DECISION SUPPORT SYSTEM FOR PRECISION FARMING

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ABSTRACT

A decision support system for precision farming is designed to assist farmers, agricultural experts, research workers or any intellectuals with guidance in making various farming related decisions and help them to access, display and analyze data that have geographic content and meaning. The concept of precision farming is not only related with the use of technologies but it is also about the five R's that is use of right input (nutrients, water, fertilizer, money, machinery etc.), at the right time, at the right place, in the right amount and in the right manner. There is need to have accurate information and suitable decisions regarding the right inputs required for the farming practices and to initiate the step towards the precision farming. DSS calculates irrigation requirement of crops. In this paper, Maps that are shown generated with the help of ArcGIS software (ArcMap tool). The system has been developed using Hypertext Pre Processor (PHP) at front end and MySQL at back end.

Keywords

Decision Support System, Precision farming, PHP

"Agriculture is the backbone of the Indian economy"-said Mahatma Gandhi five decades ago. Even today, as we enter the new millennium, the situation is still the same, with almost the entire economy being sustained by agriculture, which is the mainstay of the villages. Not only the economy but also every one of us looks up to agriculture for our sustenance too. Therefore, it is no surprise if agriculture gets the celebrity status in the name of Precision Farming (PF). The emergence of information technology has resulted in ever-increasing demand to use computers for efficient management and dissemination of information. Keeping in view the need of farmers and researchers to collect important and updated information for interactive, flexible and quick decision-making, a model of decision support system for precision farming is developed.

A decision support system (DSS) is a computer based information system that supports business or organizational decision-making activities. A properly designed DSS is an interactive software based system intended to help decision makers compile useful information from a combination of raw data, documents, personal knowledge or business models to identify and solve problems and make decisions.

Precision Farming is a scientific approach to improve agricultural management by the application of Information Technology (IT) and satellite based technology to identify, analyze and manage the spatial and temporal variability of agronomic parameters (e.g. soil, nutrient, water etc.) within field by timely application of only required amount of input to optimize profitability, sustainability with minimized impact on environment (Mondal et al 2004). The new tools applicable to precision farming (PF) are the advances in electronics and computers such as remote sensing, global positioning system (GPS) and geographic information system (GIS). Geographic information system (GIS) helps people access, display and analyzes data that have geographic content and meaning. It has capabilities to collect, manage, analyze, report and share vast amount of agricultural data so as to give assistance in discovering and establishing sustainable agricultural practices.

The concept of precision farming is relatively simple, which consist of 5 R's that is use of right input (nutrients, water, fertilizer, money, machinery etc.), at the right time, at the right place, in the right amount and in the right manner, used to enhance production, decrease input, improve quality or to protect environment.

The proposed decision support system for precision farming is developed to provide the accurate information or data and to have right decisions. In order to apply the right inputs (nutrients, water, fertilizer, money, machinery etc.) in the right amount, farmers must have accurate information or data regarding the particular area. Keeping in mind the need of precision farming, the important aspects of farming entrepreneur are carefully picked up, analyzed and presented in the form of maps that are generated with help of ArcGIS software (ArcMap tool). The Decision support system is developed with help of programming language PHP (Hypertext pre processor), MySQL and windows based WAMP.

Technologies used in PF cover three aspects such as data collection, analysis or processing of recorded information and recommendations based on available information. Collected data may be used to evaluate precisely the estimation of fertilizers, crop and soil characteristics, and quality of underground water. The work was started with collecting attribute data from different blocks of district. Collected data is linked from MS Excel to the database of ArcMap tool called attribute tables. The tables are processed to generate maps using suitable queries and then exported to picture format file. The generated maps are integrated into the system using web technology PHP at front end and database at back end. Designing and development of model for irrigation requirement for crops is done with the help of formulae recommended in FAO (Food and Agriculture Organizations) paper.

