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Managing soil fertility for sustainable productivity in agriculture through application of information technology based approach

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Abstract
Soil is one of the most important natural resource for agriculture, finite in nature and subject to deterioration. It requires effective and efficient utilization for maintenance and conservation for future generations. Crop harvests tend to exhaust soils of their nutrient pool, resulting in nutrient mining which if not adequately replenished results in decline of agricultural productivity over a period of time. The long term sustainability of production in agricultural systems depends upon proper management of soil fertility. It is often reported that a wide range of variation is observed between the potential and actual yield of the crops under farmers field. There are several factors like soil factors, climatic factors, plant factors and biological factors. The resultant of interaction of these factors ultimately determines the final outcome in the form of economic yield. Among these factors nutrient management holds the key in terms of soil fertility and sustainable productivity.

Keywords: Nutrient requirement, Target yield, Fertilizer use efficiency, Nutrient uptake, inorganic management, organic management, integrated nutrient management, efficiencies

Introduction
The supplementation of nutrients to crop is directly depends upon the soil efficiency and the fertilizer use efficiency which ultimately becomes the limiting factor for yield increment beyond the nutrient supplying capacity. One of the best method to work out the nutrient requirement of the crop is based on the fact that each crop uptakes and accumulates a certain quantity of nutrient in them to produce a unit quantity of dry matter, which can be quantified for different crops. These nutrient uptake values of crop when used in conjunction with the target yield and fertilizer use efficiency under specific conditions will provide near estimations of exact crop nutrient requirements and fertilizer needs to obtain a certain desired yield level, which forms the basis of this software.

The software is created using visual basic programming language, the programme is intelligent enough to accept users input and dynamically process the inputs to provide readymade solutions, to a user's requirement. It is an interactive software and can accept input from users and based on the input received furnish customized results, both in content and presentation, to the user. This software assumes that yield is the function of nutrient supplementation from the soil and through fertilizer sources. Thus, this software breaks the limitations of geographic variations to work out the nutrient requirements and can be applicable under wide range of agro climates. The software can not only determine the crop nutrient requirements but also the quantities of different fertilizers and manures to be applied to the crop under different types of nutrient management practices such as inorganic, organic, integrated and intercropping situations.

The software is of immense importance as it can provide immediate information to solve the problem of the user and to provide assistance in making decisions related to crop nutrient requirement and their management. The farmers/land users and researchers urgently need information about the crop nutrient requirements, nutrient uptake, and the quantity of various fertilizers and manures to be applied to the crop for obtaining desired production levels under a certain soil fertility level. The architecture of this software is organised in such a manner that wide range of users including farmers/ agriculture extension officers/ subject matter specialists/ researchers with different demands to crop and soil related data and mehtods can utilize it and obtain information's. It is also capable of giving warnings and alerts to the user related to target yield and the quantities of different fertilizers to be applied to the soil wherever required.

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The first screen of the software displays the space for furnishing the software code and password and window for selection of choice of programme, which allows users to access to different sections of the program. After furnishing the software code, password and selecting a programme, on pressing the enter button the desired modules like
1. Inorganic nutrient management
2. Organic nutrient management
3. Integrated nutrient management
4. Nutrient management under intercropping conditions
5. Efficiency calculations
can be accessed and different information's can be generated after furnishing certain necessary data. The programme is self-explanatory and users with agriculture background can furnish information's without any assistance.

Introduction
Soil is one of the most important natural resource for agriculture, finite in nature and subject to deterioration. It requires effective and efficient utilization for maintenance and conservation for future generations. Crop harvests tend to exhaust soils of their nutrient pool, resulting in nutrient mining which if not adequately replenished results in decline of agricultural productivity over a period of time. The long term sustainability of production in agricultural systems depends upon proper management of soil fertility. It is often reported that a wide range of variation is observed between the potential and actual yield of the crops under farmers field. There are several factors like soil factors, climatic factors, plant factors and biological factors. The resultant of interaction of these factors ultimately determines the final outcome in the form of economic yield. Among these factors nutrient management holds the key in terms of soil fertility and sustainable productivity.

