A MATHEMATICAL MODEL ON EFFECT OF FERTILIZER IN SOIL FERTILITY

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By

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CERTIFICATE

I feel great pleasure in certifying that the thesis entitled **"A Mathematical Model on Effect of Fertilizer in Soil Fertility"** by **Manish Khajanchi** under my guidance. He has completed the following requirements as per Ph.D regulations of the university.

(a) Course work as per the university rules.

(b) Residential requirements of the university (200 days)

(c) Regularly submitted annual progress report

(d) Presented his work in the departmental committee

(e) Published/accepted three research papers in a referred research journal,

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ABSTRACT

This study deals with mathematical modeling represent the effect of added soil fertilizer on soil fertility. The mathematical model was developed to estimate the availability of soil nutrients under different fertilizer practices with specific crops is based on some measurable variables. Estimation of the effect of long term application of fertilizers on status of soil nutrients is also possible through mathematical model. The present work consist of two models, first model deals in finding out effect and residual effect both of applied fertilizer on the status of available soil nutrient in continuous cropping system. Second one measure the effect of fertilizer on the status of soil nutrients other than the nutrient applied through fertilization. Average fertilizer nutrient efficiency parameter about different practices of phosphorus was calculated for blackgram crop and average soil nutrient efficiency parameter was calculated for macronutrients like nitraogen, phosphorus and potassium and micronutrient like zinc, copper, manganese and ferus under the crop of blackgram and wheat. Various soil physico-chemical properties of different blocks in Bhilwara district were measured. It was observed that soil pH in most of block varies neutral to slightly alkaline medium, in some field it was found strongly alkaline and acidic in few field. Soil electrical conductivity found almost in safe range but soil organic carbon status is tremendously low almost in all blocks which show low incorporation of manure and plant residues. Karl Pearson correlation coefficient was measured between different soil fertility parameters, a positive correlation of pH was measured EC, OC and P whereas negative correlation was measured between EC and OC further a low degree positive correlation was observed between EC and P. In the assessment of groundwater a negative correlation was measured between Cl and pH whereas F shows slightly negative with Ca and Mg. NO_3 shows positive correlation with Cl, Ca, Mg and SO_4 while a slightly positive correlation was shown between pH and NO_3.

Candidate's Declaration

I hereby certify that the work, which is being presented in the thesis, entitled "A Mathematical Model on Effect of Fertilizer in Soil Fertility" in partial fulfilment of the requirement for the award of the Degree of Doctor of Philosophy, carried under the supervision of Dr. Rajesh Sharma and submitted to the (Department of Mathematics, Govt. College, Bundi), University of Kota, Kota represents my ideas in my own words and where others ideas or words have been included. I have adequately cited and referenced the original sources. The work presented in this thesis has not been submitted elsewhere for the award of any other degree of diploma from any institutions. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Date: (Name of the Scholar)

This is to certify that the above statement made by **Manish Khajanchi** (Registration No. **RS/1828/13**) is correct to the best of my knowledge.

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(MANISH KHAJANCHI)

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List of abbreviations

SOM	Soil Organic Matter
OC	Organic Carbon
EC	Electrical Conductivity
CEC	Cation Exchange Capacity
BIS	Bureau of Indian Standards
TH	Total Hardness
FYM	Farm Yard Manure
TDS	Total Dissolved Solids
DAP	Di Ammonium Phosphate

Chapter 1

INTRODUCTION

1.1 SOIL

Soil is the combination of solid mineral particles, organic material and water. It is the normal, unconsolidated, mineral and organic matter occurring on the surface of the Earth [1], i.e. the usual soil classification is carried out based on the size distribution of mineral solid particles which can be divided into three different categories- (i) Sand, (ii) Clay and (iii) Silt. Following table represent distribution of particle size of Sand, Clay and Silt.

Soil particle size [2]

Particle	Diameter (mm)	Number per 1 gram of soil	Surface area (cm^2) per 1 gram of soil
Sand	0.05−2	89×10^5−112	15−308
Clay	<0.002	4×10^{11}	4×10^5 (non-swelling) 8×10^6 (swelling)
Silt	0.002−0.05	2×10^7	888

Soil is a natural body, having mineral and organic component as well as physical, chemical and biological properties. A legitimate concept of the nature of soil must avoid the common error that soil is simply a fusion of unconsolidated material resulting from the weathering processes of underlying rocks. Any categorization of soil suffers from the disadvantage that it is impossible to relate it to the great complexities of soil genesis and properties. The terms used in defining the soil in different systems seldom is exactly equivalent.

Soil composition is very diverse and it can be governed by different factors like climatic conditions and parent material etc. Soil is composed of three phases: solid (mineral and organic), liquid and gaseous and exhibits properties resulting from the physical and chemical equilibrium of three phases. The most important factors influencing soil properties are the chemical compositions of the solid component, its mineral structure and the state of dispersion.

Soil formation is a two step process. In first step alternation of the primary mineral which are constituents of the parent rock take place through physical and chemical processes of weathering. The second stage (pedogenesis) results in the formation of a soil profile from the weathered rocked material, leading to the development of a mature soil as the final product of the interacting processes. It is not so easy to separate and differentiate pedogenic and weathering processes because both processes happen simultaneously at the same place.

1.2 SOIL FERTILITY

Soil is the single most important natural medium for crop production. Every crop requires several nutrients for its natural growth and development which it receives from the soil. Word "fertile" is Latin originated means “to bear” and a soil will be considered fertile if it bears the capacity to produces crops abundantly under favorable environment. It is the inbuilt ability of soil to make available essential chemical elements for plant growth. Thus, soil fertility can be defined as the soil ability to supply all essential nutrients to plant in readily forms and in a proper balance. Thus, soil fertility is an important requirement for crop production. Soil fertility is influenced by the chemical, physical and biological conditions of the soil and by the quantity and balance of essential nutrients present in it. It is necessary that removed nutrients from soil to plants must be restored by proper application of organic and inorganic fertilizers to maintain soil fertility. A high fertile soil can also get exhausted of reserve nutrients if no suitable replenishment takes place. On the basis of the soil capacity to supply nutrient and type of crop, Selection of nutrient to be replenished and application of proper amount in soil take place. A fertile soil is always productive. But a fertile soil may not necessarily productive. Poor drainage, flood, drought, insects, etc. are some common factors which resist production though the soil is quite fertile. In modern agriculture, soil fertility is a part of dynamic system. Soil nutrients are being exhausted by plants animals, some nutrient like nitrogen can be lost by leaching or erosion whereas other like phosphorus and potassium, may be tied up with certain soil clays. If production agriculture were a closed system, nutrient balance might be relatively stable.

The principle of “Law of the Minimum” propounded by Justus von Liebig in the mid-1800’s states that if one of the nutritive elements is deficient or lacking, plant growth will be poor even when all the other elements are abundant. Deficiency of any nutrient even it is required in bit amount can resist the development and growth of crops.

Soil Fertility Depends on Various Soil Properties

Soil Organic Matter

Organic matter is a temporary product or a stage in a natural cycle of decay or decomposition manure or plant residue. It is continuously changed by further decomposition. Soil physical properties are drastically changed with the variation in organic matter. Organic matter plays an important role in binding the soil particle together into aggregate. Thus, organic matter affects the soil structure, water retention capacity and movement of water and air in and out of soil. Dead plants material feed microorganisms which is the huge source of total organic content of the soil. Structure of soil gets modified and improved when organisms like earthworms feed organic matter.

Soil pH

pH is a measure of activated hydrogen ion in soil solution. Relation between H^+ and pH is given by $[H^+]=10^{-pH}$. Among the various soil properties, pH is the one which affects soil nutrients availability very much [3, 4]. pH of the ideal soil is lie between 6.5 to 7.5 i.e. neutral, most of the nutrients are available to plant in this pH range hence it is very compatible range for plant's growth. Highly acidic soil i.e. low pH results into toxicity of Al and Mn. Slightly alkaline soil is good for the plants which requires calcium. High pH results in low micro-nutrient mobility, but water-soluble chelates of those nutrients can supply the deficit.

Electrical Conductivity (EC)

Electrical conductivity of a material measures the ability of transmit of electric current, its unit is milli Siemens per metre (mS/m) or deci Siemen per metre (dSm^{-1}). In other words EC shows the amount of soluble salts in a sample. Soil EC depends on the moisture contained in a soil particles. Soil EC directly related to crop production or yield [5, 6], strong correlation was measured between EC and CEC and pH [7, 8]. A high positive correlation was measured between EC and soil texture and particle size [9].

Soil Temperature

It is a representation of soil internal energy. Temperature plays an important role among various biological and chemical processes in soil. A proper soil temperature is required in seed germination process. A very high temperature may cause of death of living organisms in soil. Soil has low temperature if it contains more water because water absorb huge energy to increase its temperature which results into low soil temperature. In general, temperature of soil lies in the range of -20 to 60 C.

Soil moisture

The amount of contained water in a material is termed as soil moisture. It directly affects the exchange of water and heat energy transfer between soil surface and the atmosphere through the process of evaporation and plant transpiration. Water is in readily form if moisture is adequately available in soil. Soil water retention is directly depends on soil type, it is very low for sandy soil whereas maximum for clay.

Soil nutrients

Agricultural production is directly depends over available nutrient. For sustained high crop yields, the application of nutrients is required. The term 'nutrient availability' has been used and defined in many ways. The Soil Science Society of America has defined available nutrients: (i) the amounts of soil nutrients in chemical forms accessible to plant roots or compounds likely to be convertible to such forms during the growing season, and (ii) the contents of legally designated available nutrients in fertilizers determined by specified laboratory procedures which in most states constitute the legal basis for guarantees.

Soil productivity is highly correlated with nutrient availability. Soil productivity is capacity to produce an optimal yield of crop and plant under suitable environmental condition. Nutrients management is a very important factor to maintain soil productivity. Amount of available soil nutrients is termed as soil fertility. Soil analysis process can be used to decide suitable fertilizer recommendations for crops in the field. Nutrient availability can be assessed by observations and various tests, used for the prediction of the response of the plant and nutrient management. The adequate availability of essential soil nutrients does not assure that they are readily available for plant's growth due to the unavailability of other factors discussed above. Hence, adequate levels of nutrients alone do not guarantee soil productivity. If a soil has all suitable environmental conditions for plant growth considered as productive soil. Practically it is not possible to keep all factor of crop production at an optimal level therefore most of the factors are at suboptimal level.

The main objectives of modern agriculture system are optimal and sustaining crop yields. But to achieve these objectives, nutrient deficiency is major problem. Last century is witnessed of significant increase in crop yield due to the use of chemical fertilizer. Soil infertility in terms of nutrient deficiency has become major factor to curb crop yield.

Cation exchange capacity (CEC)

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilisers and other ameliorants [10]. CEC is measured in meq/100gm or (cmol(+)/kg) [11]. It has been observed that a soil with huge quantity of negatively charged ion is more fertile because they absorb more cations [12]. Calcium, magnesium, potassium and sodium are the major exchangeable cations associated with CEC, these are also known as base cations [13].

The soil CEC of soils depends on clay percentage, clay type, organic matter and pH of soil. CEC for pure sand or sand size2 μm and for silt of size 2mm is very low.

1.3 MATHEMATICAL MODEL

A model can be defined as a conceptual representation of real life object, or we can say a model represent something in a simplified form. It may be simple or complex depends on the problem. A model may be a pattern, description or system of postulate present some state of affairs.

