CROP CULTIVATION INTELLIGENT SYSTEM

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Abstract

Agriculture has a significant role to play in the economic development of India and the farmer community is the back bone of the agriculture sector. Intelligence refers to the capacity to acquire and apply knowledge. The researcher has developed an intelligent environment in the form of 'Crop Cultivation Intelligence System'. This intelligent system Pre-process data, available from heterogeneous data sources, utilises Mathematical Model's expertise and presents output in the form of knowledge in knowledge presentation. Agriculture Stake holders in the form of knowledge consumer, apply Crop Cultivation related query and gain generated knowledge in this segment of knowledge presentation. This 'Agriculture Intelligence' helps the farmer community in their decision making of farm management and agribusiness activities such as i) Predicting agriculture commodity market price before cultivation, ii) Determining best choice of cultivars to plant in their farm iii) Determine optimum cultivation date v) Evaluate demand and supply risk and vi) Investment Prioritising.

***Keywords*:** Agriculture Intelligent; Optimum Date Selector; Crop Price Prediction.

1. Introduction

Since the origin of mankind, agriculture has been a leading activity of every civilization to exploit natural resources like land for the satisfaction of mankind's basic need-'food'. Amongst all the ancient economic activities, agriculture is considered as one of the oldest and most important activities of human beings.Nowadays technology plays an important role in pattern identification and decision making. Agriculture has a noteworthy role to play in the economic development of India. Agriculture sector accounts for 14% of Gross Domestic Product (GDP) of the Indian economy. About 70% of the population of India lives in rural areas and majority of them depend upon agriculture as their primary source of income [1].

Government of India concentrated on the Improvement of Cultivator's knowledge of the Soil, Improvement of the Fertility of the Soil, Irrigation Facilities, Fertilizer utilization, Cattle-Manure utilization, Precise Pesticides usage and Grazing in Forest Area. ICT can be useful in many ways through mobile, internet, computers, GIS and sensor technology that makes it possible to spread agricultural information widely and in different formats to the farmer community.By delivering such important information to rural people, ICT can make a significant contribution in their social and economic development. ICT applications are available to provide information for the farmer regarding the crop production. Some of them in India include i-khedut[43], E-Mitra[44], Bhoomi[45], StarAgri[46], MahaAgri[47], Lokmitra[48], E-post [49], E-seva[50], E-sagu[51], Gramdoot[52] and Praja[53]. Other government and private portals also offers for agriculture information to help the farmer community. Some of them are E-Chaupal[54], agmarknet[55], agriwatch[56], itcportal[57], kishan[58], indiagriline[59] and e-agriculture [60] etc. Through ICT in the form of Sensor Technology - Wireless Sensor Network (WSN) useful in various important farm level activities such as sensor based auto irrigation system, environmental degradation parameter identification, water deficiency identification, soil structure deficiency identification etc.

The Indian farmer community faces major problems at the pre-cultivation level. The majority of them do not have any idea about the expenditure needed for future cultivation. They do not even have the estimation of the cost that they will have to bear during the production period in terms of use of fertilizers, pesticides, and other such requirements. Furthermore, they are unable to determine the future revenue generation including risk factor that they will face after production of the said cultivated crop. Such ignorance of the farmer community leads them towards attempt of suicide. As per the National Crime Records Bureau (NCRB) of India, 5650 farmers committed suicide in 2014 and farmer suicides account for 11.2% of all suicides in India [64]. There are many factors responsible for such condition, such as low returns, price crash, high operational cost, failure of crop etc. Considering the above mentioned troubles of the agriculture community, agriculture information alone is not sufficient to solve such problems and there is an urgent need of proper linkage of agriculture technology and ICT in the form of knowledge based information system to disseminate knowledge to the farmer community.