Nutrient management is one of the most important and critical factors that determine the final output of the crops in the form of grain yield or economic yield. Nutrient recommendations to the farmers are usually done on the basis of soil test values and the crop, which the farmer would like to grow. Under such type of blanket recommendations the important factors like the target yield which farmer would like to obtain from the crop, the genetic potential of the crop variety selected, soil efficiency and the added fertilizer nutrient use efficiencies which play an important role in the uptake of nutrients absorbed by the crop plants to the total quantity of the nutrients applied in the soil, are not properly taken into consideration. This resulted in huge differences in the yield, non-judicious application of nutrients either insufficient or excessive, which resulted in either poor crop yields or toxic effects of excessive fertilization. These ultimately resulted in poor economics of cultivation; deterioration of soil health, affects the long term sustainability of the production system and farmers suffer huge losses.

Basics of the software
Several models have been developed to work out the crop nutrient requirements, but most of them take into consideration only single plant nutrient or a specific crop under specific management condition. This software system takes into account most of the parameters (nutrient uptake by the crop, soil nutrient content, soil efficiency, which influences crop nutrient requirement and their respective fertilizer needs. The system takes into consideration soil test crop response equations as the key basic concept to work out the nutrient requirement of the crop and then takes into account different fertilizers and their fertilizer use efficiencies to work out the quantities of various fertilizers required to be applied.

The various components of these equations are furnished either as customized equations for different crops to generate results based on users input or the user can also submit his values as per the requirement of the software to obtain results. The basic equations utilized in the software are as under.

Nutrient requirement (NR) = T x NU - SNC x SE
Where,
T = Target yield (q/ha)
NU = Nutrient uptake (kg/q)
SNC = Soil nutrient content (kg/ha)
SE = Soil efficiency (%)

This equation when used in conjunction with fertilizer use efficiency will provide near estimations of quantities of the fertilizers, which are required to obtain a certain desired yield level, which forms the basis of this software.

$$\text{Fertilizer requirement (FR)} = \frac{NR \times 100}{FNC} \times \frac{100}{FUE}$$

NR = Nutrient requirement to obtain a target yield (kg/ha)
FNC = Nutrient content in fertilizer (%)
FUE = Fertilizer use efficiency (%)

This software can determine the crop nutrient requirements for different crops and the quantities of different fertilizers and manures to be applied to the crop under different types of nutrient management practices such as inorganic, organic, integrated and intercropping situations for obtaining a realistic desired target yield along with efficiency calculations.

The architecture of this software is designed in such a way that a wide range of users with different requirements can easily use the software and generate desired information's by furnishing certain soil and crop related parameters. Each module has been supplied with options to determine nutrient and fertilizer requirements depending upon the choice of the user and the amount of information he/she can furnish:

1. Crop nutrient and fertilizer requirements based on blanket recommendations can be obtained in the absence of any soil and crop related data and as such can be used for places where no information is available.
2. Crop nutrient and fertilizer requirements based on built in readymade nutrient uptake equations that can be obtained by furnishing the soil test values and the target yield for a particular crop and the options for availability of different fertilizers. The user can select any of the available fertilizer material for supplementation of particular nutrient and the required quantities of different fertilizers can be obtained at a set fertilizer use efficiency of 50%.
3. Crop nutrient and fertilizer requirements based on actual soil test values crop nutrient uptake, target yield and soil efficiency can also be obtained by furnishing the desired information for a particular crop. After selecting the nitrogen, phosphorus and potassium fertilizer sources the required quantities of different fertilizers can be obtained at a site specific fertilizer use efficiency.

Operation of the software
The software can be easily installed on any PC or can be run directly through the disk. To operate the software one needs to double click on it. The first screen of the software will appear displaying the information's about the author and the space for furnishing the software code the password and. After furnishing the desired software code and password and selecting a language one can enter the main menu of the

software the module from the choice of nutrient management on pressing the enter button the desired module can be accessed (fig. 1& 2).