Modeling is the study of processes and objects in one frame by using processes and objects in other frame as models.

Mathematical modeling is a process to present the real life problem into mathematical model and solve further refined it for better and accurate results. In general we can say every process in which a problem convert into some mathematical equations is known as mathematical modeling. So it is hard to find any area of research or study which escape from it. Every system which may be mechanical, environmental, agricultural, biological etc. can be described in an appropriate way through mathematical model. Mathematical model is the representation of real object in mathematical forms. Mathematical models consist of numbers, symbols, functions, equations or formulas. These models can be solved using simple or complex techniques as per the requirement.

It is possible to separate mathematical models based on the philosophy of the approach, with regard to the mathematical form of the model, in sometimes also depending on the application area of the model.

Optimization Models

This type of models can be used for finding optimal solution of problem. Well known linear or nonlinear programming problems are examples of sufind an optimal ch models.

Dynamic & Static Models

This classification of these models is based on the fact that result depends on time or not Static model shows equilibrium behavior of the system, it is known as steady state also whereas dynamic models account for the time varying responses of a system. They are mostly used in engineering based problem.

Deterministic & Probabilistic Models

These models are basically based on the uncertainty of final results. When final results are not known certainly even all possible outcomes are known it belongs to stochastic models while the deterministic models comprise all possible outcomes with accuracy by their current state and the future values of external variables.

Linear Vs Nonlinear

In general, mathematical models consist of variables which represent the quantities of interest in system, operators algebraic or differential, functions etc. If all the operators used in mathematical model show linearity then this model is termed as linear otherwise nonlinear. Mathematical programming models will be linear if objective function and constraints of problem can be expressed as linear equation whereas if anyone of objective function or constraints is not expressed as linear is known as nonlinear.

Mathematical Modeling in Soil Science

Mathematical modeling has been applied to a soil pollution problem in Nepal. In which finite difference method had been applied successfully to predict the residual effect of potassium which is an important constituent of poly methanated effluent a by-product of alcohol. Mathematical model was given as equation

$$\left.\frac{\partial(K(t,d))}{\partial t}\right|_{t \quad fixed} = C_1(t) * d^3 + C_1(t) * d^3 + C_1(t) * d^3$$

where K(t,d) is concentration of K at time t and depth d [14].

In a study in Iran, it was found that the logistic model is more reliable in comparison to quadratic model and linear plateau model for estimation of N fertilizer requirements for vegetable crop lettuce. Used model equation were

$$Y = \frac{A}{(1+\exp(b-cN))}$$

$$N_u = \frac{A'}{(1+\exp(b'-cN))}$$

for logistic model. Where Y is yield in lettuce fresh mass, N_u is nitrogen uptake by lettuce, N is applied Nitrogen, A is maximum yield, b and b' are parameters of yield and nitrogen uptake.

Whereas the linear plateau model was given by

$Y = B + CN$ for $N<N_x$

$Y = A$ for $N>N_x$

where B and C are intercept and slope parameter

N_x is application rate of N for interception.

The quadratic model was given by

$$Y = A + bn + CN^2$$

where A is interception parameter and B is linear response coefficient and C is quadratic response coefficient [15].

In a study at China, A regression model was constructed for autumn soybean yield and net profit as follows

$$y_1 = 2849.07 - 824.8x_1 + 731.60x_2 + 476.75x_3 - 331.9x_1^{\ 2} - 298.56x_2^{\ 2}$$

$$+191.30x_3^{\ 2} + 118.15x_1x_2 - 214.70x_1x_3 + 374.20x_2x_3$$

$$y_2 = 10946.39 - 3420.49x_1 + 2907.82x_2 + 1862.94x_3 - 1620.85x_1^{\ 2}$$

$$-1290.50x_2^{\ 2} + 668.84x_3^{\ 2} + 711.95x_1x_2 - 619.43x_1x_3 + 1366.37x_2x_3$$

where y_1 is yield kg/hm^2, y_2 is net profit yuan/hm^2, Sowing date is (x_1 , month/day), x_2 is plant density(plants/hm^2) and x_3 is N fertilizer level kg/hm^2 [16].

Sherlock and Goh [17] suggested simple mathematical equation to govern the ammonia volatilization losses in the field, which was

$$dNH_X = U_0\{e^{-k_1 t} - e^{-k_1(t+dt)}\}$$

where dt is program stepping time.

dNH_X ias amount of NH_4^+-N generated in the topsoil in the time dt (% of applied N),

U_0 is amount of urea originally in the topsoil at time 0 expressed as a percentage of the N applied,

t denotes the time taken after application of urea,

k_1(hr^{-1}) represents first order urea hydrolysis constant.

Wang and Chen [18] suggested mathematical model on movement and transformation of NH_4^+ were given by

$$\theta\frac{\partial C_1}{\partial t} + \rho\frac{\partial S_1}{\partial t} = \frac{\partial}{\partial z}\left(D_{sh}(u,\theta)\frac{\partial C_1}{\partial z}\right) - q\frac{\partial C_1}{\partial z} - k_2(\theta C_1 + \rho S_1) + k_1\theta C_N\frac{18}{14}$$

$$\frac{\partial S_1}{\partial C_1} = \frac{b}{\sqrt{C_1}}\left(S_{1m} - S_1\right)$$

$$S_1 = 0 \qquad C_1 = 0$$

$$C_1 = C_1^0(z) \qquad t = 0, z \geq 0$$

$$-D_{sh}(u,\theta)\frac{\partial C_1}{\partial z} + qC_1 = 0 \qquad z = 0, z = z_D, t > 0$$

Uptake, movement and transformation of NO_3^- in soil was given in following ways

$$\theta \frac{\partial C_2}{\partial t} = \frac{\partial}{\partial z}\left(D_{sh}(u,\theta)\frac{\partial C_2}{\partial z} \right) - q\frac{\partial C_2}{\partial z} + k_2(\theta C_1 + \rho S_1)\frac{62}{18} - k_3 \theta C_2$$

$$-D_{sh}(u,\theta)\frac{\partial C_2}{\partial z} + qC_2 = p(t).C_{2R}(t) \qquad z = 0, t \geq 0$$

$$C_2 = C_2^0(z) \qquad t = 0, z \geq 0$$

$$-D_{sh}(u,\theta)\frac{\partial C_2}{\partial z} + qC_2 = 0 \qquad z = z_D, t > 0.$$

To measure the impact of waste matter of paper and pulp manufacturing plants on microorganisms in soil in Uttaranchal Tarai mathematical modeling were used [19]. The proposed model was given by $A = A_0 e^{ks}$, where A is the activity difference at distane s, k is constant and A_0 is maximum attainable value of A. Result revealed that microbial biomass and activity difference were declined exponentially as distance increased.

Marinov suggested mathematical model to describe nitrogen cycle for a system of soil, water and plant [20].

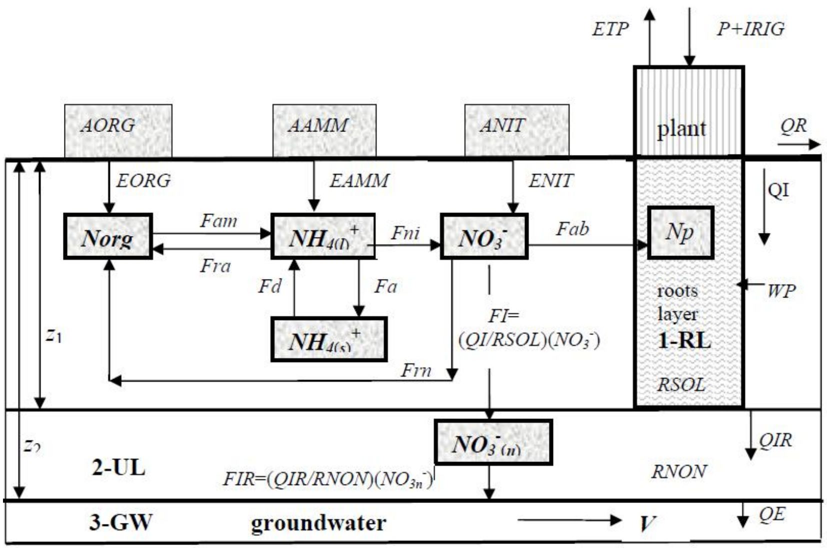

Figure1.1: Nitrogen Trasformation in Soil

Following equations represent changes between different nitrogen compounds of above mentioned model,

$$\frac{d(NO_3^{-1})}{dt} = ENIT - FI + Fni - Frn - Fab,$$

$$\frac{d(NH_4^{+})}{dt} = EAMM + Fam - Fni - Fra,$$

$$\frac{d(Norg)}{dt} = EORG + Frn + Fra - Fam,$$

Mathematical model was developed by Eluozo and Afiibor [21] to monitor the behavior of nitrogen on salmonella (microbes) transport at coastal area of Port Harcourt in Nigeria, governing equation of the model was

$$V\frac{\partial C_s}{\partial t} = \frac{\partial C_s}{\partial z} q_z C_s + D_s \frac{\partial C_s}{\partial z} - M_b \frac{\mu_0}{\gamma_0}\frac{\partial C_s}{\partial z} + \frac{\partial C_s}{\partial t}\frac{C_s}{K_{s_0} + C_s} + \frac{\partial C_s}{\partial z}\frac{C_A}{K_{A_0} + C_A}$$

Above equation express the parameters which affect the behavior of nitrogen on salmonella transport in homogeneous fine sand in coastal area.

To estimate the nitrogen status in soil under different fertilizer practices in continuous cropping system, a mathematical model was developed [22]. Following balance equation was used to predict the steady state of nitrogen level

$$S_t = S_{t-1} + F_t - U_t + E$$

where S_t represents available soil nutrient after tth crop, F_t is applied fertilizer nutrient, U_t is uptake nutrient and E is average build-up in soil.

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Chapter 2

AIM AND OBJECTIVE

2.1 AIM AND OBJECTIVE

For a sustainable agricultural productivity it is necessary to maintain the supply of required nutrient, that's why a huge amount of various nutrients has to be applied in soil through different fertilization practices. Such type of practices definitely improves the soil health further enhance productivity in long run. Excessive incorporation of chemically synthesized fertilizer creates tremendous issue like soil acidification or decrease in soil organic matter [23]. Excess Nitrogen incorporation to fields spoil the soil which decline the harvest. Continue use of chemical fertilizers also contaminate the ground water sources through leaching [24]. Chemical fertilizers are absorbed by soil faster than plant due to high soluble property. Agriculture has become the largest contributor of nitrogen contamination of ground water [25, 26] due to the large application of nitrogen originates fertilizers for high productivity of crops [27, 28].

An understanding of the factors that affect the status of available plant required nutrients in soil and their effect of availability of soil nutrients and their contamination in groundwater is important for many applications. This understanding is necessary to estimate the assimilative capacity of a soil and whether input fertilizer are likely to accumulate within the soil profile or leach to contaminate groundwater. An understanding of these factors will also help in identification of suitable remediation methods.

To design and control the operation of soil ecosystem model the mathematical modeling can play an important role. Several comprehensive institutional models have been developed in recent years for this purpose. Mathematical based environmental models are comparatively less expensive also work more rapid than other experimental approach, and it can be taken as an effective tool in the decision making.

Objective

- Formulate mathematical model for prediction of status nutrients in soil.
- Find its solution under specific fertilizer applications.

