. Lack of transparency in the supply chain becomes a major problem.

To overcome these challenges, this paper aims to develop an e-commerce platform 'SHETIGRAM' that uses blockchain technology and machine learning algorithms. The importance of blockchain in agricultural marketplaces has been high- lighted in [13], which presents a conceptual idea. Platform uses XGBoost algorithm to predict the demand and price of the agricultural commodities and the trends are displayed on the platform allowing the farmers to access the information about market demand and price of commodities. As highlighted in article [11], the use of USSD (Unstructured Supplementary Service Data) is important for enhancing accessibility to digital platforms among rural farmers. Many of these farmers use feature phones ie button phones rather than smartphones, making it necessary to provide a user-friendly solution that does not require advanced technology.

Thus, the proposed platform benefits both farmers and consumers. For farmers, it provides direct access to consumers by ensuring fair prices for the commodities and increase their profits. Similarly, on the consumer side, platform provides transparency in product quality ,improves trust and hence benefiting consumers as well.

II.Related Work

Several platforms are developed to improve the agriculture and aims to support both farmers and consumers. This section discusses the findings from various papers.

The paper titled “N. Imesha, et.al., Building a Digital Bridge Between Sri Lankan Farmers and Retailers: Conceptual Mobile Application Prototype” [1] describes the prototype of a mobile application called Agri Sri. It is designed to connect farmers with retailers in Sri Lanka and enables transactions without middlemen. Application uses algorithms like Price Skimming Technique and Harvesine Algorithm have been used for efficient communication between farmers ans retailers.When these algorithms were used it showed limited reach of product usage and market. “T. Sambrajyam, et al., Prakruthi Sedhya: A Natural Farming Mobile App”[2]explains about the application called Prakruthi Sedhya which aims to help farmers by assisting them in farm related activities.The main disadvantage of this application is that it can only be used by people of Andhra Pradesh since it is a complete Telugu language-based app.“J. Desai, et al.,Farmer Connect” application developed in [3] [4] connects buyer and the seller directly by eliminating the middlemen.[3] Forecasting prices of agriculture commodity using ARIMA model. But ARIMA cannot handle large data sets and may not capture patterns with respect to long term forecasting.Similarly, “R. Ogubuike, A. Adib, and R. Orji, Masa: AI Adaptive Mobile App for Sustainable Agriculture”[5] describes the development of a mobile application called “Masa” whose objective is to sell farmers products directly and offers features like personal- ized recommendation but there are few drawbacks related to security and moreover small-scale farmers in rural areas may struggle with limited access to the technology which reduces the app’s usage. Several papers, including ”P. A. Thakare, et al, E-Portal for Farmers” [7], “C. N. Mande, et al, Portal for Farmers to Sell Products at Better Rates” [8], and “S. Shirke, et al, Development of Portal for Farmers to Sell” [9] all these papers describe about various online platforms which aimed at improving market access for farmers by providing direct sales. But all such available platforms do not provide features like real-time price forecasting and demand analytics. Due to this, farmers will be unaware of the market trend and face difficulties in planning the commodity production.”A. Mallik, C. Tran, and A. Twagirumukiza, USSD Digital Wallet ” [10] focuses on using USSD to create a digital payment solution that bridges the gap between technology and banking, bringing access to the majority of people who lack widespread internet access and this approach can be applied to the agricultural sector to help rural farmers to access the platform without the need of smartphone and Internet. In this paper, ” P. Saranya and R. Maheswari, Proof of Transaction (PoTx) Based Traceability System for an Agriculture Supply Chain” [12] the authors present an blockchain-based system in the agricultural supply chain .In this system, entire supply chain members are involved including farmers, distributors ,retailers, consumers. Major drawback is that it still involves intermediaries such as distributors and retailers who have access to transaction details and therefore it does not provide direct transaction between farmer and consumer.

III.PROPOSED WORK

*A. **Transparent transaction using Elliptic Curve Digital Sig- nature Algorithm (ECDSA)***

One of the major issues in the agricultural supply chain is the lack of transparency, middlemen interference, and un- fair pricing. Price instability, supply chain inefficiencies, and limited access to digital resources further weaken farmer’s positions. These challenges hinder fair trade and sustainable practices. A blockchain-powered e-commerce platform can resolve these issues by enabling tamper-proof transactions, eliminating intermediaries, and providing real-time market intelligence, making the system more efficient and accessible for farmers.