Based on the recommendations of the expert consultation of FAO methodologies for crop water requirements and results of other studies, the FAO (Allen et al 1998) developed a formula for computing crop irrigation requirements under standard conditions. The standard conditions assume a disease free and well fertilized crop grown in large plots under optimum soil moisture conditions and obtaining optimum production under the prevailing climatic conditions. By calculating the volume of field and water discharge rate (or water flow rate) of water pump, time period required for irrigation of crops can be calculated. The FAO Penman-Monteith method (Equation 1.3) is recommended as the sole ET0 method for determining reference evapotranspiration. For computation of irrigation requirement of crops (Michael 2008), only precipitation factor is considered as other factors or losses (runoff, deep percolation, leaching requirement) have minimal effect on irrigation requirement of crops and can be neglected, as shown in the equation 1.1. In Drip irrigation or sprinkler systems, losses can be neglected.

$$I = ET_c - P \qquad (1.1)$$

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Where

I Irrigation requirement [mm day-1], it is the amount of water to be supplied by irrigation to a disease free crop growing.

ETc Crop evapotranspiration under standard conditions [mm day-1], evapotranspiration denotes the quantity of water transpired by the plants during their growth or retained in the plant tissue, plus the moisture evaporated from the surface of soil and vegetation. (Equation 1.2)

P Precipitation (Rainfall)[mm day-1]

$$ETc=Kc^{*}\ ET0 \quad (1.2)$$

Where

Kc Crop coefficient [dimensionless]

$$ET0=\frac{0.408\Delta\,(Rn - G) + \gamma\,(900/(T+273))u2\,(es\text{-}ea)}{\Delta + \gamma\,(1+0.34u2)} \quad (1.3)$$

Where

ET0 Reference evapotranspiration [mm day-1]

Rn Net Radiation at the crop surface [MJ m-2 day-1], it is the difference between the incoming and outgoing solar radiation including both shortwave and long wave lengths (Equation 1.13)

G Soil Heat Flux density [MJ m-2 day-1], for day it is relatively small, can be ignored thus its value can be taken as 0.It is the energy utilized in heating the soil.

T Air Temperature at 2 m Height [oC] (Equation 1.6)

u2 Wind speed at 2 m Height [m s-1] (Equation 1.12)

es Saturation vapour pressure [kPa], pressure of water vapours in the air contributes to the total vapour pressure. (Equation 1.9)

ea Actual vapour pressure [kPa] (Equation 1.11)

es-ea saturation vapour pressure deficit [kPa]

Δ Slope of saturation vapour pressure [kPaoC-1](Equation 1.10)

γ psychrometric constant [kPaoC-1] (Equation 1.5)

$$P=101.3((293-0.0065^{*}z)/293)5.26 \quad (1.4)$$

$$\gamma = \frac{CpP}{\varepsilon\,\lambda} \quad (1.5)$$

Where

P atmospheric pressure [kPa] (Equation 1.4)

z elevation above sea level [m]

λ latent heat of vaporization, 2.45 [MJ Kg-1]

ε ratio molecular weight of water vapour/dry air =0.622

Cp specific heat at constant pressure, 1.013 * 10-3[MJ Kg-1oC-1]

$$Tmean= (Tmax+Tmin)/2 \quad (1.6)$$

Where

Tmean mean air temperature [0C]

Tmin minimum air temperature [0C]

Tmax maximum air temperature [0C]

$$e0(Tmax) =0.6108 \exp [17.27^{*}Tmax / (Tmax +237.3)] \quad (1.7)$$

$$e0(Tmin) =0.6108 \exp [17.27^{*}Tmin / (Tmin +237.3)] \quad (1.8)$$

$$es = [e0(Tmax) + e0(Tmin)]/2 \quad (1.9)$$

Where

e0(Tmax) saturation vapour pressure at minimum air temperature [kPa] (Equation 1.7)

e0(Tmin) saturation vapour pressure at minimum air temperature [kPa] (Equation 1.8)

exp 2.7183(base of natural logarithmic) raised to the power

$$\Delta=\frac{4098[0.6108 \exp (17.27^{*}T/(T+237.3))]}{(T+237.3)2} \quad (1.10)$$

$$ea = [e0(Tmin)^{*}RHmax/100 \;+\; e0(Tmax)^{*}RHmin/100] /2 \quad (1.11)$$

Where

RHmax Maximum Relative Humidity [%], it expresses the amount of water vapour in the air.