2. Study of Prediction System

The researcher has reviewed prediction system related literature for knowledge extraction such as prediction of the future market value of agricultural crop before crop cultivation. There were several studies conducted which determine future market price based on archive price data [3-7]. The volatility of an agriculture commodity price is very high and therefore price forecasting for decision makers in this domain has become more sensitive and challengeable compared to non-agricultural domain. The approaches used by different researchers are time series analysis with various statistical techniques and soft computing techniques such as neural network. All the studies [3-7] predict price in agriculture domain on their archival price data only. The prediction based on *only on price data* may not be as appropriate as it depends on many other factors such as meteorological and market demand and supply mechanism. In this context, the researcher started studying the literature regarding the contribution of meteorological parameters in the prediction systems [8-14].Many other researches were also conducted in the domain of impact of climate change on agriculture production [15-20, 22-24]. All the literature reviews as about *meteorological parameters studies* directly or indirectly refer to the impact of meteorological parameters in production and market price prediction. Such parameters also affect various agriculture field operations such as sowing, water management, crop protection, soil management, and harvesting. In the era of competitive market, the agriculture commodity is also affected a lot by demand and supply rule. To find out the force of demand-supply mechanism in agriculture commodity market, the researcher has gone through several studies that prove its contribution [25, 27].

By having literature review with regards to impact of agriculture commodity supply with its price, this study considered a new parameter 'Old Supply' into market price determination of the agriculture commodity. With the help of three meteorological parameters Temperature, Humidity, Rainfall and Old Supply as the fourth parameter, this study would like to generate a sustainable decision support system that would help the farmer community in this direction. So the researcher studied various systems which guide in developing decision support system [28-33]. All literature reviews related to DSS in the domain of agriculture sector, directly or indirectly refer to the decision support in agriculture production and operations such as sowing, water management, crop protection, soil management, harvesting etc. Using meteorological and fiscal parameters, the researcher has developed a mathematical model that helps in predicting agriculture commodity market price. Therefore the researcher reviewed studies of mathematical model in various agricultural activities [34-41].

Throughout literature reviews, the researcher did not find any DSS that guides or helps the farmer community before cultivation of the agriculture commodity for their investment decision. Many mathematical models were also used in the studies of agriculture sector. But most of the researcher used those mathematical models without any additional intelligence support or system. Based on the findings of the study of prediction systems, the researcher has proposed a *Crop Cultivation Intelligent System* architecture and its implementation as described in the next topic.

3. Intelligent System Design

Intelligence refers to the capacity to acquire and apply knowledge. The researcher has designed the intelligent prediction system architecture for agriculture stake holders to help them in their decision making process. As shown in Figure 1, the entire architecture has three major components such as i) Pre-Processing, ii) Periodical Updates & Mathematical Model and iii) Knowledge Inference. Such Intelligent environment helps the farmer community to avoid guess work and to improve performance in their decision making of farm related activities such as crop cultivation. To do so the researcher has utilized many approaches as mentioned in the next topic.

The first component consists of three sub components such as Data Source, Pre-processing and Data Storage. *Data source* contains data from heterogeneous data sources which will be pre-processed by ***Pre-processing*** sub component using pre-processing techniques such as *Data Cleaning*, *Data Integration*, *Data Reduction* and *Data Transformation* and then transferred to non-volatile media *Data Storage*. Other than first, rest components receive input from its earlier component, process it and transfer the resultant output to its next component for further process in the system. The final output in the form of knowledge will help agriculture stake holders in decision making of their agriculture activities such as farm level activities and agribusiness activities.