- Estimation of soil macronutrients status under specific fertilizer application.
- Predict the level of soil micronutrients under the influence of different fertilizer practices.
- Predict the steady state level of soil macro- and micronutrients under the long run fertilizer practices.
- In this work, some physico-chemical properties of soil have been estimated in different blocks of Bhilwara and established correlation between them.

2.2 IMPORTANCE OF PROPOSED RESEARCH WORK

A quantitative description of availability of micro- and macronutrients in soil is required to predict the impact of human influence on the soil health and environment also. For further recommendations of fertilizer applications, it is required the same mentioned above.

In the present study, we worked on finding out the influences or effects of different fertilizer application on soil fertility through mathematical modeling. Firstly, we introduced the underlying physical concept and then translate in to a mathematical model, and find its solution. Then validitation of model was checked by applying on available field data. Results obtained through theoretical approach or mathematical model were closely agreed with observed available data.

Assessment of soil physico-chemical properties using available data of different blocks in Bhilwara district of Rajasthan provides brief overview about the status of various parameter of soil in the district. It helps to choose suitable recommendations and amendments in fertilization practices to improve soil fertility and optimize crop yield. Correlation coefficients has also been measured to study the interdependency of various parameters. Moreover, additional research is required to develop accurate and rapid measurement techniques for the necessary input parameters. Modeling concepts should be coupled with mathematical framework for maximum utilization in real environmental issues. This work will be primarily devoted to various issues related to the modeling of soil fertility.

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Chapter 3

REVIEW OF LITERATURE

3.1 SOIL NUTRIENTS

No discussion on soil fertility management would be complete without introducing nutrients required as plant nutrition. In 1954, Arnon stated that an element must be considered as essential its deficiency affect plants metabolism adversely or its deficiency resist plant to complete the cycle of reproduction, vegetation etc. and this deficiency can be prevented through proper supply of this element. Nicholas(1961) suggested the term functional nutrient for the element that affects plant metabolism. A Plant needs 16 elements or nutrients for its growth and for the completion of life cycle further they can be divided into major three parts.

(i) Basic nutrients- Oxygen, Carbon and Hydrogen are three basic nutrients which constitute 96% part of plant’s dry matter. Carbon and oxygen constitute 45% each and hydrogen constitutes nearly 6 percent of total.

(ii) Macronutrients- These further can be divided into two parts namely primary which is required in large quantity by plants and secondary is required in small quantity. Primary nutrients are Nitrogen, Potassium and Phosphorus whereas Sulphur, Calcium and Magnesium are secondary. Their deficiency specially of N, P, K is corrected by application of fertilizers.

Nitrogen (N): Nitrogen is an important constituent of living cells. Nitrogen is the major part of chlorophyll which leads to photosynthesis hence it is directly involve in metabolic and energy transfer process. Further Nitrogen involves in various other function like leaf quality, seeds quantity, crop yield and plant growth etc. Its deficiency result into delay fruiting, yellow leaves, reduced yield etc.

Phosphorus (P): Phosphorus is responsible for tranlocation of older tissue to younger one i.e. to move elements into seed and fruits. It is also involve in cell nucleus formation, process of supplying starch, cell division etc. Its deficiency revealed into poor growth, poor flowering, purple stems or leaves etc.

Potassium (K): Potassium plays major role in completion various enzymatic reactions involved in metabolic process. It plays an important role in energy transformation. Besides it potassium is also essential for photosynthesis, maintain in water balance in plant. Its deficiency leads to curled leaves.

Micronutrients- Soil nutrients which are required for the growth of plant in very little quantity are termed as micronutrients or trace elements. Fe, Zn, Cu, Mn, B, Mo, and Cl are micronutrients required by plants. These elements have great influence on plat growth even they are required in a bit amount. Its improper supply, more or less both are very harmful for plant.

Table 3.1: Functioning of micronutrients and effect due to their deficiency

Name	Functions	Deficiency
Ferus/Iron (Fe)	(i)Enzyme formation, (ii)Catalyst in the synthesis of chlorophyll	(i)Yellow or pale leaves and veins
Manganese (Mn)	Enzyme activity in photosynthesis and respiration	(i)Yellow leaves (ii)Yellow or green veins (iii)Brown of black spot near veins
Boron (B)	(i)Regulating metabolism of carbohydrates (ii)Movement of harmones (iii)Cell wall formation and cell division etc.	(i)Terminal bud die (ii)Rosette of curled and thick leaves (iii)Brown or cracked fruits or roots and tubers
Zink (Zn)	(i)Plant growth through the synthesis of indoleacetic acid (ii)In proterin synthesis	(i)Mottled leaves (ii)Irregular yellow area
Copper (Cu)	(i) In Nitrogen metabolism (ii)Synthesis enzyme used in carbohydrate and protein metabolism	(i)Die back of shoot tip and terminal leaves (ii)Brown spot

3.2 BRIEF OVERVIEW OF FERTILIZERS

Fertilizer is any organic or inorganic product which may be natural or synthetic is added in the soil to supply nutrients which are required for plant growth. Main purpose of using these products is to improve the level of soil nutrients which are inherently less. They must be supplied with the object to remove deficiency. For a material to be considered as a fertilizer, it must have nutrient in adequate amount and in readily or potential usable form. Fertilizers must be used with the only purpose of improving soil fertility so that it can enhance larger harvests.

Soil is the loose surface of the earth’s crust, which is the natural medium for plants to grow and it supplies sufficient amount of nutrients for plants’ growth. Soil erosion , salt accumulation, improper nutrient supply are some major cause to curb soil fertility. Long back we are in practice of using mined inorganic fertilizer whereas the chemically synthesized fertilizer has been used for last few decades. More than half of the world population is being fed as a result of synthetic fertilizers’ use.

Fertilizers can be mainly classified as

1) Bio fertilizer

2) Chemical fertilizer

1). Bio fertilizer

Those fertilizers which are used to improve the soil fertility using biological wastes or biological forms are known as bio fertilizers. It contains no chemical. They are very useful for soil because they have microorganisms which produce organic nutrients in soil. Soil is the natural habitat of various microorganisms which are really beneficial for agriculture. Few of them absorb the nitrogen and convert it in to readily available form to plants and few microorganisms called phosphate solubilizing bacteria act solubliz the insoluble phosphate in soil and convert into readily form.

When a bio fertilizer is supplied to soil, living available microorganisms in it colonizes the rhizosphere which promotes primary nutrient supply hence helps in improving plant growth [29]. Use of bio fertilizers results into healthy and sustainable soil further reduce the problem arisen due to soil pollution and a nontoxic crop can be taken [30]. Bio fertilizer can be classified as follows-

(i) Vermicompost: It is an organic manure which is produced by soil microorganism like earthworm in the form of as worm casting by earth worm feeding on biological or plant waste. It contains adequate quantity of essential macronutrients and several micronutrients which are required for the plant growth. It is the most preferable nutrient source for organic farming. It has veen observed that vermicompost contains 21.3% nitrogen, 0.93% phosphorus and 0.44% carbon [31]. In some other study it was found that vermicompost has 11.5% organic carbon, 1.3% total nitrogen, 1.3% phosphorus and 2.6% potassium [32].

(ii) Farm Yard Manure (FYM): To prepare such type of fertilizer one need cow dung, urine, plant residue and dairy waste. A small amount of N through FYM can be readily available to plants while remaining amount is available after decomposition in soil. In a study, it was found that nutrient contains in FYM were 0.62% N, 0.31% P and 0.71% K [33].

(iii) Poultry manure: Poultry manure is a cheap source of macro and micro nutrients in comparison of other. It also helps to enhance soil carbon and nitrogen content, soil porosity. For short term, it can improve soil organic content. It can also be used as a source of N, P and K [34].

2). Chemical fertilizer

A chemical fertilizer is a material of synthetic origin (fully or partially) is used to apply in soil to maintain proper plant growth. These are produced or developed synthetically from inorganic materials mainly. Generally they are used to cover the deficiency essential nutrients nitrogen, phosphorous and potassium.

A fertilizer material is known as complete fertilizer if it contains all three major nutrients N, P and K whereas it is incomplete fertilizer if any one of these three is absent. Complex fertilizer is a chemically synthesized material which is consists of more than one prime nutrient. If two or more fertilizer material mixed together may be as dry powder, granules, pellets, bulk blends or liquids is known as mixed fertilizer. We can divide chemical fertilizers in following types.

1. Nitrogenous Fertilizers

A plant takes up its nitrogen in the form of either ammonium or nitrate ion. These inorganic nitrogenous fertilizers may contain one or both of these ions. In some of the fertilizers, nitrogen is present in amide form. In soil it is rapidly converted into ammonium form through biological or chemical transformations. The common nitrogenous fertilizers can be classified as-

(i) Ammonical or Ammonium fertilizers: Ammonia in these fertilizers is obtained either as a by-product from the destructive distillation of coal or from synthetic ammonia plants where it is produced by combining hydrogen with nitrogen taken from air. These are in readily form because they highly soluble in water. Absorption of ammonium ions by soil colloidal is resulted into minimum leaching of these fertilizers. Ammonium sulphate, Ammonium chloride are the examples of such type of fertilizers.

(ii) Nitrate fertilizers: These fertilizers are obtained as natural products of salt deposition or manufactured products from synthetic ammonia. They are readily soluble in soil solution, replacing the nitrate ion for plant absorption. These fertilizers are very useful in early age of crop. High mobility of the nitrate ion in the soil causes leaching of these fertilizers in dipper layer of soil. In dry soils, nitrate fertilizers were observed superior to the other forms of nitrogenous fertilizers. Continuous use of nitrate fertilizers reduces soil acidity significantly. Sodium nitrate ($NaNO_3$) is its examples, which is common in India.

(iii) Amid fertilizers: These fertilizers basically contain carbon and hence classified as organic compounds. Such type of fertilizer is highly soluble in water and they get easily decomposed by soil microbial. Commonly used amid fertilizers are Urea (NH_2-CO-NH_2) and calcium cyanamide ($CaCN_2$) are its examples. When applied in soil, they quickly converted into ammonical nitrogen and then to nitrate form.

(iv) Nitrate and Ammonium fertilizers: This type of fertilizer contains nitrogen in ammonical as well as nitrate forms. Examples of such type of fertilizers are ammonium nitrate, ammonium sulphate nitrate etc. Soil range in which these fertilizers can be used is very large and they are in readily form because of good solubility in water. They have the properties of both nitrate and ammonium nitrogen i.e. readily available nitrogen due to nitrate and least leaching lose due to ammonium. The drawback this fertilizer is, it left acidic effect on soil in long run.

Besides these Anhydrous ammonia, Aqueous ammonia and solution containing urea and ammonium nitrate or ammonia are used as nitrogenous fertilizers but not common in India.

2). Phosphatic Fertilizers

Liebig in 1840 discovered that phosphate contained in bones is dissolved in sulphuric acid and it could become available for plants. In 1842 Lawes synthesized plant available phosphate from rock phosphate and sulphuric acid which is known as superphosphate. It was a great revolution in the field of phosphotic fertilizers. The phosphotic fertilizer contains some amount of P_2O_5 that's why phosphorus content in fertilizers is expressed as percentage of phosphorus pentaoxide. Types of phosphatic fertilizers are-

(i). Water soluble phosphatic fertilizer: Phosphate contained in these fertilizers is easily dissolved in water hence they are easily available to plants. Minimal leaching loss was observed of these fertilizers because they are prone to fixation but the fixed part could not available for plants. Fixation is the worst problem in acidic and alkaline soils. Single Superphosphate (CaH_2PO_4) (16-18% P_2O_5), Double Superphosphate $CaH_4(PO_4)_2$ (32% P_2O_5), Triple Superphosphate $Ca(H_2PO_4)_2$ (42% P_2O_5), Ammonium phosphate are some common example.