Equations:

*1. **Key Generation***

Private Key (d): This is an integer, randomly selected satisfying the following condition $l \leq d < n$ where n is taken to represent the order of the elliptic curve.

Public Key (Q):

$$Q = d * G \qquad (1)$$

*2. **Signing Process***

Hashing the Message: Firstly, a cryptographic hash function like SHA-256 is applied to the received message to generate a hash:

$$R = k * G \qquad (2)$$

Random Integer Selection: An integer k is randomly chosen such that $l \leq k < n$ Calculating Elliptic Curve Point:

$$z = H(m) \qquad (3)$$

The x-coordinate of R, denoted as r, is calculated using:

$$r = R * x * mod|n| \qquad (4)$$

If r equals zero, the process of selection is done over again. Computing Signature Value (s):

$$s = k^{-1}(z + dr)\, modn \qquad (5)$$

If s is zero, this step is done again. The signature is then represented in the form of the point (r, s).

*3. **Verification Process***

Checking the Signature:

$$w = s^{-1}\, modn$$

Next, calculate u_1 and u_2:

$$u_1 = z * wmod|n|, u_2 = r * wmod|n|$$

The point P is calculated as:

$$P = u_1 G + u_2 Q \qquad (6)$$

The x-coordinate of P is then:

$$v = P * x * mod|n| \qquad (7)$$

Verifying the Signature: The last procedure verifies validity in case of v=r

*B. **Personalized recommendation using Bidirectional Encoder Representations from Transformers (BERT) Algorithm***

Customized recommendation is drafted in the platform in order to show products to the end users. The product showcase in the user's dashboard is corelated with their behaviour and interactions with the platform. This display, based on the historical searches improvise the user experience in the e- commerce platform. Among various customized recommendation methodologies, content-based recommendation method- ology is carried out since it is more advantageous over other methods, specifically collaborative filtering.

Natural Language Processing (NLP) routine in content-based filtering method helps to figure out the text typed by the users by extracting keywords like categories, price of the products. With this keyword from the previous searches NLP recommends the user with the products that binds with the extracted keywords. However, there is wide range of NLP algorithms available, BERT (Bidirectional Encoder Representations from Transformer) algorithm is used which will interpret the users search phrases and relates with appropriate farm products. By implementing BERT algorithm, it enhances user experience even if the user hasn't interacted with the platform.

In this TABLE I, the dataset named commoditydata.csv is used which consists of data from January 2020 to May 2024 and contains the following columns:

TABLE I

Name	Description
Date	Date of purchase of the commodity
Region	Region where commodity was sold
Commodity	Type of product such as fruits or vegetables etc.
Price	Price of commodity sold
Qty Purchased	Quantity of commodity that was purchased
Total Spend	Total spend on commodities and is calculated by price*quantity purchased
Min Price	Minimum price in a particular region for the specific commodity.
Max Price	Maximum price in a particular region for the specific commodity.
Modal Price	Most frequent price (average price) for the commodity in aparticular region.

DATASET DESCRIPTION

$$L(\theta) = \sum_{i=1}^{n} l(y_i, \hat{y}i) + \sum_{k=1}^{K} \Omega(f_k) \quad (8)$$

The MLM Loss is calculated using cross-entropy between the predicted and actual word:
where,
x_i is masked word and

$$\mathscr{L}_{\text{MLM}} = -\sum_{i\in\text{masked tokens}} \log P\,(\,x_i \mid \text{context}\,) \quad (9)$$

$\log P\,(x_i \mid \text{context})$ is the probability of the right token according to the context.

Equations:
The input representation for BERT is done by adding token, segmentation and position embeddings.

Equations:
The equation for the XGBoost model is as follows:

$$E_{\text{input}} = E_{\text{token}} + E_{\text{position}} + E_{\text{segment}} \quad (10)$$

Prediction result of each decision tree is added up and stored in y_i
K denotes total number of trees k denotes individual trees
f_k is the kth tree
Objective function:

$$\hat{y_i} = \sum_{k=1}^{K} f_k(x_i) \quad (11)$$

It has two main parts : Loss part and Regularisation part
Loss part: Measures the extent to which the predicted values match the actual values. The first term in the function basically adds up the errors, i.e. losses in all predictions.