Fig. 1

Fig. 2

The different modules of the software and their operations are as under

1. Inorganic nutrient management
Selecting the inorganic nutrient management option from the choice of nutrient management form the main menu of the software one can access this module of the software. The screen will appear having options for furnishing the information's required to obtain results depending upon the quantity of data available with the user (fig. 3). This module provides three options to the user for getting information.

Fig. 3

Step I- One can generate information on nutrient requirement, respective fertilizer requirement and the expected yield that can be obtained by application of that quantity of nutrients to the crop in the absence of availability of any soil and crop related data based on blanket recommendations (fig. 4& 5)

Fig. 4

Fig. 5

Step II- The user can furnish soil test values, set a target yield and select a crop from the options and pressing the calculate button to determine the quantity of nutrients required to obtain the set target yield based on readymade nutrient uptake

Fig. 6

Step III - The optional space provided in the software can be utilized in the presence of desired data of crop nutrient uptake, soil efficiencies and fertilizer use efficiencies. To obtain information from this module one needs to provide the Soil test values Set a target yield Select a crop Nutrient uptake values for different nutrients Soil efficiency Fertilizer use efficiency after furnishing all the information's in the optional column and then press the calculate button on the screen.

Fig. 8

2. Organic nutrient management
Selecting the organic nutrient management option from the choice of nutrient management form first screen of the software one can access this module of the software. The screen will appear having options for furnishing the information's required to obtain results depending upon the quantity of data available with the user (fig. 10). This module

Fig. 10

Step II- To obtain recommendations with this module the user can furnish Soil test values Set a target yield Use of biofertilizers Select a crop from the options and choice of manure after furnishing these information's and pressing the

equations provided with the software and from the options for selection of different fertilizer for nutrient supplementation the quantities of different fertilizers required can be obtained at a set fertilizer use efficiency of 50% (fig. 6-8).

Fig. 7

Based on these informations accurate site specific recommendations can be made available to the user and accurate estimates of the quantities of the nutrients required to obtain the set target yield can be determined. Then by selecting the appropriate fertilizers for nutrient supplementation one can determine the required quantities of the different fertilizer materials based on the fertilizer use efficiency furnished by the user (fig. 9).

Fig. 9

provides two options to the user for getting information.

Step I- One can generate information on nutrient requirement, respective manure requirement and the expected yield that can be obtained with the application of that quantity of nutrients through organic manures to the crop (fig. 11).

Fig. 11

calculate button one can determine the quantity of manures along with the quantity of rock phosphate required to obtain the set target yield based on readymade nutrient uptake equations provided with the software. The recommendations

on organic nutrient management are based on five-year basis to obtain consistently the set target yield of the particular crop with nutrient supplementation from a selected source of organic nutrient. Since the quantities of the phosphorus required by the crop could not be met through the application of manures alone, therefore the recommendations for application of rock phosphate will also be made by the software, which is considered to be a organic source of phosphorus (fig. 12 & 13).

Fig. 12
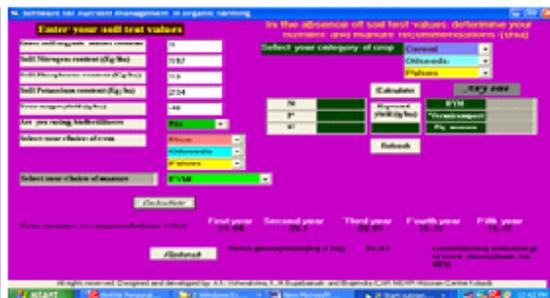
Fig. 13

3. Integrated nutrient management

Integrated nutrient management is considered to be the best approach for crop nutrient management, which takes into consideration both the organic as well as inorganic sources of nutrient supplementation but the estimation of different nutrients and calculations of their fertilizer and manure equivalents is a complex process. Selecting the integrated nutrient management option from the choice of nutrient management from the first screen of the software one can access this module of the software. The screen will appear having options for furnishing the information's required to obtain results depending upon the quantity of data available with the user. This module provides three options to the user for getting information.