(ii). Citric acid soluble phosphatic fertilizers: These fertilizers are not soluble in water but in acidic or weak acidic water. Contained phosphorus in these fertilizers are of HPO_4 form. These fertilizers are very much suitable for acidic soil, in low pH it is converted into monoalcium. Basic slag (18% P_2O_5) and Dicalcium phosphate (34-39% P_2O_5) are example of such fertilizers.

(iii). Water insoluble phosphatic fertilizer: These kind of fertilizers are not soluble in water but slightly soluble in weak acidic and highly soluble in strong acidic medium. They are recommended to be used in strongly acidic soils. This type of fertilizer contains phosphorus in PO_4 form. They are applied in large amount with green manure or organic materials. Rock phosphate (20-40% P_2O_5), Bonemeal(2-25% P_2O_5) and Steamed bonemeal (22% P_2O_5)

3). Potassic Fertilizers

Potash is the third most important primary essential nutrient required by the plants. Although potash is nutrient which is removed from soil more than nitrogen and phosphorus but it is normally not deficit in soil because soil replenishes it very fast. Potassium sulphate (50% K_2O) and the muriate of potash (60% K_2O) are common example of these fertilzer.

Muriate of potash contains more potassium than potassium sulphate on the basis of the percentage. Muriate of potash is recommended for acidic soils. Potassium sulphate is preferred for well aerated, calcareous (more calcium contained) and alkaline soils. Potassium sulphate is recommended for sulphur deficit soil. Any potassic fertilizer does not alter the pH of the soil. When a potassium salt is applied to a soil it is immediately dissolved and undergoes ionization. A portion of K^+ ions remains in the soil solution, another portion gets adsorbed to clay complex by CEC reactions and a third portion is converted into unavailable form.

3.3 EFFCTS OF FERTILIZER ON

3.3.1 **Soil Nutrient Status**

A significant improvement in ammonium and nitrate N available in soil was observed with the combined use of natural and chemical materials [35].

Application of 100% NPK through fertilizers resulted in highest increase of all organic fractions of N while 100% NPK+FYM increased amino acid N and hexosamine N [36]. In a study Kher and Minhas concluded a better status of all hydrolysable N can be maintained by appliying Nitrogen in comparison of control whereas the combined supply of N and P nutrients enhanced soil amino acid bound N significantly [37]. Verma and Bhagat showed that NH_4-N content of the soils decreased while NO_3-N increased gradually with an increase in soil depth up to feeding zone of wheat roots under straw incorporation and straw mulch treatment [38].

Green manure and FYM application with or without N fertilizer markedly increased total hydrolysable N [39]. In some other experiment significant increase in oraganic carbon and available soil were revealed in a application of crop residue [40]. Significant increase in available soil N were measured with increasing doses of NPK (50 to 150%) results was more appreciable about higher level of fertilizers [41]. It was revealed that urea and wheat residue in combination improved amino sugar N level in soil while the level of amino acid N found increased as a result of urea and manure application in sandy loam soil [42].

In a four year experiment at Kharagpur, Hegde found higher available nitrogen in fertilized plots in comparison of unfertilized plots [43] further he reported significant effect of 100% NPK fertilizer application on available nitrogen. In a six year study, Prasad indicated a deficiency of 23%, 44% and 16% in available N, P and K respectively on plots where neither manures nor inorganic fertilizers were applied [44].

At CSKHPKV Palampur, declined in available N from 540.5 kg/ha to 532 kg/ha were measured for rabi and for kharib it declined to 475.75 kg/ha. [45].

Basumatary and Talukdar reported that combined use of chemical fertilizers and manures or biofertilizers increased the level of NH_4-N, NO_3-N, total N and organic N fractions of soil in comparison of the soil treated with chemical fertilizers only [46]. In a four year experiment, application of recommended dose of nitrogen fertilizer to wheat- rice crop system markedly increased soil NO_3-N over the control plots, 74% of this increase occurred below 90 cm [47]. It was observed that application of manure in long run increased microorganism activity in soil [48], which encourages the transformation of organic P fraction to P inorganic fractions. A marked increase in phosphorus availability was reported with increase in the rate of applied fertilizer P.

In an experiment on a sandy loam soil, it was found that big portion of added P was converted into saloid-P and Al-P which further converted into Ca-P in long run [49]. In an experiment conducted on an alkaline clay loam soil [50], it was observed that P fertilization increased saloid-P, Al-P, reductant soluble P and Ca-P, but Fe-P remains unaffected.

Harenz reported significant increase in total P and equilibrium concentration of the soil solution with increasing fertilizer levels [51]. In an eighteen year fertilizer application experiment on an acid Alfisol in Palampur, Sharma found that regular application of phosphatic fertilizers has resulted in significant build up of Al-P in 100% NP and 150% NPK treatments due to under utilization and over application of P, respectively in these treatments. He also reported that Fe-P was found lower in comparison of its initial value except in 150% NPK while Ca-P increased because of continuous manuring and cropping in almost all the treatments except control and 100 % N only [52].

In a study, the effect of sewage sludge on phosphorus transformations under wheat cultivation, it was reported that available P soil status increased with increasing P levels but, the maximum availability of P was reported with the application of sewage sludge + DAP at the rate of 75 kg ha^{-1} [53]. The increase and decrease of soil available P depended on the addition or omission of chemical P in soil. Also it was observed a significant increase in the available P status of soil in the plots receiving fertilizer P and FYM. In a experiment Prasad found that application of FYM increased Al-P, Ca-P and residual-P by 0.3%, 1.7% and 0.7 %, respectively over 100% NPK applied alone, but Fe-P decreased by 1.3% showing thereby an increase in Ca-P at the expense of Fe-P [54].

During the study of the changes in P fractions under continuous corn cultivation with and without P fertilization Zhang and Mackenzie observed significant difference in P fractions between fertilized and non-fertilized plots. In fertilized plots, P (organic) was not depleted but P (inorganic) fractions increased [55]. Inadequate fertilizer P may decline P (organic) more than P (inorganic). Phosphorus addition increased predominantly $NaHCO_3$- P (inorganic) and secondly NaOH- P (inorganic). Only a small portion of added P was transformed into the most stable P form of P i.e. residual-P.

A combination of chemical NPK and FYM treatment in long run was found more effective for total P uptake than the other fertilizer treatments for maize [56]. In a long run fertilizer experiment on sandy soils, status of P was observed declined in the plots where only nitrogen and potash were applied in comparison to plots receiving phosphorus and manure application [57]. In another long term fertilizer experiment, Tiwari reported increased available P in the plots received 100% and 150% NPK as compared to control plots [58]. Verma reported that available P status increased in plots receiving P fertilizers and other amendments like lime over control and plots receiving only N fertilization [59]. He found that there was a significant increase in Al-P, Fe-P, Ca-P and residual P forms with the application of inorganic fertilizers along with amendments like FYM and Zn application. He further reported that after continuous cropping and fertilization for 29 years there was 44 and 11% increase in available P in 150% NPK and 100% NPK and manure, respectively over 100% NPK alone application.

Reddy reported that available phosphorus increased in all the treatments compared to initial value. There was a 15 to 20 kg increase in available P in treatments that received organic and chemical nutrition over initial status of 24.4 kg/ha [60].

Sharma [61] reported that significant increase in available phosphorus content of soil was measured in the plot receiving 100% NPK and FYM over the plot receiving 100% NPK due to continuous application FYM. Significant change in soil fertility were measured in long run application of manure and plant residue in rice wheat system further increased soil p status were reported when organic manure applied with chemical fertilizers [62].

In a study of transformation of applied potassium in combination with organic manures and BGA, Prasad and Rokima observed that the increase in water soluble, exchangeable and non-exchangeable K with the application of FYM, BGA or FYM plus BGA over chemical fertilizers was in the range of 2 to 3, 2.5 to 5.3 and 3 to 33 ppm, respectively [63]. Patiram and Singh found that the amount of exchangeable K in the soil remained almost same in all the plots without manure application [64]. Dhanorkar found that FYM application improved water soluble K status of soil but reduced fixed K by about 50% [65]. He also reported that the soil K status increased by 1.3 to 5.4 folds by continue application of FYM. Combined application of chemical fertilizers and FYM increased the exchangeable K content in soil over NPK treatment only as well as over initial status.

In a study of six year experiment, Sharma and Verma revealed that addition of *Lantana* from 10 to 30 tones per hectare increased all the fractions of potassium significantly and maximum increase was found in exchangeable K followed by water soluble K over control [66]. Regular application of fertilizers improved available K in soil in comparison of control application further the combined application of manure and 100% NPK enhance potassium plant uptake [67].

3.3.2 Soil Physical Properties

A reduction in bulk density has been measured as a result of the application of organic matter. Sharma and Sharma revealed that application of increased level of fertilizer and FYM resulted in the reduction of soil bulk density from the initial value, but in the plots without manure application no change in bulk density were found [68]. In a three year long experiment on silty clay loam in palampur, decreased bulk density were measured after the application of french bean residue and Dhaincha [69]. Similar results were found for clay loam soil in Kaul (Haryana), 8.1% reduction in bulk density were measured after the application of *Dhaincha* 33 t ha^{-1} [70].

Saxena and Yadav recorded lower values of bulk density in soils in rice-wheat cropping system owing to green manuring with green gram [71] while increase in bulk density were also measured with the increased rate of NPK [72].

In sandy clay soil, application of green manure and greengram biomass under rice wheat system resulted into declined bulkdensity [73]. Similar results have also been found with the application of organic manure [74]. Sharma reported significant increase in water retention capacity with the combined use of organic and chemical fertilizer in rice wheat system [75].

Hynes and Naidu found that combined application of lime, manure and fertilizer affect soil organic matter, soil porosity and water holding capacity further they reported appreciable rise in hydraulic conductivity and bulk density [76]. Similar results were also revealed by Zhang and Hang with the incorporation of green manure, plant residue or we can say using traditional approach in agriculture [77, 78]. In some other experiments, Hati and Swaroop reported increase in the volume of macropores while decrease in micropores, as an effect of continuous long run fertilization [79]. Nadiya and Anderson in different studies on effect of long run agricultural management reported increasing saturated hydraulic conductivity and water infiltration rate [80, 81]. Gregorich found significant positive difference in availability of soil organic carbon as a result of incorporation of animal manure and plant residue over the application of inorganic fertilizer in same amount [82].

3.3.3 Soil Chemical Properties

At Arlington, soil acidification was revealed as a result of long run incorporation of urea and ammonium nitrate. Average pH values were observed between 5.6 to 4.8 [83]. A negative correlation was found between exchangeable acidity and base cations as an effect of N fertilization i.e exchangeable acidity increased as cations declined. The decline was most significant in exchangeable Ca^{2+}, which was 31% less in the 150 lb N/acre treatment than in the zero N control, and 36% less exchangeable Mg^{2+} [84].

It was reported that application of 336 kgN/ha/year for 5 years on Kentucky silit loam resulted in lost of 4.3 $cmol_c$ per kg and gained 1.0 $cmol_c$ per kg exchangeable base and exchangeable acidity respectively [85]. The effective CEC found declined from 8.9 to 6.13 $cmol_c$ kg^{-1} i.e reduction was 31%. At a fertilizer application of 168 kg N ha^{-1} yr^{-1}, CEC was declined to 7.1 $cmol_c$ kg^{-1} it was 20% reduction.