RHmin Minimum Relative Humidity [%]

$$u2= (uz^{*}4.87)/ \ln (67.8^{*}z-5.42) \quad (1.12)$$

Where

uz measured wind speed at z m above ground surface [m s-1]
z height of measurement above ground surface [m]

$$Rn = Rns - Rnl \quad (1.13)$$
$$Rnl = \sigma\, [(tmaxk^4 + tmink^4)/2][0.34 - 0.14*\sqrt{ea}][1.35*Rs/Rs0 - 0.35] \quad (1.14)$$
$$Rns = (1-\alpha)*Rs \quad (1.15)$$
$$Rs = (as + bs*n/N)*Ra \quad (1.16)$$
$$N = 24*\omega s/\Pi \quad (1.17)$$
$$Rs0 = (0.75 + 2*10^{-5}*z)*Ra \quad (1.18)$$
$$Ra = (24*60)*Gscdr[\omega s \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\sin(\omega s)]/\Pi \quad (1.19)$$
$$dr = 1 + 0.033 \cos(2\Pi*J/365) \quad (1.20)$$
$$\delta = 0.409 \sin(2\Pi*J/365 - 1.39) \quad (1.21)$$
$$\omega s = \arccos[-\tan(\varphi)\tan(\delta)] \quad (1.22)$$

Where

Rns net solar or shortwave radiation [MJ m-2 day-1], fraction of solar radiation that is not reflected from earth's surface (Equation 1.15)
Rnl net outgoing long wave radiation [MJ m-2 day-1] (Equation 1.14)
σ Stefan-boltzmann constant [4.903 * 10-9 MJ K-4m-2 day-1]
tmaxk maximum absolute temperature during 24 hr period [K=0C+273.16]
tmink minimum absolute temperature during 24 hr period [K=0C+273.16]
α albedo or canopy coefficient which is 0.23
Rs incoming solar radiation [MJ m-2 day-1], the amount of radiation which reaches the evaporating surface at a particular place depends upon location in terms of latitude and the time of year.(Equation 1.16)
as regression constant 0.25
bs constant 0.65
as+bs fraction of extraterrestrial radiation reaching the earth on clear days
n actual duration of sunshine [hours]
N maximum possible duration of sunshine or daylight hours [hour] (Equation 1.17)
Rs0 clear sky solar radiation [MJ m-2 day-1](Equation 1.18)
Ra extraterrestrial radiation for daily periods [MJ m-2 day-1](Equation 1.19)
Gsc solar constant= 0.0820 MJ m-2 min-1
dr inverse relative distance earth-sun (Equation 1.20)
ωs sunset hour angle [radian](Equation 1.22)
φ latitude [radian] =(Π*decimal degrees/180)
δ solar decimation [radian] (Equation 1.21)
J number of days in a year between 1 (1 January) and 365 or 366 (31 December)

RESULTS AND DISCUSSIONS

The objective set for the project was to design and develop a decision support system for precision farming so that farmers, agricultural experts, research workers or any other person can take interactive, flexible and quick decisions. The proposed system is developed to implement using PHP at front end and MySQL at back end. The development of decision support system for precision farming requires the comprehensive backup from database about basic resources being used in agriculture. There cannot be any further precision in agriculture without the availability of database pertaining to the variability in soil, types of crops, important commodities handled, land holding patterns and classification, quality of underground water available, category of blocks according to geographic and climatic characteristics, irrigation requirement of crops under standard conditions or other factors associated with different aspects of agricultural production system. Precision Farming involves advance decision making at agricultural expert level as well as at farmer level.

At agricultural expert level, the development of decision support system for precision farming fulfils the requirements of the farmer which are based on accurate information and suitable decisions regarding the right inputs required for the farming practices and to initiate the step towards precision farming. This aim can be achieved by understanding the variations in the input. Precision farming requires the information tool like GIS to assess and understand the field variations. The generation of maps for crop and soil properties is the most important activity in precision farming. The collected data may be used to evaluate estimation of input factors (water, nutrients, fertilizers, machinery, money etc.). The agricultural expert can take following decisions:

Decision regarding the estimation of fertilizer requirement can be taken from fertilizer requirement estimation category.

Information regarding the type of land (e.g. good cultivated land) can be seen in land analysis. This decision is helpful in the case when agricultural experts want to increase the yield of particular crop by using the concept of precision farming.

Decision regarding the net return income (per acre per year) of different farmers (farmers are divided into five categories i.e. marginal farmer, small farmer, semi-medium farmer, medium farmer, large farmer) of blocks can be taken from socio economic analysis.

Decision regarding availability of machinery in blocks can be taken from machinery analysis.