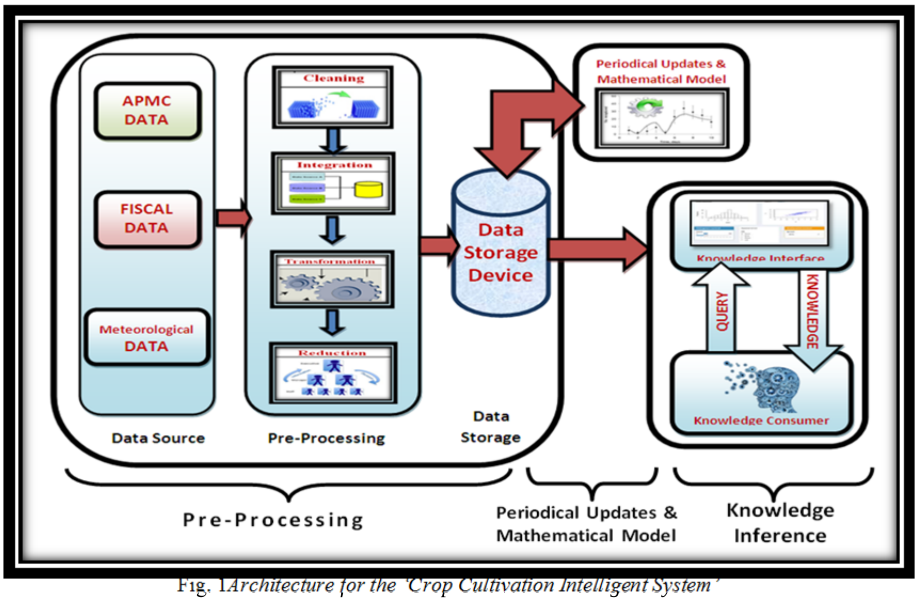

Fig. 1*Architecture for the 'Crop Cultivation Intelligent System'*

All other general and technical issues are available in detail in [36] that give in depth idea about the real issues the researcher faced during the development of this intelligent system. Architecture for the 'Crop Cultivation Intelligent System' is displayed in Figure 1 with its sub-components

3.1. *Pre-Processing*

Data pre-processing is a critical step that involves transforming raw data into an understandable format. Real-world data such as agriculture price data, fiscal data and meteorological data is often incomplete, inconsistent and is likely to contain many errors (noisy) like contain value '*NR*' instead of numeric value in commodity price. Data pre-processing is a proven method of resolving such issues. Data pre-processing prepares raw data for further processing in crop cultivation intelligent system and such pre-processed data is transferred to data storage for further usage in this system. This component consists of three sub components such as i) Data Source, ii) Pre-Processing and iii) Data Storage

Data Source sub component utilizes various heterogeneous data sources. It downloads APMC data and Fiscal data from APMC portal [55] on commodity basis for Surat APMC, Gujarat, India. It also downloads daily Meteorological data from Indian Meteorological Department [61] and World Weather Portal [62]for 'Surat' station, Gujarat, India. Data collection is a very crucial task as the data exists at various locations with different formats. To collect data from various heterogeneous resources, the researcher downloaded commodity wise agriculture market price data from APMC portal for selected ten agriculture commodities. Downloaded agriculture market price data from January 2004 to December 2014 was used as training data and from January 2015 to December 2015 data was used as testing data in the entire study. Such downloaded data was available in web page form and the researcher converted it into its equivalent comma separated value (.CSV) file and then into database table using spread sheet application software for further analyses. Likewise, meteorological data and fiscal data were also converted for further analyses.

Data Pre-Processing is a collection of techniques applied over downloaded data to eliminate noisy, missing and inconsistent data and thereby enhancing the quality of data and efficiency of the system. It is a vital technique in Agriculture Intelligence [42]. The researcher has designed and implemented algorithm for pre-processing techniques for Data Cleaning, Data Integration, Data Transformation and Data Reduction to clean noisy, missing and inconsistent data from heterogeneous sources.

In ***Data Storage***, the researcher stored three files such as Price Data, Meteorological Data and Fiscal Data as input database table and Model Data as output database table.

Without support of these pre-processing phases, it is very difficult to process further in this intelligence system. These pre-processed data is then stored in permanent storage device in the form of database tables.

3.2. *Periodical Updates and Mathematical Model*

Agriculture Commodity market is a very volatile market. So the mathematical model should update its *Beta value* and *Intercept of the line* value. This component accepts pre-processed data periodically (the period is of one month) and calculates new beta value and intercept value for each agriculture commodity and updates it to mathematical model. In the current scenario of global warming the system needs updating frequently instead of monthly updating to take benefits of this intelligent system.