Regularization part: Adds a penalty if the model becomes complex and thus takes into account how complex it becomes.

C. *Forecasting using XGBoost*

To display and to analyse the variations of demand and price over time, the commodity prices and demand are forecasted by applying a machine learning algorithm called XGBOOST- Extreme Gradient Boosting. These forecasts are added in the farmers dashboard, therefore, the farmers can plan commodity production accordingly. Similarly, these predictions help in re- ducing the wastage that might take place due to overproduction or underconsumption.

XGBoost is a boosting algorithm which is based on Deci- sion Trees. This model is accurate because it combines the predictions of multiple decision trees i.e. weak models and produces accurate prediction. This continues until a correct prediction or the maximum number of models is reached.

D. *USSD Protocol*

In many rural areas, smartphone usage remain limited, which prevents farmers from interacting with different plat- forms and causes them to miss potential profits. To solve this problem, Unstructured Supplementary Service Data (USSD) protocol is used, which provides immediate interaction between the client(farmer) and the server(platform) even when there's no internet.

A main advantage of USSD is that it runs over the GSM network using only basic 2G connectivity. This gives access to larger population particularly rural areas The main goal is to allow rural farmers to access features of the Shetigram platform via USSD, mainly in rural areas . Through this system, farmers can dial a service code from his or her feature phones (basic phones with no internet) to connect with the USSD gateway.

The functionalities include:
a) Registering on the platform
b) Listing products
c) Products and orders
d) Market trends

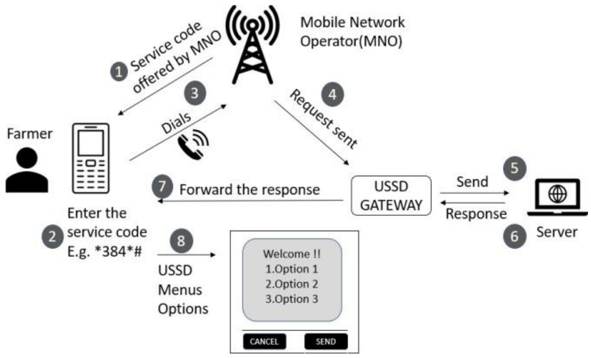

Fig. 1. *USSD System Architecture*

Fig. 1 depicts the system architecture which is basically a client-server model where the farmer who is the client send the request to the server(platform) via USSD gateway.

IV. Implementation Work

A. *Transparent transaction using Elliptic Curve Digital Sig- nature Algorithm (ECDSA)*

The architecture of the proposed system consists of the following components: User Interface (UI): A tool for the target audience to communicate with the platform, purchase products.

Smart Contracts: Self-executing documents that legally set out the conditions of deals between growers and buyers. They oversee the contracts and guarantee compliance and automatic disbursement of funds when a contract has been met.

Blockchain Layer: An open, distributed database that serves as a record of all transactions to prevent fraud and monopo- lization online. This layer assures data authenticity.

Cryptographic Security: Using analysis Elliptic Curve Dig- ital Signature Algorithm (ECDSA) to control and conduct the transaction, confirm the credibility and the authority of information transmitted on the platform.

Once a consumer approaches a business for the acquisition of their product, the process commences with the meticulous assembly of a smart contract, incorporating salient parameters such as product specifications, pricing, quantity, and stipu- lated terms. This is followed by strict scrutiny of inputs to confirm data accuracy and check for errors. Next, a Smart Contract is created that depicts the transaction details in which the SHA-256 hashing algorithm is applied for achieving the immutability and integrity of the respective transaction. It is then sealed with the digital signature using Elliptic Curve Digital Signature Algorithm (ECDSA) by using the consumer's private key for validation. This signed contract is then posted on the Ethereum Blockchain, which authenticates the contract through public key validation.