Decision regarding the right nutrient requirement in a particular block can be taken from soil characteristics analysis.

Decision regarding the accurate amount of irrigation requirement of crops can be taken from irrigation model for crops. Below figures show input fields and output result.

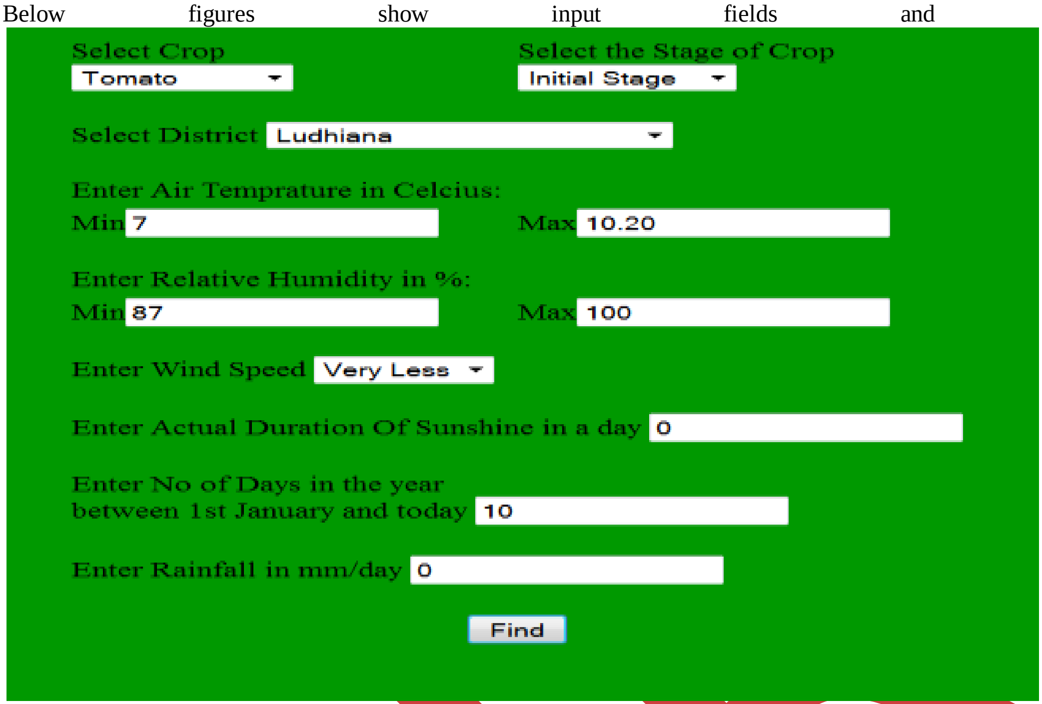

Fig-1

Fig-2

- Decision regarding the suitable crop of particular block can be taken from crop based query and crop information mentioned in general analysis section.