Periodical Updates is a core component in this intelligent system in the form of a program to sustain the system. As shown in Figure 1 periodical updates have data from storage device, calculate beta value for given commodity and month, and again search respective model from the storage device and update its beta value. Such updated beta value will be utilized in future by mathematical model for various application mentioned in this intelligent system such as ‘Agriculture commodity market price prediction’, ‘Cultivar’s Choice’, ‘ Optimum Cultivation Date’ and ‘Fiscal Decision Support’.

A **Mathematical Model** is a conditional image of the researched object, designed to simplify the investigation. This mathematical model accepts and updates beta value and intercepts value from the early component ‘Periodical Updates’ and intelligently transfers value to the next component ‘Knowledge Presentation’ for dependent variable. Crop market price prediction model declared using mathematical equation 3.1 and 3.2 is as given below. In this model, Predicted Market Price $(\hat{y})$ is dependent variable and Daily Average Temperature (x_1) , Humidity (x_2) and Rainfall (x_3) as well as Old Supply (x_4) are independent parameters.Mathematical Model development process is very critical and essential in entire system development. It acts as a part of intelligent components in this system. Model development process is gone through various stages process such as Using Archival Price, Using Meteorological Parameter and Using Fiscal Parameters. This every stage has its own experiments and results and based on which it finally constructed general model as given below.

$$y' = \sum_{k=1}^{p} \beta_k \times x_k + Const \quad 3.1$$

$$\hat{y} = y' + (\alpha - 1) \times y' + e \quad 3.2$$

Where,

$\alpha =$ *Fitness Factor*

$y =$ *Price*

$y' =$ *Price with MLR*

$y' =$ *Predicted Price*

$n =$ *Number of Observations*

$e =$ *Influence Error*

$p =$ *4 (Number of Parameters)*

$$Const = \bar{y} - \left(\sum_{k=1}^{p} \beta_k \times x_k \right)$$

Here as shown in equation (3.1) ***n*** is the number of parameters. In this study value of ***n*** is 4 i.e. four parameters such as Temperature, Humidity, Rainfall and Old Supply are used to construct the given mathematical model. As shown in equation (3.1), ‘***Const***’ is the intercept of the regression line. Equation (3.2) gives the predicted value of the dependent variable $\hat{y}$ based on dependent variable of equation (3.1) y', influence error e and fitness factor α . The value of this fitness factor varies for different agriculture commodities and month. β_1 gives the beta value for respected parameters i.e. when value of ‘i’ is 1 the β_1 will give the beta value for first parameter (x_1) – Temperature and so on.

In this way the output of equation (3.1) substituted in equation (3.2) and finally dependent parameter value $\hat{y}$ i.e. predicted agriculture produce market price is calculated. For the model performance enhancement, the researcher introduced a new *Fitness Factor*α. “Fitness Factor α is the number element contributing to generate the best result amongst the possible given set of results. The resultant set do not have best result after and before of this value.” α has been calculated using the following steps.

1. Began by evaluating starting and ending boundaries of the experiments dataset. Considering the past agriculture commodity market price data, the researcher decided to start experiments from starting boundaries 0.5 and end with the ending boundary 3.0 with a step value of 0.05 and generated experiments data set values.
2. For every Individual fitness computation, used training samples for that respective month was used and the data was tested accordingly and then, individual learning error E was calculated. The formula is as follows:

$$E = \sum_{i=1}^{m} E_i \quad (3.5)$$

there into,

$$E_i = \frac{|y_i - y_i'|}{y_i} \quad (3.6)$$

Here, m is the number of validating sample; E_i is the i[th] sample error i.e. the absolute difference between actual value y_i and predicted value y_i' of the i[th] sample rounding at 25 (i.e. nearest integer value completely divisible by 25)

3. After having the individual fitness computation and learning error E, the Mean Absolute Percentage Error and Accuracy percentage for an individual experiment dataset value was calculated as follows:

$$MAPE = \frac{E}{m} \times 100 \quad (3.7)$$

$$Accuracyper = 100 - MAPE \quad (3.8)$$

Such accuracy percentage in the form of resultant value in resultant dataset was stored.