In a forty year long experiment on Kansas silt loam with the app of 22 kg/ha It was found that CEC declined from 19.1 to 12.8 $cmol_c$/ kg, in comparison of control N it was 33% reduction [86].

In a two year field survey, It was revealed that degradation of soil in Chineses hickory and soil acidification are serious result of long term intensive fertilization practices [87].

3.3.4 Soil Microbiological Properties

Soil microorganisms play a very important part in maintaining fertility of soil and crop yields by involving in various biochemical processes [88]. It has been observed that the structure of microorganisms and their activities were significantly affected by various soil management practices [89]. It has been revealed that the practices associated with organic farming have a positive impact on diversity of soil microbial whereas chemical fertilizers have bit negative impact over microorganism community [90]. Loss in soil phosphorus under control, NK and N+FYM treated plots was 5.1 $kgha^{-1}$, 5.2 $kgha^{-1}$ and 15.8 $kgha^{-1}$ respectively. Highest level of culturable microbes, microbial biomass N and C were observed in the plots treated with NPK and manure [91]. In a 36 years long field experiment conducted at Punjab Agricultural University, Ludhiana (India), it was found that the SOC pool was minimum 7.3 Mg ha^{-1}under control and maximum 11.6 Mg ha^{-1} about 100% NPK+FYM. The correlation coefficient of available soil organic carbon with Infiltration rate and crop yields were found positive [92].

3.4 INTERNATIONAL AND NATIONAL STATUS OF WORK DONE

Mathematical Modeling has huge applications in different fields like biomedical sciences and environmental sciences etc. Several Mathematical model has been developed to study environmental pollution, soil pollution problem, various parameters of the soil such as electro conductivity, pH etc. Finite difference method has been used successfully to predict the residual effect of potassium on soil [14].

Mathemtical modeling to assess the mobility and deposition of the particle which pollute soil or water system has become very popular in few decades. Many researchers have developed many models to achieve for such problems. Process of transport of nutrients and other particles in soil has been reviewed by many authors [93 - 95].

Quadratic models are found good to describe crop response to fertilization except maximum point on the curve. Some plateau model like linear plateau [96] found useful for agronomic crops [97] and vegetables [98] and logistic model found suitable with agronomic crops [99].

Various studies shows that the intensive use of nitrogen fertilizer in farming causes serious problem like water contamination or pollute ground water due to leaching [100, 101]. Transformation and uptake of N in soil crop system has also been discussed by various researchers [101, 102].

The appropriate use of chemical fertilizers is beneficial to improve agricultural production, plague control etc. But the remaining of these substances is major threaten to soil ecosystem [103]. The discharge of these fertilizers to surface water plays a major role in declining the living organisms and the deterioration of ecosystem [104, 105].

Physically based environmental cum mathematical models are less expensive and faster than other experimental strategies, and more effective to measure different soil properties. Landfill Degradation and Transport (LDAT), numerical based model was developed by White and Robinson [106].

Several Crop Simulation model have been designed to simulate soil-atmosphere process in field. Duchon used the CERES-Maize model to predict maize yield [107] whereas Hodges used CERES-Maize model to measure the fluctuation in maize production [108]. Crop simulation model can also be used to predict regional agricultural production [109], farm level adaption issue [110]. It has been observed that was microbial level of agriculture field is adversely affected by the point and nonpoint pollution sources further it curb soil fertility [111]. In arid or semi-arid regions, salinization has been observed as a serious soil problem. It is highly influenced by climate, soil type, crop, water quality for irrigation and fertility management practice etc. Prathapar and Robbins compared the level of saline water in capillary with estimated water level using three mathematical model which are a numerical NM and two analytical method QSSAM (quasi steady state) and TSAM (transient state).They reported estimated value obtained through NM were very close to observed value and followed by TSAM [112].

Most of the transport equations are of non-linear form and numerical method is a suitable approach to understand the problem completely. Various partical transport equations can be solved by finite-difference and finite-element methods. These methods require solving large number of equations and good knowledge of mathematical techniques to implement [113].

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Chapter 4

MATERIALS AND METHODS

4.1 SOIL CONSTITUENTS

Soil is consists of three phases namely solid, liquid and gaseous phase, each one in a specific proportion depends on the quantity of its constituents and their role in formation in soil. Following figure illustrates the composition by volume of an average soil.

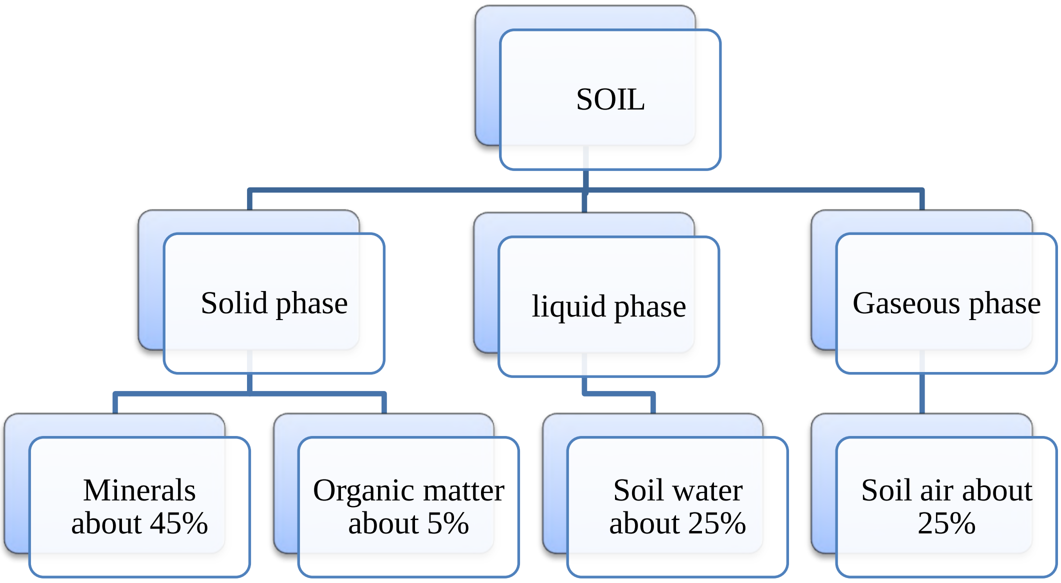

Figure 4.1: Classification of soil by volume

MINERALS

The mineral constituents of soil inherited from the parents rocks have been exposed for various periods of time to weathering and pedogenic processes. The common primary minerals in soil inherited from the parent material can be arranged in to parallel series, according to their susceptibility to weathering processes:

- Series of felsic minerals; plagioclase > K-feldspar muscovite > quartz,
- Series of mafic minerals; olivcne>pyroxenes > amphiboles > biotic.

They are, however, considered to be the source of certain micronutrients elements. The approximate composition of mineral constituents of surface soil shows that quartz is the most common mineral in the soil, constituting 50 – 90% of the solid phase. Even in geochemical condition favourable for the leaching of silicates, quartz remains as basic soil mineral. Feldspar is of low relative resistance to weathering in the soil environment and their alternation usually provides materials for clay mineral formation. Carbonates and metal oxides are usually accessory mineral in soil of humid climatic zones, while in soil of arid climatic zones they may be significant soil constituents.

THE LIQUID PHASE – SOIL WATER

Precipitation and Groundwater are principally two sources of Soil water. Each contributes to the amount of moisture in the soil, depending mainly on the climate and the water balance between the atmosphere and the plant-soil system. The amount of water lost to the atmosphere comprises the sum of the water transferred by evaporation and of that transferred by plant transpiration, forming together the evapotranspiration. This depends directly on the climatic conditions as well as the properties of the plant-soil system. The evapotranspiration that would take place under optimum precipitation conditions and soil moisture capacity is known as the potential evapotranspiration.

THE GASEOUS PHASE – SOIL AIR

Soil air, or Soil atmosphere, is the characteristic name given to the mixtures of gases moving in the aerated zone above the water and filling the soil pores. Their flow in aerated zone is completely governed by atmospheric factors like moisture, temperature and pressure conditions. Soil air composition is bit different than atmospheric air. Soil air contains 1–6% less oxygen by volume and 10 to 150 times more CO_2 in comparison of atmospheric air.

These differences in the concentration of CO_2 and O_2, between soil air and the atmosphere, result in partial pressure gradients between the two systems along which CO_2 moves towards atmosphere from soil whereas the oxygen moves in opposite direction i.e. atmosphere to soil. Gas exchange between soil air and the atmosphere occurs also along temperature gradients and in sites where rainwater introduces atmospheric gases into the soil. Beside the major constituents, minor or trace amounts of other gases may occur in the soil air, originating from deepseated sources or as products of organic or mineral reactions in the soil environment.

4.2 SOIL OF BHILWARA DISTRICT

The latitude of Bhilwara is 25.346251and the longitude is 74.636383. Its average elevation is of 421 metres or 1381 feet. Bhilwara covers the area 10,455 km^2. Climate of Bhlwara district is humid and it has average annual temperature approx 22 degree Celsius. In Bhilwara humidity is at the highest level in August, mean daily relative humidity is approx 80 percent in this month. Except the monsoon season its atmosphere remains dry over the year. Annual recorded mean rainfall is 635.1mm from 1971 to 2012. District receives almost 95% of annual during June end to mid of September by southwest monsoon. As per the census report of 2001, the population of Bhilwara district was 2,009,516, which was 26.14% more than the previous census report of 1991. Bhilwara is covered in north by Ajmer, In south Chittorgarh covers it, in east it is covered by Bundi district and in west Rajasamand covers the district.

On the basis of observed soil variation in district, soils can be classified in major four ways: (i) Clay loam or medium black: This type of soil is found in the hilly areas of central region of the district it covers approx 38400 ha land i.e approx 3.67 % area. (ii) Loam: This type of soil is found in the almost entire district it covers 719830 ha land i.e. 68.85% area. (iii) Sand and sandy loam: Such type of the soil is found generally available near the banks of river which covers 107890 ha land or 10.32% area. (iv) Loam pebbly & stony: This type of soils is normally found in hilly areas of the eastern blocks of the district which covers approx 143520 ha land or 13.73% area. Figure 4.3 represents soil map of Bhilwara district.

In Bhilwara 543214 ha land is used in agriculture. Major cultivated crops are Kharif (Maize, Blackgram, Sorgum, Cluster bean and Sesame) and Rabi (Wheat, Mustard, Barley and Gram), which cover approx 461000 ha land. Besides it Fruits, Vegetables, Medicinal and Aromatic crops are also taken.

Bhilwara is divided in 12 blocks or tehsil namely (i) Asind, (ii) Suwana, (iii) Jahazpur, (iv) Kotri, (v) Mandal, (vi) Mandalgarh, (vii) Shahpura, (viii) Raipur, (ix) Beejoliya, (x) Banera, (xi) Sahara and (xii) Hurda.