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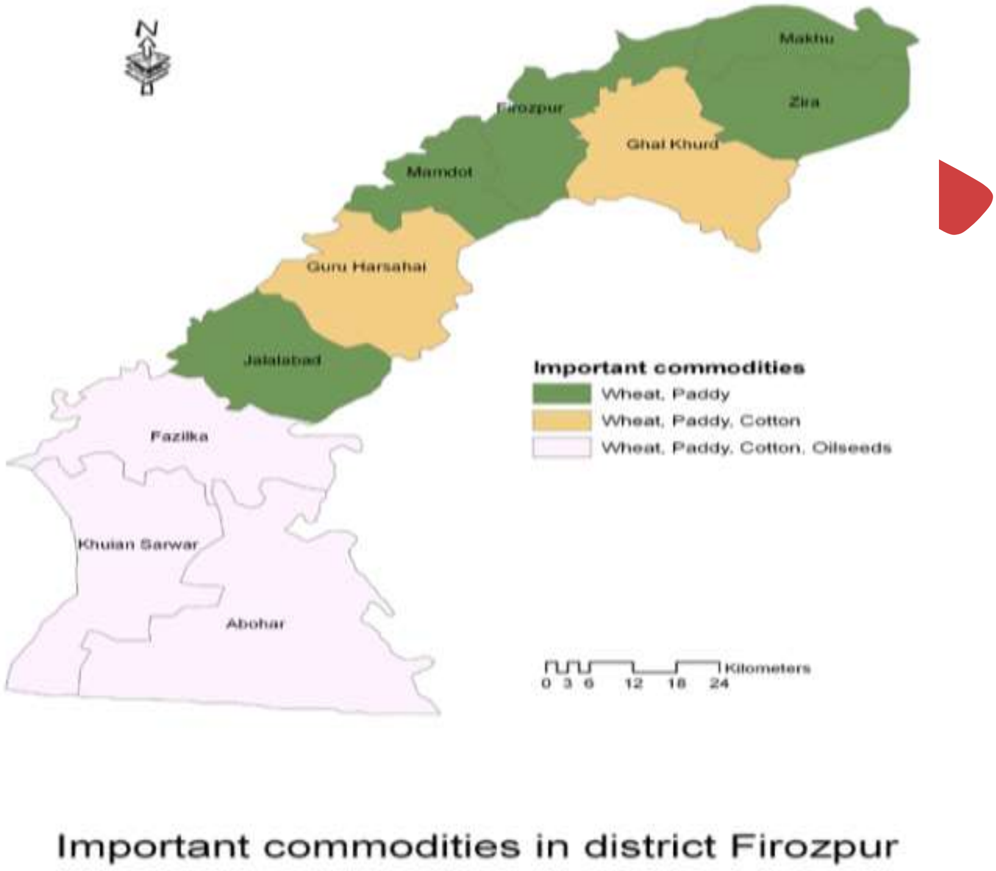

Fig-3

At farmer level, decision support system is computerized system for making decisions. The farmer can get information at click of the mouse. They need not to travel to Agricultural Universities for that. The process of information analysis can enable farmers to understand their business more specifically. Under different situations suitable decisions can be taken, few are explained below:

The decision support system precisely calculates the water required for the irrigation of crops under different climatic conditions with respective to different locations of Punjab state.

After using the decision support system, farmer can get the information regarding good or bad underground water availability in particular block of district Firozpur.

General analysis explains type of area i.e. whether a particular block is flood prone area, cotton belt area or alkaline area.

Famer can have brief information of particular block by selecting the location in the options available. The system will show the results in the tabular form. Fig 1 shows the information regarding the Abohar block.

Block Name	ABOHAR
No of Villages	58
Net Crop Area	77786 ha
Irrigated Crop Area	144226 ha
Important Commodities Handled	Wheat, Paddy, Cotton, Oilseeds
Other Crops	Guara, Jatropha, Pulses, Sesamum
General Remarks	Cotton Belt Area, Marginal to Unsuitable Groundwater
Market Centers	Abohar
Micro Deficient Soil	Sulphur, Zinc
Alluvial Soil	Light-Heavy
Alkaline Soil	Normal

Fig 4: Information of Selected block

DSS is more helpful for the farmers who belong to different districts of Punjab (other than Firozpur) and want to have their own agricultural land for farming practices in district Firozpur but don't have any idea or information about the land, infrastructure, soil, crops, location, socio economic net income of farmers etc. of different blocks of district Firozpur.

Farmer or agricultural expert can check or find whether the soil of particular block is nutrient deficient or not and which type of nutrient is required for the soil of that block.

Research workers or experts can access the right information to aid the process of precision farming. E.g. the area of American cotton crop in Abohar block is more than other blocks of district Firozpur.

Farmer can find the estimation for the fertilizer requirement (N, P, and K) in particular block of district Firozpur.

Decision support system for precision farming determines the type of soil whether it is alkaline or normal and quality of alluvial soil (Light-Medium or Medium-High). For E.g. Alkaline soil is soil with pH higher than 7.0. A soil with pH 7.5 or more decreases the chances of good plant growth. Areas that receive less than 20 inches of rain per year are usually alkaline.

DSS is also concerned with which types of crop can be grown in different blocks of district Firozpur.

Though widely adopted in developed countries, the adoption of precision farming in India is yet to take a firm ground primarily due to its unique pattern of land holdings, poor infrastructure, and lack of farmers' inclination to take addition onus of management including socio-economic conditions. That's why the decision support system for precision farming is developed to understand the variations which are explained with the help of maps.

The most important for any proposed precision agricultural model is its own sustainability. This is possible only if it requires special tools and resources like decision support systems to prescribe the most appropriate management strategy to increase the productive efficiency

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