4. Repeat step 2 and step 3 for all experiments dataset values and generate resultant dataset consisting of accuracy percentage values.
5. Find out the maximum value (that is actually equilibrium trade-off value) from the resultant dataset. After and before this point in experiment data sets, the accuracy value is always lower. This resultant data set value is known as α.

3.3. *Knowledge Inference*

The objective of *Knowledge Inference* is to express knowledge in computer-tractable form, such that it can be used to help the intelligent system perform well. Visualization is one way of presenting knowledge. Knowledge Inference is necessary for better user experience; improving agriculture stake holder understanding and creation of new knowledge. It is a crucial component of this system for agriculture stake holder. This component accepts data from the previous component Pre-processing and Data Storage as well as from Mathematical Model and proceeds further. This component has two sub components, *Knowledge Interface* and *Knowledge Consumer*. Knowledge Consumer is a person or group of persons and an agriculture stake holder(s) who would like to have knowledge benefits from this Crop Cultivation Intelligent System.

3.3.1. *Knowledge Inference*

Knowledge Interface is a GUI environment which accepts query data from agriculture stake holder. Based on accepted query data, it generates knowledge and displays it. Knowledge Interface also displays generated knowledge in the form of graphs for visual convenience of the agriculture stake holder. In this component two type of processes are carried out i) Accepting Query and ii) Display generated knowledge.

There are two panels of the system. i) Admin Panel which is managed by the system administrator for the system level options and ii) User Panel for gaining user based knowledge from the system by agriculture stake holder. Login of both level and their access in this application are as shown in following Figure 3 below.

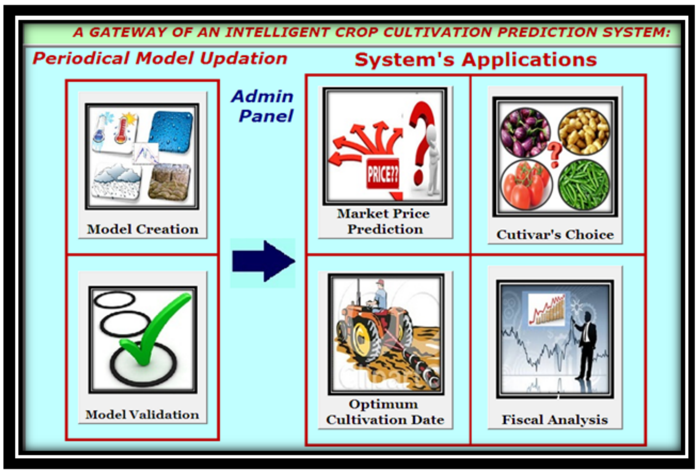

Fig. 3*Home screen of Crop Cultivation Intelligent System – Admin Panel*

As shown in Figure 3 above, knowledge consumers have four sub applications on their Home screen such as i) Market Price Prediction, ii) Cultivar's Choice, iii) Optimum Cultivation Date and iv) Fiscal Analysis. From such applications they get answers to many questions which help them in their decision making. The farmer can get answers of many questions such as i) *Which Cultivar gives best price at the `time of cropping of the agriculture commodity?*or ii) On Which date the farmer has to cultivate the crop to gain ultimate at the time of cropping? or iii) What will be the price of specified agriculture commodity on specific period in future? or iv) What will be the demand of particular agriculture commodity in market on specific period in future?. These types of questions often arise by the farmer before cultivation of crop. For the ease of reader, researchers display first two application's GUI over here.