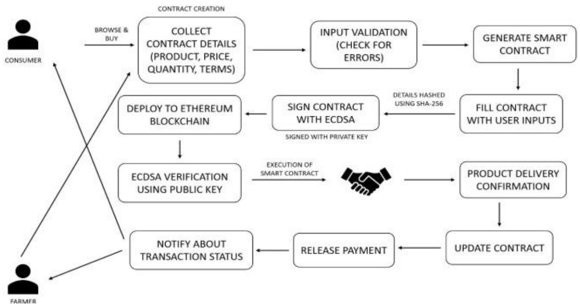

Fig. 2. *Process Flow*

Upon successful validation, the smart contract undergoes execution, wherein predefined conditions are evaluated, fa- cilitating the transaction process. Following the confirmation of product delivery, the contract autonomously disburses the payment to the farmer. The entire process flow is depicted in Fig. 2

B. *Personalized recommendation using Bidirectional En- coder Representations from Transformers (BERT) Algorithm*

Implementations of BERT involves 2 main steps

1. Pre-processing the text: The input representation for BERT is done by adding token, segmentation and position embeddings.
   a) Token embeddings: every sentence starts and end with [CLS] and [SEP] tokens respectively
   b) Segmentation embeddings: This identifies the sentence by receiving a designation for each sentence
2. Positional embeddings: Every token has a position that tells the sentence to which a particular token belongs to.
3. Pre Training Task: It includes 2 main processes: Training the model is represented in Fig.3
   a) Modelling Masked Language: Masking of tokens is done with a motive to train the model in order to learn the relation between other tokens and the context. Masked token is denoted by [MASK].
   b) Sentence prediction: The main purpose of implementing BERT algorithm is to predict the masked token. Since BERT is bi-directional it considers the whole context to predict the masked word

C. *Forecasting using XGBoost*

The Workflow is described as follows:

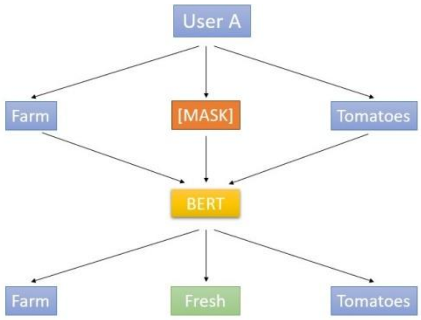

Fig. 3. *BERT Training Task*

Data Pre-processing:
Once data is collected, preprocessing is done which includes filtering and resampling .Data is filtered in the form of week, month and season. It is also categorised on the basis of region and commodity as well. Resampling involves tuning to a required frequency like weekly, monthly, seasonal.

For each frequency Mean Price, Total Quantity Purchased and Total Spend are calculated and taken into account while training.
Model Training:
It involves the following steps:
a) Dataset is split up into Training and Testing data
b) XGBoost Model: Three XGBoost regressors are used in the training for forecasting the demand, price and total spend. The R-squared is given as argument in order to minimise the error metrics.
c) Forecast Result: Once model is trained for each region: commodity pair, forecast is obtained for the period included in the testing datas and the forecasted results are stored. Results are visualised using bar charts for easy under- standability by the farmers.

The overall accuracy for the rice commodity of Chennai region is displayed in Fig.4

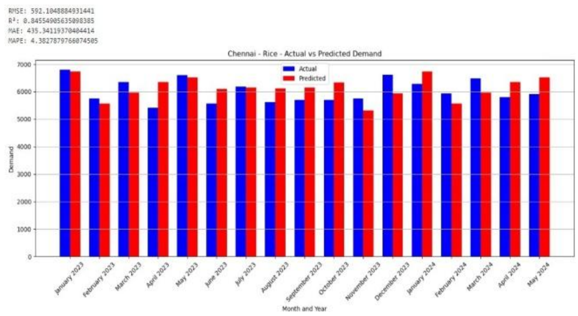

Fig. 4. *Overall Accuracy using XGBoost*

D. ***USSD Protocol***
In Fig.5, USSD is implemented by focussing on the follow- ing technologies :USSD Gateway: Africa's Talking API provides communication between the farmer and the platform. Mobile Network Operator(MNO) forwards USSD requests to server and send the responses back to the user with the help of API.

Backend :The backend is developed with Flask, which is a Python web framework. It handles the USSD requests. SQLite is used as the database to store information such as farmer registration details, product listings etc. SQLite makes it easy to access the data's and provide easy retrievals.