Figure 4.2 : Bhilwara Block Map

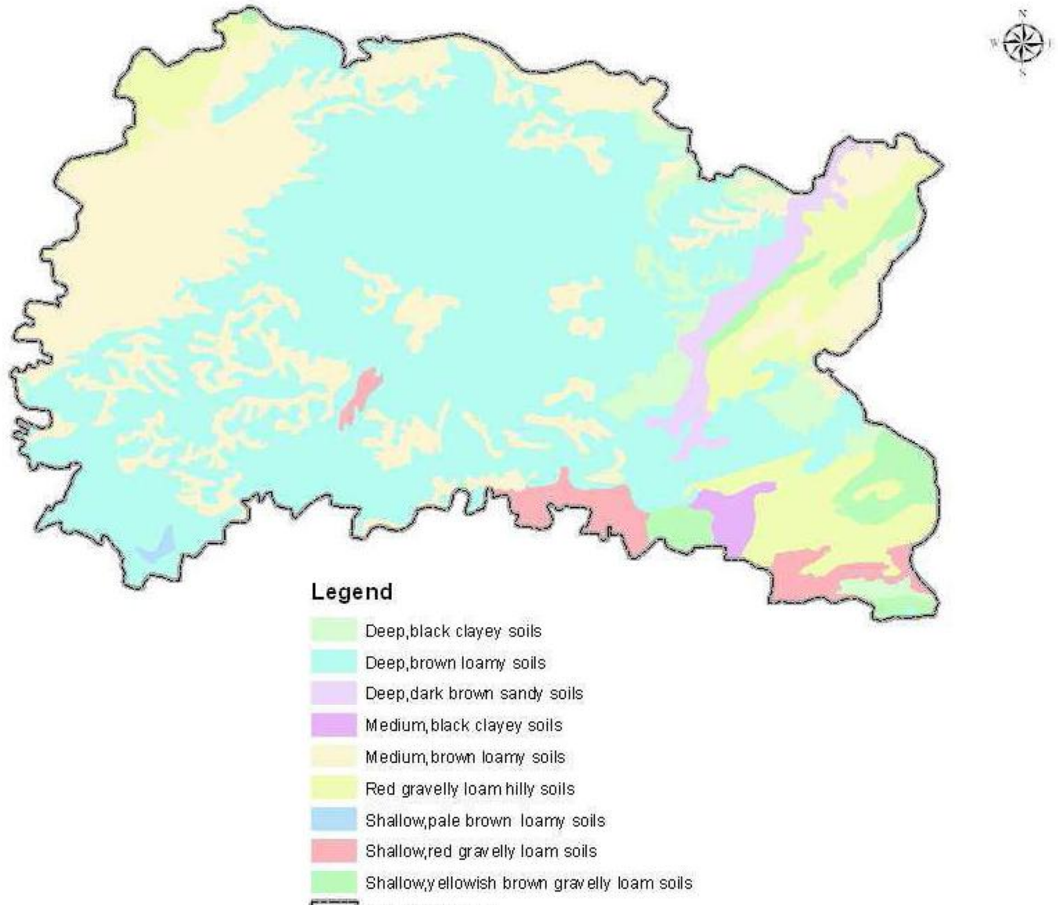

Figure 4.3: Soil Map

4.3 DATA COLLECTION

Soil and water data were collected from soil testing lab, Bhilwara, where soil samples of different villages and almost all blocks/ tehsil of Bhilwara were examined to know the status of soil characteristics like its pH, status of organic carbon, soluble salt content, availability of soil micronutrients and macronutrients etc. The soil samples were mixed thoroughly before analysis after that approx 500 gram material was taken for analysis from sample. Then this 500gm sample was analyzed for different nutrients using standard procedures. Available phosphorus was extracted by sodium bicarbonate extractable phosphorus [114]. The organic matter content was determined by Walkey and Black method [115].

4.4 DIFFERENCE EQUATION

Difference equation may be considered as discrete analogue of differential equation. Normally real problem based model are time dependent which could be in two ways. First, if time is taken as continuous variable, it will lead to differential equations. Second, if time is considered as discrete variable then the model might be based on difference equation. Balasubramanian worked on various application of first order homogeneous difference equation and its oscillatory behavior [116]. Agarwal and Popenda revealed some concept of difference equation further discussed various research field based on difference equation [117]. Muthuswamy and other developed difference equation based model to study nitrogen status of soil [22]. Sloughter also solve real time based problems using difference equations [118].

First order difference equation can be defined for a variable V based on its previous value *as* $V_t = \phi(t, V_{t-1})$. where $\boldsymbol{\phi}$ is the function of two variables t and V_{t-1}. This equation is called first order due to the only existence of first lag (V_{t-1}). The first order linear autonomous difference equation is expressed as

$$V_t = \alpha V_{t-1} + \beta \tag{1}$$

where α and β are constants. Solution of this equation can be obtained by recurrence relation or iterative method, it is given by

$$V_t = \begin{cases} \alpha^t V_0 + \beta\left(\dfrac{1-\alpha^t}{1-\alpha}\right) & , \quad \alpha \neq 1 \\ V_0 + \beta & , \quad \alpha = 1 \end{cases}$$

for α≠1, it can be rewritten as

$$V_t = \alpha^t\left(V_0 - \frac{\beta}{1-\alpha}\right) + \frac{\beta}{1-\alpha}$$

where $\dfrac{\beta}{1-\alpha}$ is steady state value of *V*.

The first order linear non autonomous difference equation is given by

$$V_t = \alpha_{t-1}V_{t-1} + \beta_{t-1} \tag{2}$$

using recurrence relation, solution of (2) is given by

$$V_t = \prod_{i=0}^{t-1}\alpha_i V_0 + \sum_{j=0}^{t-1}\beta_j \prod_{i=j}^{t-1}\frac{\alpha_i}{\alpha_j}$$

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Chapter 5

MATHEMATICAL MODELLING OF LEACHING (P) OF FERTILIZERS IN SOIL: MODEL FORMULATION

5.1. INTRODUCTION

Excessive use of chemical fertilizers is harmful for the biological power of soil, which must be prevented as all nutrient transformations are performed by soil microorganisms. Organic matter can be considered as energy bank for soil microorganisms whereas organic carbon represent soil health index. Using nutrient management practices one can reduce the application of chemical or inorganic fertilizers and enhanced efficiency of soil also gain more profit. Finck discussed that the nutrient supply, the flows and the nutrient added must be managed properly to achieve good amount of yield while minimizing environmental toxicity [119].

Phosphorus plays an important role in overall growth of plant hence huge amount of phosphorus is used in different fertilization practices in field. Depletion of phosphorus in soil influences the addition of phosphorous. Although the benefits of P on agricultural production are evident, but Schröder examined that it can also be a harmful polluting agent of surface waters and can promote eutropication [120].

So the level of soil P must be managed at that concentration which allows to good crop production, prevents the escape of P to surface water bodies and adequate animal waste disposal. This paper provides the description of a mathematical model for such a prediction of soil p level for a rotational crop system. Sen [121] and Ahmed [122] examined that in rotation, legumes increases the availability of several nutrients for succeeding crops. Legume cultivation leads to increase soil available P probably ascribed to development of P-solubilizing organisms in root zone of legumes. Usherwood has revealed that contribution of phosphorus in crop yield is highest when phosphorus is applied with nitrogen [123]. A preliminary verification of data of fertilizer experiment is also presented here.

5.2 MATHEMATICAL FORMULATION OF PROBLEM

For predicting the steady state of phosphorus levels in plots which have received the same fertilizer treatments over the years, the following equations (1) and (2) were taken as governing equations which represent the soil phosphorus after fertilization and the residual effect of fertilization on soil phosphorus after another crop of continuous cropping system respectively,

$$P_{(i,B)} = P_{(i-1,W)} + F_{i,B} - U_{iB} - F_r + E_B \tag{1}$$

$$P_{(i,W)} = P_{(i,B)} - U_{iW} + E_W \tag{2}$$

Where $P_{(i,B)}$ shows the phosphorus level in soil after the blackgram crop in ith year, $F_{i,B}$ shows the amount of fertilizer applied to ith crop of blackgram only, U_{iB} shows the amount of phosphorus uptake by ith crop of blackgram, $P_{(i,W)}$ shows the phosphorus level in soil after the wheat crop in ith year U_{iW} shows the amount of phosphorus uptake by ith crop of wheat, F_r runoff amount of fertilizer applied, E_B and E_W are the built-up level of phosphorus due to the factor other than considered in basic equations.

We assume that uptake of phosphorus U_{iB} by blackgram crop depends on the phosphorus available in soil after the previous wheat crop $P_{(i-1,W)}$ and the applied fertilizer $F_{i,B}$,

$$U_{iB} = f(P_{(i-1,W)}, F_{i,B})$$

Or it can be written as,

$$U_{iB} = \gamma_B P_{(i-1,W)} + \delta_B F_{iB} + C_B \tag{3}$$

Where constant γ_B shows the expected soil phosphorus nutrient efficiency $(0 \le \gamma_B \le 1)$ for blackgram crop, δ_B shows expected fertilizer nutrient efficiency $(0 \le \delta_B \le 1)$ for blackgram crop and C_B shows the uptake of phosphorus from unaccounted sources by blackgram crop $(C_{\mathbf{B}} \ge 0)$.

Similarly the uptake of phosphorus U_{iW} by wheat crop depends on the phosphorus available in soil after the previous blackgram crop $P_{(i-1,B)}$ only as fertilization practice is not applied on wheat crop,

$U_{iW} = g(P_{(i,B)})$ Or it can be written as,

$$U_{iW} = \gamma_W P_{(i,B)} + C_W \tag{4}$$

Where constant γ_W shows the expected soil phosphorus nutrient efficiency $(0 \le \gamma_W \le 1)$ for wheat crop, and C_W shows the uptake of phosphorus from unaccounted sources by wheat crop $(C_W \ge 0)$.

5.3 SOLUTION OF MODEL

Using (3) in (1), we get

$$P_{(i,B)} = P_{(i-1,W)} + F_{i,B} - (\gamma_B P_{(i-1,W)} + \delta_B F_{i,B} + C_B) - F_r + E_B$$

Or $$P_{(i,B)} = (1-\gamma_B)P_{(i-1,W)} + (1-\delta_B)F_{i,B} - F_r + E_B - C_B \tag{5}$$

Using (4) in (2), we get

$$P_{(i,W)} = P_{(i,B)} - (\gamma_W P_{(i,B)} + C_W) + E_W$$

Or $$P_{(i,W)} = (1-\gamma_W)P_{(i,B)} - C_W + E_W \tag{6}$$

Using (6) in (5), we get

$$P_{(i,B)} = (1-\gamma_B)(1-\gamma_W)P_{(i-1,B)} + (1-\delta_B)F_{i,B}$$

$$+\{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\}$$

(7)

Using iteration in (7), we have

$$P_{(i,B)} = (1-\gamma_B)^2(1-\gamma_W)^2 P_{(i-2,B)} + (1-\delta_B)[(1-\gamma_B)(1-\gamma_W)F_{i-1,B} + F_{i,B}]$$

$$+\{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\}$$

$$\times[(1-\gamma_B)(1-\gamma_W) + 1] \tag{8}$$

Iterating the right hand side of the above equation, we get

$$P_{(i,B)} = (1-\gamma_B)^n (1-\gamma_W)^n P_{(i-n,B)} + (1-\delta_B)\sum_{j=0}^{n-1}(1-\gamma_B)^j (1-\gamma_W)^j F_{i-j,B}$$

$$+\{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\}$$

$$\times\left[\frac{1-(1-\gamma_B)^n(1-\gamma_W)^n}{1-(1-\gamma_B)(1-\gamma_W)}\right] \qquad (9)$$

This equation shows relationship of $P_{(i,B)}$ with the available soil phosphorus status at the end of (i-n) th crop and the amount of fertilizer nutrient applied from n to ith crop.