As shown in Figure 4, knowledge consumers have *Market Price Prediction*. Figure 4 shows the merged chart for all these three analyses. This chart helps the user to compare these periods or commodities into one platform and helps in decision making. Here predicted Price-I, Predicted Price-II and Predicted Price-III one respective price predictions for the given three commodities / Periods as shown in Figure 4. For each option (commodity / Period), the predicted average price per ton in Indian Rupee is displayed for, the given period. So such multiple price predictions can be utilized in various ways and will be useful to take decision in future agricultural activities

Out of those questions, as a solution to the question one, the knowledge consumer will select *Cultivar's Choice* option. Now, as shown in Figure 5, the consumer chooses the 'Season' in which he would like to cultivate the crop. Based on the input season, the system will offer recommendation of the top most two commodities for cultivation as shown in Figure 5, with a view of getting higher price obtainable at the time of cropping period. Those who need recommendation for more than two commodities can go through a detail cultivar's choice.

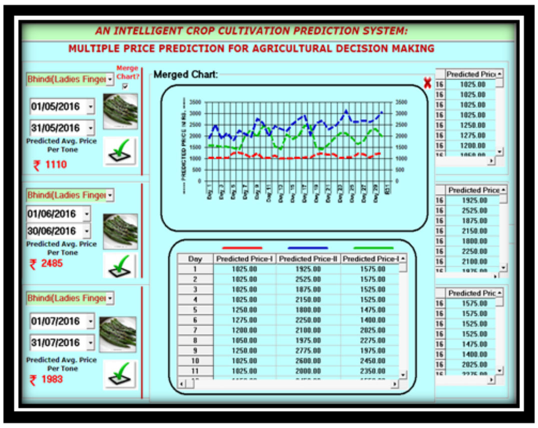

Fig. 4 *Merged Chart for same commodity with different periods*

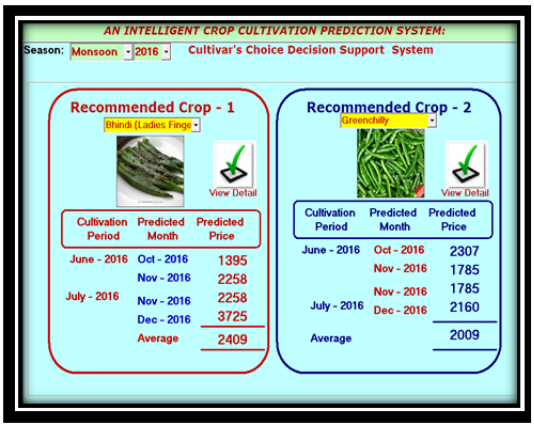

Fig. 5 *Cultivar's Choice – Crop Recommendation*

So, Knowledge Interface will give generated knowledge to the knowledge consumer based on the sub application selected by the knowledge consumer.

3.3.2. *Knowledge Consumer*

For this intelligent system, the major knowledge consumer is the Farmer Community but this intelligent system also benefits other agriculture stake holders as knowledge consumers such as APMC, Agriculture Product Broker, Agriculture Product Trader, Agriculture Product Price Policy Maker, Agriculture Retail Market or an Agriculture Market Retailer in their decision making.

Based on the application – *Market Price Prediction* of this system, the following agriculture stake holders can take benefit in their domain.

- ✓ *Agriculture Market Retailers can* avail the benefit of this knowledge to gain profit in short time in their agri-business activity.
- ✓ This generated knowledge helps *APMC Traders* in advance to form policy regarding Whole Sale Price of that agriculture commodity.
- ✓ Based on price prediction knowledge, the *Agriculture Product Traders* can take decision regarding storage of specific agriculture products.

Based on the application **–** *Cultivar's Choice* and *Optimum Cultivation Date* of this system, the following agriculture stake holder can take benefit in their domain.

- ✓ The Farmer Community can get help in their decision making of the cultivar's choice in their farm based on the figure out earnings through that agriculture commodity.
- ✓ The Farmer Community can also take decision about the investment for farming activities before cultivation for the agriculture commodity that will be cultivate in their farm.
- ✓ Based on the Optimum Cultivation Date, the farmer community can schedule various resource utilization and cultivars planting and thereby get benefit from it.
- ✓ Optimum Planting Date also helps farmer community to gain higher market price at the time of cropping of that agriculture commodity.