Workflow and Integration:
Session trigger: The farmer dials the USSD code provided by the Mobile Network Operator(MNO). The dialing leads to the forwarding of the request through the USSD gateway to the Flask server.

Processing the request: Flask processes the request and sends the response back to the gateway.
Menus: USSD sends back the response and farmers are presented with the menus like Register, Listing Products, View Products an soon

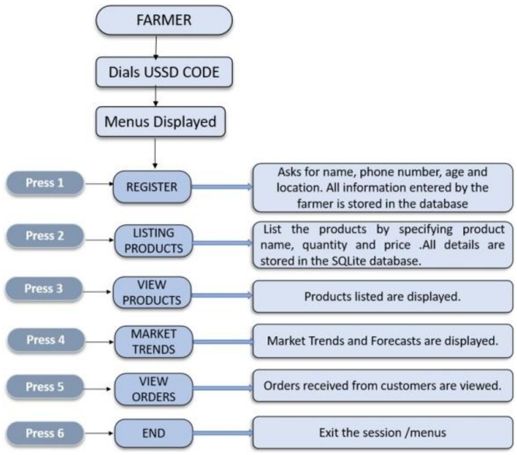

Fig. 5. USSD Process flow

VI. Result and Discussion

A. ***Transparent transaction using Elliptic Curve Digital Sig- nature Algorithm (ECDSA)***
The reason why the selective usage of elliptic curve cryp- tography, specifically in the form of the ECDSA (Elliptic Curve Digital Signature Algorithm), is easily recommended with blockchain technological applications are due to its comparatively low usage and high security. This allows choosing smaller key sizes, e.g., 256 bits to provide the same level of security as a 3072 bits RSA key; thus, it has a smaller computational and storage cost. Generate digital signatures is another factor of ECDSA enabling transaction signing without revealing the owners' private keys.

This is clear with the advanced use of ECDSA schemes over other schemes such as RA and DSA particularly for Ethereum and Bitcoin, which is supported by enabling cryptographic standards and peer reviewed qualitative research. Alongside the previously outlined low computational and verification time, ECDSA is capable of operating in high volume transaction environments is shown in TABLE II. Together these have been ascertained to offer actual usable recommendations for how safe Blockchain transactions can be conducted to establish a firm basic framework.

TABLE II COMPARISON TABLE

Algorithm	Key Size (bits)	Security	Speed	Memory Usage	Key Genera- tion	Signature Verifica- tion
ECDSA	256	High	Fast	Low	$O(1)$	$O(n)$
RSA	3072	High	Slower	High	$O(n^3)$	$O(n^2)$

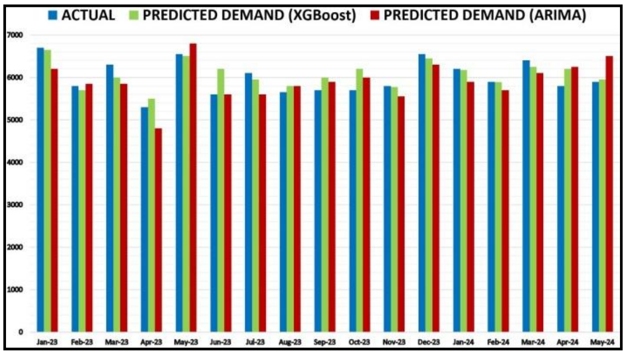

Fig. 6. Model Comparison

Root Mean Squared Error (RMSE): It calculates the average of prediction errors

*B. **Personalized recommendation using Bidirectional Encoder Representations from Transformers (BERT) Algorithm***

Among various customized recommendation methodologies, content-based recommendation methodology is carried out since it is more advantageous over other methods as shown in the TABLE III, specifically collaborative filtering. Collaborative filtering is about filtering users of similar tastes. Where in case of Content based filtering, it analyses an individual's habitual interests and personalize the display to the users.

The merits of using BERT algorithm is that: BERT understand the context bidirectionally ie., either from left to right or from right to left. This helps in predicting the masked token based on the context before and after it. BERT is pre-trained to predict the token accurately which will enable to develop an in-depth understanding of the language. It also fine-tunes data to proceed with sentiment analysis, text classification, and question answering in the required domain.