Equation (9) can be reduced to the equation to predict $P_{(i,B)}$ from initial value like P_0 by taking n=i

$$P_{(i,B)} = (1-\gamma_B)^i (1-\gamma_W)^i P_0 + (1-\delta_B)\sum_{j=0}^{i-1}(1-\gamma_B)^j (1-\gamma_W)^j F_{i-j,B}$$

$$+\{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\}$$

$$\times\left[\frac{1-(1-\gamma_B)^i(1-\gamma_W)^i}{1-(1-\gamma_B)(1-\gamma_W)}\right] \qquad (10)$$

If a constant amount of fertilizer ($F_{i,B} = F_B$) is used every year then equation (10) can be written as,

$$P_{(i,B)} = (1-\gamma_B)^i (1-\gamma_W)^i P_0 + (1-\delta_B)F_B\left[\frac{1-(1-\gamma_B)^i(1-\gamma_W)^i}{1-(1-\gamma_B)(1-\gamma_W)}\right]$$

$$+\{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\}$$

$$\times\left[\frac{1-(1-\gamma_B)^i(1-\gamma_W)^i}{1-(1-\gamma_B)(1-\gamma_W)}\right] \qquad (11)$$

The level of phosphorus in the soil under the long run application of fertilizers can also be obtained by taking limit as $i \to \infty$ in the equation (11). If $P_{(\infty,B)}$ represent the steady state of soil phosphorus status under constant fertilization, equation (11) becomes

$$P_{(\infty,B)} = \frac{(1-\delta_B)F_B}{1-(1-\gamma_B)(1-\gamma_W)}$$

$$+\frac{\{(1-\gamma_B)(E_W - C_W)+E_B - C_B - F_r\}}{1-(1-\gamma_B)(1-\gamma_W)} \qquad (12)$$

Now we discuss the solution for residual effects on soil phosphorus status for another crop in continuous cropping system.

Using equation (5) in (6), we get

$$P_{(i,W)} = (1-\gamma_W)(1-\gamma_B)P_{(i-1,W)} + (1-\gamma_W)(1-\delta_B)F_{i,B}$$

$$+(1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W \qquad (13)$$

Using iteration in (13), we have

$$P_{(i,W)} = (1-\gamma_W)^2(1-\gamma_B)^2 P_{(i-2,W)}$$

$$+(1-\gamma_W)(1-\delta_B)[(1-\gamma_W)(1-\gamma_B)F_{i-1,B} + F_{i,B}]$$

$$+\{(1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W\}\{1+(1-\gamma_w)(1-\gamma_B)\}$$

Iterating the right hand side of the above equation, we get

$$P_{(i,W)} = (1-\gamma_W)^n(1-\gamma_B)^n P_{(i-n,W)}$$

$$+(1-\gamma_W)(1-\delta_B)\sum_{j=0}^{n-1}(1-\gamma_W)^j(1-\gamma_B)^j F_{i-j,B}$$

$$+\{(1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W\}$$

$$\times\left[\frac{1-(1-\gamma_w)^n(1-\gamma_B)^n}{1-(1-\gamma_w)(1-\gamma_B)}\right] \qquad (14)$$

by taking n=i this equation reduced to the equation to predict $P_{(i,B)}$ from initial value like P_0

$$P_{(i,W)} = (1-\gamma_W)^i (1-\gamma_B)^i P_0 + (1-\gamma_W)(1-\delta_B)\sum_{j=0}^{i-1}(1-\gamma_W)^j (1-\gamma_B)^j F_{i-j,B}$$
$$+\{(1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W\}$$
$$\times\left[\frac{1-(1-\gamma_w)^i(1-\gamma_B)^i}{1-(1-\gamma_w)(1-\gamma_B)}\right] \quad (15)$$

When constant amount of fertilizer ($F_{i,B} = F_B$) is used every year then the above equation can be reduced in,

$$P_{(i,W)} = (1-\gamma_W)^i (1-\gamma_B)^i P_0 + (1-\gamma_W)(1-\delta_B)F_B\left[\frac{1-(1-\gamma_w)^i(1-\gamma_B)^i}{1-(1-\gamma_w)(1-\gamma_B)}\right]$$
$$+\{(1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W\}$$
$$\times\left[\frac{1-(1-\gamma_w)^i(1-\gamma_B)^i}{1-(1-\gamma_w)(1-\gamma_B)}\right] \quad (16)$$

As $i \to \infty$, $P_{(\infty,W)}$ represent the steady state of phosphorus status due to residual effect of constant fertilization, then the equation (16) becomes

$$P_{(\infty,W)} = \left[\frac{(1-\gamma_W)(1-\delta_B)F_B}{1-(1-\gamma_w)(1-\gamma_B)}\right]$$
$$+\left[\frac{(1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W}{1-(1-\gamma_w)(1-\gamma_B)}\right] \quad (17)$$

5.4 VALIDITATION OF MODEL

Phosphorus level in soil (observed and estimated using model) is tested by computing a reliability indices as proposed by Leggett [124]. This index denoted by *k* interpret that the model predictions agree with observations within a factor of *k*. The index is defined using geometric approach and is justified through agreement with another index developed using statistical techniques. These indices denoted, respectively, by k_g and k_s are given by,

$$k_g = \frac{1+\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1-y_i/x_i}{1+y_i/x_i}\right]^2}}{1-\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1-y_i/x_i}{1+y_i/x_i}\right]^2}}$$

and $$k_s = \exp\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\log\frac{y_i}{x_i}\right)^2}$$

where X_i and Y_i are the predicted values using model and corresponding observed values respectively. Prediction through model is perfect if $k_g = k_s = 1$.

The Source of Data

The above prescribed model was applied on investigation entitled "Integrated nutrient management in blackgram (Phaseolus mungo L.)" was conducted during 2003-04 and 2004-05 by Rathore [125] at RCA, Udaipur. The experimented field belongs to typical sub-humid climatic conditions mean annual rainfall is 637 mm, soil was clay loam in texture. Initially, to ascertain various characteristics of the experimental field, soil samples were taken upto 15 cm depth contained 268.40 kg N ha^{-1} using Alkaline permanganate method by Subbiah [126], 19.50 kg P ha^{-1} using Olsen's method by Olsen [115], 370.80 kg K_2O ha^{-1} using Extraction with 1 N neutral ammonium acetate at pH 7.0 and estimated by Flame photometer method by Richards [127]. This experiment was consisted of thirty two treatment combinations, out of these we are using here only four which are

i. No phosphorus

ii. 50% P (20 kg P_2O_5 ha^{-1})

iii. 75% P (30 kg P_2O_5 ha^{-1})

iv. 100% P (40 kg P_2O_5 ha^{-1})

Phosphorus entirely was drilled through Di-Ammonium-Phosphate (DAP) before sowing of the crop also uniform application of nitrogen @ 15 kg N ha^{-1} was done as basal through DAP + urea.

After harvesting soil samples were taken from each plot upto 15 cm depth, and analyzed. Plant nitrogen analysis was done using Nessler's reagent, spectrophotometrically method by Snell [128] whereas the yellow colour method was used to analyze phosphorus [129].

The average soil phosphorus efficiency was calculated using the uptake U_t^0 and soil available phosphorus P_{t-1}^0 from control plots-

$$\gamma = \frac{\sum U_t^0 P_{t-1}^0}{\sum (P_{t-1}^0)^2}$$

The average fertilizer nutrient efficiency parameter of applied phosphorus was calculated by using difference of uptake in treatment and control and unit of applied P fertilizer. If uptake from control plot is U_t^0 and form a plot of some treatment is U_t and applied amount of fertilizer is F unit, then

$$\delta = \frac{U_t - U_t^0}{F}$$

Results

The estimation of various parameters γ, δ, C and E for each crop and for each treatment are presented in table 5.1. Soil phosphorus efficiency (γ) is very high (0.9215304) for wheat than blackgram. Fertilizer phosphorus efficiency (δ) are approximately same for 20 and 30 kg P ha^{-1}, while for 40 kg P ha^{-1} is approx 18% higher. Uptake from unaccounted sources is very less (0.2243) for blackgram than wheat which is very high (4.0349). Table 5.1 shows that maximum depletion took place about 100% P treatment for blackgram crop than 50% P and 75% P treatment if built up in soil for blackgram assumed constant as in control then fertilizer run off (F_r) calculated maximum 87% for 100% P treatment and approx 86% for 50% P and 75% P treatment. Maximum built up; as the residual effect of 100% P treatment applied for blackgram seen for wheat crop. While built up about 50% P and 75% P treatment are moderate as a residual effect over wheat crop.

Table 5.1: Estimates of γ, δ, C and E-F_r for phosphorus for the crops in the sequence

Parameter	Crop	
	Blackgram	Wheat
γ	0.278	0.921
δ		
50% P (20 kg P_2O_5 ha^{-1})	0.052	
75% P (30 kg P_2O_5 ha^{-1})	0.055	
100% P (40 kg P_2O_5 ha^{-1})	0.061	
C(kg P ha^{-1})	0.224	4.034
E-Fr (kg P ha^{-1})		
Control	7.905	16.2
50% P (20 kg P_2O_5 ha^{-1})	-9.41	17.52
75% P (30 kg P_2O_5 ha^{-1})	-17.93	18.65
100% P (40 kg P_2O_5 ha^{-1})	-27.065	20.58

Steady state level of soil phosphorus about various treatments is shown in table 5.2. Accumulation of phosphorus in soil is maximum about both crop about 100% P. Comparison between predicted and observed phosphorus soil level is presented in table 5.3 and 5.4 for both crops respectively. The reliability indices show observed and predicted data from model are approximately same and for the treatment 100% P are closely agreed.

Table 5.2: Predicted steady state soil phosphorus levels for the crops in the sequence

Treatment	Crop	
	Blackgram	Wheat
Control	17.448	13.534
50% P (20 kg P_2O_5 ha^{-1})	20.202	15.070
75% P (30 kg P_2O_5 ha^{-1})	21.983	16.340
100% P (40 kg P_2O_5 ha^{-1})	23.512	18.390

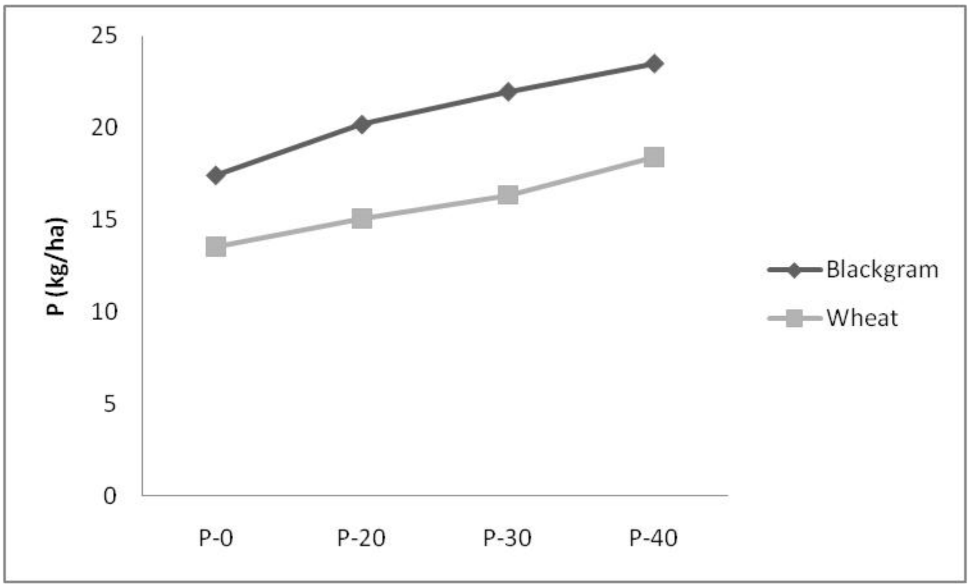

Figure 5.1: Steady state level of phosphorus after Blackgram and Wheat

Figure 5.1 shows significant increase in expected soil P status in long run with the increase in application of P fertilizer also residual effect of fertilizer over wheat is appreciable.