Based on the application – *Fiscal Analysis* of this system, the following agriculture stake holders can take benefit in their domain.

- ✓ This application helps Price Policy Makers to form policies regarding Minimum Support Price (MSP) in advance.
- ✓ Cold Storage Agencies can take decision regarding storage or vacating of specific areas for agriculture products rooted in the possibilities of higher / lower 'Arrival' availability in future

4. Experiments Results

The experiments were conducted for different agriculture commodities for the same training and testing period. The model validation experiments were carried out for such ten different agriculture commodities on their testing data and accuracy results were generated. These selected ten commodities are Bhindi (Ladies Finger), Brinjal, Cabbage, Cauliflower, Green Chilly, Lemon, Potato, Onion, Surat Beans (Papdi) and Tomato. The results of these commodities were generated as shown bellow. In this result section, for the convenience of the reader, the result of one agriculture commodity has been displayed in detail and the remaining has been displayed in summarized form.

Three different approaches such as 'Yearly', 'Seasonal' and 'Monthly' has been opted. Table 1 below represents accuracy for such different approaches with fitness factor for those agriculture commodities. Actual price of the agriculture commodity is compared with the predicted price of this system and accordingly accuracy has calculated for each approach. To enhance the accuracy level, the researcher also conducted the experiments 'season' wise as well as 'monthly'.

Table 1 Accuracy Comparative Analysis

Agriculture Commodity	Without Fitness Factor	With Fitness Factor - α			
		Yearly	Seasonal	Monthly	Fitness Factor-α
Bhindi	67.96	74.21	76.81	83.67	1.35
Brinjal	67.76	56.05	63.33	84.42	1.26
Cabbage	67.55	56.85	64.74	87.70	1.17
Cauliflower	65.57	70.85	78.69	87.21	1.23
Green Chilly	58.80	74.75	80.07	82.07	1.55
Lemon	59.32	82.44	69.74	83.89	1.49
Onion	56.80	71.76	80.27	85.72	2.09
Patato	49.08	79.05	83.27	91.52	1.84
Papdi	69.96	74.00	77.11	86.76	1.40
Tomato	64.00	59.45	68.11	80.85	1.46

Table 1 shows the comparative analyses of three different approaches for selected agriculture commodity. Table 1 itself suggests that 'Monthly' approach is better than the other two approaches as it gives better accuracy as well as it has the ability to predict the price for a particular month too. As shown in Table 1, for every agriculture commodity experimentally the researcher has found different values of fitness factor to which that agriculture commodity gives highest accuracy.

5. Conclusion

This study intelligently predicts the agriculture commodity market price of Surat, (Gujarat, India) APMC. Three different approaches 'Yearly', 'Seasonal' and 'Monthly' were validated, and based on experiments of an integrated prediction model, the researcher constructed 'Monthly' model with fitness factor '**α**' to predict future market price in the form of generated knowledge. Agriculture commodity market is a highly volatile market; still the researcher achieved more than 80% accuracy in all selected agriculture commodities. This 'generated knowledge' can help the farmer community in their decision making of farm management activities such as i) Taking investment decisions at farm level by predicting agriculture commodity market price before crop cultivation, ii) Determining optimum cultivation date, iii) Determining best choice of cultivars to sow and iv) Evaluating fiscal analysis.

This intelligent system also helps other agriculture stake holders such as agriculture brokers and intermediates in their agri-business decision making such as i) Determining optimum purchase period and quantity of the agriculture commodity and ii) Evaluating agriculture commodity storage risk analysis. By applying different agriculture market data for required agriculture commodities, this model can be generalized in the form of a strong and effective tool against the indistinct and unclear agriculture market price analysis situation.

Thus such intelligent system also helps the agriculture stake holders such as farmers, APMC Traders, Whole Sale Traders, Cold Storage capitalists, etc. in their decision making at the farm level and agribusiness activities. This will consequently lead them to achieve their ultimate goal of improved earnings.

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