Step I- One can generate information on nutrient requirement, respective fertilizer and manure requirement and the expected yield that can be obtained by application of that quantity of nutrients to the crop in the absence of availability of any soil and crop related data (fig. 14& 15).


Fig. 14
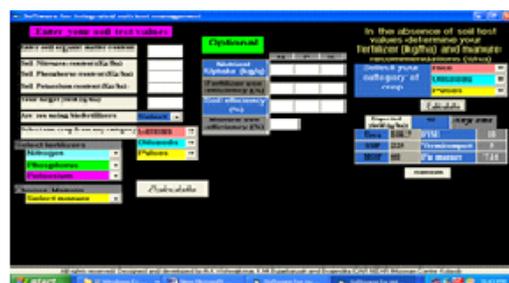
Fig. 15
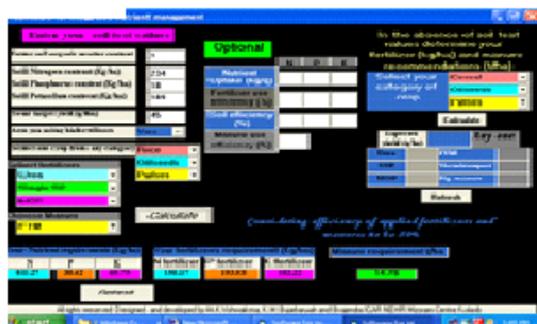
Fig. 16
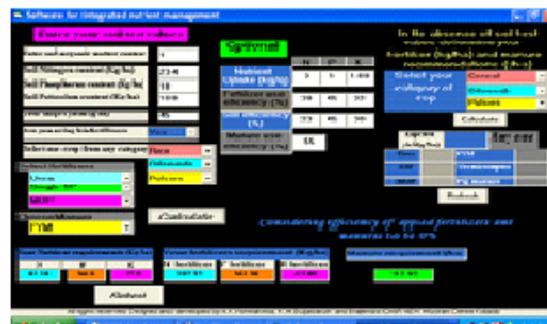
Fig. 17

Step II- The user can furnish soil test values, set a target yield, select a crop from the options, application of bio fertilizers, different fertilizers available for use, the selection of manures to be applied to the crop can be obtained by pressing the calculate button one can determine the quantity of nutrients required to obtain the set target yield based on in built readymade equations provided with the software and the quantities of different fertilizers and manures required can be obtained at a set fertilizer use efficiency of 50% (fig. 16).

Step III- The optional space provided in the software can be utilized in the presence of desired data and accurate site specific recommendations can be made available to the user.

To obtain information from this module one needs to provide the Soil test values Set a target yield Select a crop Application of bio fertilizers Different fertilizers available for use The choice of manures to be applied to the crop Nutrient uptake values for different nutrients Soil efficiency Fertilizer use efficiency and manure use efficiency after furnishing all the information's in the optional column and then press the calculate button on the screen. This will provide the user with accurate estimates of the quantities of the nutrients required to obtain the set target yield and the required quantities of the different fertilizer and manures to be applied based on the fertilizer use efficiency and manure use efficiency furnished by the user (fig. 17).

4. Nutrient management under intercropping conditions

Nutrient management under intercropping conditions is a very complex process and it is very difficult to work out the quantities of nutrients to be applied to the crop under intercropping, because of different nutrient requirement of the crops, their planting proportions and the expected yield from individual crop component. This resulted in either over fertilization to one crop and under fertilization to another crop. Thus poor crop yields were obtained, to solve the problem of fertilization under intercropping conditions this module has been designed taking into consideration the yield component of the crops and their nutrient uptake pattern (fig. 18). This module can provide solutions in two ways

Step I- When the soil test values are available but the efficiency and nutrient uptake values are not available. The user can select the main crop and intercrop from the list of crops available in the select column then yield as sole crop and intercrop needs to be furnished the soil test values.