TABLE III ALGORITHM COMPARISON

Algorithm	Type	Accuracy	Precision
BERT	Transformer based NLP	-HIGH (0.92)	0.88
Collaborative Filtering	Matrix Factorization	MODERATE (0.75)	0.70
Content-Based Filtering	Feature-based	MODERATE (0.78)	0.74

*C. **Forecasting using XGBoost***

Once the predicted results are obtained, next important step is to determine the performance of the model by means of accuracy metrics . Following accuracy metrices play a major role in evaluation of the model:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2} \qquad (12)$$

Mean Absolute Error (MAE): It calculates the difference between the predicted and the actual values.

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i| \qquad (13)$$

R-squared: Calculates the variance of the dependent variable that can be explained by the independent variable.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}i)^2}{\sum i=1^n (y_i - \bar{y})^2} \qquad (14)$$

Mean Absolute Percentage Error (MAPE): It calculates the average percentage error between actual and predicted value.

$$MAPE = \frac{100}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}_i}{y_i}\right| \qquad (15)$$

Following results were obtained for the evaluation of the model and it is shown in TABLE IV:

TABLE IV ACCURACY METRICS AND VALUES

Accuracy Metrics	Value
RMSE	592.10488849
R^2	0.8455490563
MAE	435.34119370
MAPE	4.3827879766

These results indicate reliability and accuracy in the forecasted results .The accuracy is displayed in the form of bar graphs. Fig. 6 depicts the comparison between Arima and XGBoost model.

In the TABLE V, XGBoost has the highest R-squared value and the low MAE and RMSE, thus becomes the best choice for accurate forecasting. Various algorithms have been used for agricultural forecasting like linear regression, time series analysis but among these XGBoost is efficient as it can handle large datasets effectively.

TABLE V COMPARISON OF XGBOOST AND ARIMA

ALGORITHM	R-squared	MAE	RMSE
XGBoost	0.92	1.85	2.40
ARIMA	0.89	2.12	2.75

D. *USSD Protocol*

USSD provides a digital solution that improves accessibility and convenience for farmers. By using USSD, the platform provides rural farmers with faster and efficient access to services like product listing, market trends and orders - all via simple cell phones. Unlike SMS, which works by exchanging individual messages, USSD offers real-time interactive sessions that allow farmers to quickly navigate menus and receive instant responses.

As demonstrated by the Fig. 7,when farmer dials USSD code, menus ie options will be displayed and provides access to various options.

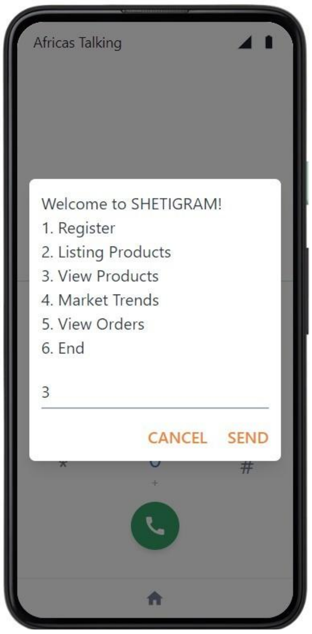

Fig. 7. *USSD Implementations*

V.FUTURE ENHANCEMENTS

Several improvements are planned to enhance the platform's functionality:

1. IoT-Driven Precision Agriculture: IoT sensors will be integrated to track temperature, moisture, nutrients and other parameters of the crops in the farm in real-time. Therefore, IoT sensor technology will enable to inspect the environmental conditions of the growing crops in an IoT greenhouse which may be supplied by a third company and the internal em- ployees only see the current date and time. This data will enhance XGBoost and ARIMA predictions, providing more precise forecasts for supply and demand.
2. Predictive Maintenance for Machinery: Machine learning will be used by the platform to predict machinery usage and potential breakdowns. This will help reduce downtime, optimize equipment usage, and lower operational costs.
3. AI Driven Dynamic Pricing: The smart contracts powered by AI can self-adjust the prices depending on the current market behaviour, as well as the supply and demand ratio. This makes it possible for the farmers to get a fair profit while the customers receive the benefit of real-time, market-driven pricing adjustments.

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