On pressing the submit button, it will calculate the different nutrients requirement for sole and intercrops to obtain the desired yield levels based on readymade uptake values for different crops. Then different fertilizers can be selected from the list of fertilizers available for nutrient supplementation and on pressing the calculate button the quantities of different fertilizers can be determined based on the set fertilizer use efficiency (fig. 19).

Fig. 18
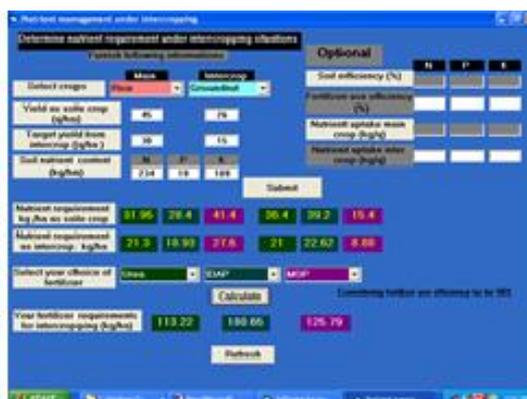
Fig. 19

STEP II- The user with more information's can obtain nutrient and fertilizer recommendations based on site specific conditions by furnishing the desired information's on main crop and intercrop from the list of crops available in the select column yield as sole crop and intercrop soil test values Nutrient uptake by main crop Nutrient uptake by intercrop Soil efficiency Fertilizer use efficiency by furnishing the desired information's in the optional columns, on pressing the submit button the information's related to nutrient requirement can be obtained, and by selecting the fertilizers from the menus and pressing the calculate button the quantities of different fertilizers required can be determined based on the fertilizer use efficiency (fig. 20).

and fertilizer use efficiencies by furnishing the desired data on Select a crop Soil nutrient status Doses of fertilizer application Crop yield under the fertilized plots.

Crop yield under the control plots after furnishing all the required information's on pressing the calculate button the information's related with nutrient uptake in the control plot and the fertilized plot will be generated along with apparent nutrient recovery, agronomic efficiency and production efficiency for nitrogen, phosphorus and potassium. This information's can be generated for the nutrients supplied through soil, nutrients derived by the crop from the fertilizer application and the total nutrient recovery and efficiencies from the soil and applied fertilizer based on the readymade nutrient uptake values for the selected crop (fig. 21).

Fig. 20

Fig. 21

5. Efficiency calculations

Efficiency calculations are complex, time consuming, exhaustive and are subject to miscalculations often, which result in driving incorrect results, and all the calculations and results obtained will be faulty. Therefore this module has been provided with the software to enable the users to obtain soil

Secondly for the users having nutrient uptake values for the crop under control and fertilized conditions the software is provided with options to furnish the values for nutrient uptake in the grain and the straw under fertilized and control plots

along with all other information's and then pressing the calculate all the total nutrient uptake values and the different efficiencies can be obtained. This, in turn can be fitted in any of the previous modules to obtain the desired nutrient and fertilizer recommendations to the crop (fig. 22 &23).

Fig. 22

Fig. 23

Limitations of the software
1. The results obtained May subject to change under varying agroclimatic conditions influencing crop growth and development.
2. The target yield may deviate with reference to various biotic and abiotic stresses.
3. The results may differ, if the target yield is set at a higher yield level then the potential yield of the particular variety. Though the software is capable enough to provide warnings on various critical levels.
4. Furnishing of incomplete and incorrect values may lead to vague and faulty results.

Conclusion
The software is of immense importance as it can provide immediate information to solve the problem of the user and to provide assistance in making decisions related to crop nutrient requirement and their management. The farmers/land users and researchers urgently need information about the crop nutrient requirements, nutrient uptake, and the quantity of various fertilizers and manures to be applied to the crop for obtaining desired production levels under a certain soil fertility level. The architecture of this software is organised in such a manner that wide range of users including farmers/ agriculture extension officers/ subject matter specialists/ researchers with different demands to crop and soil related data and mehtods can utilize it and obtain information's.

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