Table 5.3: Observed and predicted status after the harvest of each crop of Blackgram

Treatment	year 2003-04		year 2004-05	
	Predicted	Observed	Predicted	Observed
Control	17.39	18.4	16.51	20.56
50% P(20 kg P_2O_5 ha^{-1})	19.99	21.7	20.19	22.35
75% P(30 kg P_2O_5 ha^{-1})	21.67	22.83	21.97	23.33
100% P(40 kg P_2O_5 ha^{-1})	23.12	23.77	23.49	23.43

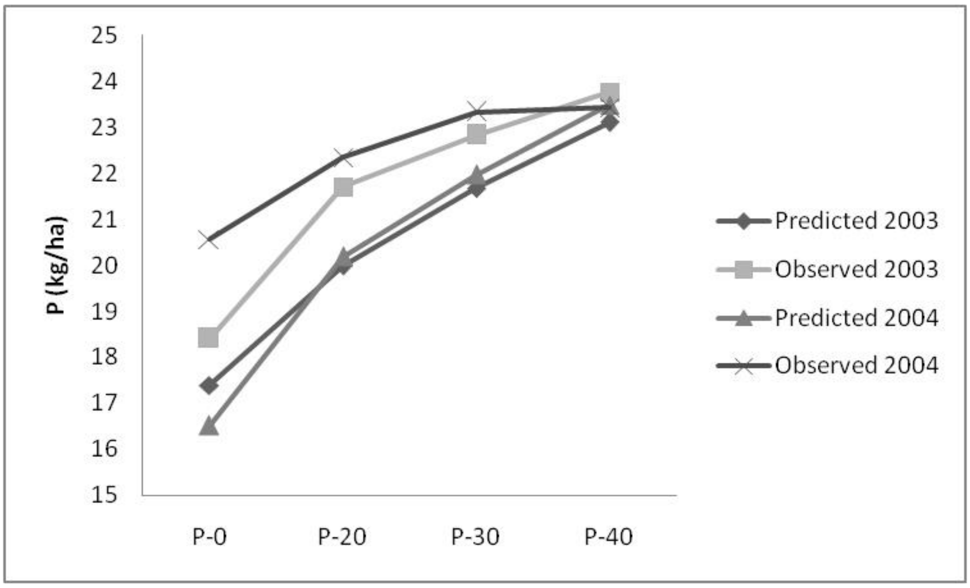

Figure 5.2: Soil P status after Blackgram

It is shown in figure 5.2 and 5.3 that increased soil P status with increase in application of P fertilization also soil P status were maintained due to application of Phosphorus.

Table 5.4: Observed and predicted soil phosphorus soil after the harvest of each crop of wheat

Treatment	year 2003-04		year 2004-05	
	Predicted	Observed	Predicted	Observed
Control	13.70	16.8	13.54	18.89
50% P (20 kg P_2O_5 ha^{-1})	15.15	18.6	15.07	19.18
75% P (30 kg P_2O_5 ha^{-1})	16.35	18.98	16.34	19.41
100% P (40 kg P_2O_5 ha^{-1})	18.28	19.92	18.38	19.52

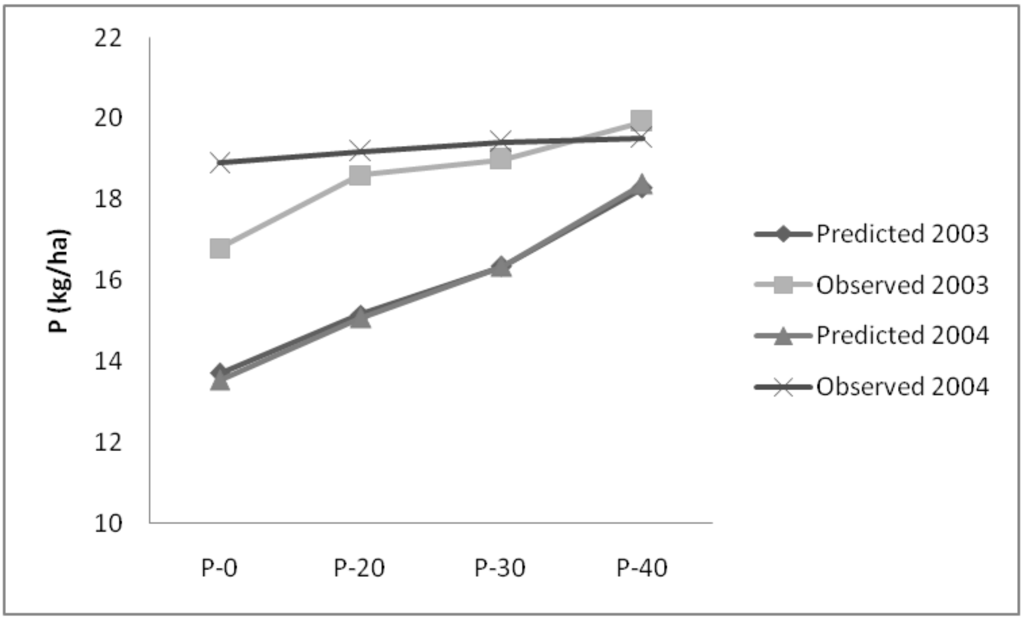

Figure 5.3: Soil P status after Wheat

Table 5.5: Reliability indices for the proposed model

Index	Treatment			
	Control	50% P ($20\ kg\ P_2O_5\ ha^{-1}$)	75% P ($30\ kg\ P_2O_5\ ha^{-1}$)	100% P ($40\ kg\ P_2O_5\ ha^{-1}$)
k_g	1.252297931	1.186353041	1.128133841	1.055642337
k_s	1.252982397	1.18662048	1.128240143	1.055655801

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Chapter 6

MATHEMATICAL MODELLING OF LEACHING (OTHER THAN P) OF FERTILIZERS IN SOIL: ANALYTICAL AND NUMERICAL METHODS FOR SOLUTION

6.1 INTRODUCTION

A proper combination of nutrients is required by plants to grow, live and reproduce. Excess or lacking of any nutrient may cause problems. Soil is the major source to supply most of the essential nutrients, required by plants. Shortage of soil micronutrients may even cause plant's death though other essential nutrients are fully available. So it is required to pay attention in this direction also. Soil variability assessment and maintenance of soil health is of great importance for environmental predictions, ecological modeling and natural resource management [130, 131]. Knowledge of the status of micronutrients in the soil helps producer to choose suitable fertilization practices also to avoid deficiency of micronutrients and toxicity problems. The basic fundamental for selection of any method for soil analysis is that, a positive correlation should exist between concentration of nutrient calculated using method and the nutrient amount which plants intake [132].

Every nutrient plays important role in execution of a specific function hence must be supplied in time and adequate quantity. Insufficient amounts of nutrients result into poor crop growth and low yield [133]. Excess supply of nutrients never helps in producing higher crop yield, even leads wastages as in addition of leaching, washing and many times raise serious causes for human health. The nitrate available in the plants may cause methemoglobinaemia disease in new born babies and creates problems in the intestine and stomach like abnormal acid secretion [134].

6.2 FORMULATION OF MODEL

In last chapter we used a mathematical model to predict phosphorus status in soil under the application P fertilizer in continuous cropping system [135]. In this chapter we present a model to predict the level of soil nutrients (macro and micro both) other than phosphorus under the influence of phosphorus fertilizer and no other fertilizer added to soil. So we consider the following equations

$$M_{(i,1)} = M_{(i-1,2)} - U_{(i,1)} + E_1 \tag{1}$$

$$M_{(i,2)} = M_{(i,1)} - U_{(i,2)} + E_2 \tag{2}$$

if we take two crops in a year.

where $M_{(i,1)}$ and $M_{(i,2)}$ are the level of a nutrient in soil after first and second crop in i[th] year respectively. Here we assume that a fixed amount $U_{(i,1)}$ and $U_{(i,2)}$ are uptake of nutrient by first and second crop respectively in i[th] year. E_1 and E_2 are the built-up level of nutrient due to the factor other than considered in basic equations for first and second crop respectively.

We assume that uptake of nutrient $U_{(i,1)}$ by first crop depends on the nutrient available in soil after the previous second crop $M_{(i-1,2)}$ i.e.

$$U_{(i,1)} = f(M_{(i-1,2)})$$

or $$U_{(i,1)} = \gamma_1 M_{(i-1,2)} + c_1 \tag{3}$$

where γ_1 shows the expected soil nutrient efficiency $(0 \le \gamma_1 \le 1)$ for first crop and c_1 shows the uptake of nutrient from unaccounted sources by first crop $(c_1 \ge 0)$.

Also uptake of nutrient $U_{(i,2)}$ by second crop depends on the nutrient available in soil after the previous first crop $M_{(i,1)}$ i.e.

$$U_{(i,2)} = g(M_{(i,1)})$$

or $$U_{(i,2)} = \gamma_2 M_{(i,1)} + c_2 \tag{4}$$

where γ_2 shows the expected soil nutrient efficiency $(0 \le \gamma_2 \le 1)$ for second crop and c_2 shows the uptake of nutrient from unaccounted sources by second crop $(c_2 \ge 0)$.

6.3 SOLUTION

Putting (3) in (1), we get

$$M_{(i,1)} = (1-\gamma_1)M_{(i-1,2)} + E_1 - c_1 \tag{5}$$

Using (4) in (2), we get

$$M_{(i,2)} = (1-\gamma_2)M_{(i,1)_2} + E_2 - c_2 \tag{6}$$

Using (6) in (5), we have

$$M_{(i,1)} = (1-\gamma_1)(1-\gamma_2)M_{(i-1,1)} + (1-\gamma_1)(E_2 - c_2) + (E_1 - c_1) \tag{7}$$

Using iteration in (7), we get

$$M_{(i,1)} = (1-\gamma_1)^2(1-\gamma_2)^2 M_{(i-2,1)}$$

$$+[(1-\gamma_1)(1-\gamma_2)+1]\{(1-\gamma_1)(E_2-c_2)+(E_1-c_1)\}$$

Again iterating, we get

$$M_{(i,1)} = (1-\gamma_1)^n(1-\gamma_2)^n M_{(i-n,1)}$$

$$+\left[\sum_{j=0}^{n-1}(1-\gamma_1)^j(1-\gamma_2)^j\right]\{(1-\gamma_1)(E_2-c_2)+(E_1-c_1)\} \tag{8}$$

This equation shows the relationship of nutrient in soil of $M_{(i,1)}$ and available soil nutrient status at the end of (i-n)th crop

or $$M_{(i,1)} = (1-\gamma_1)^n(1-\gamma_2)^n M_{(i-n,1)}$$

$$+\left[\frac{1-(1-\gamma_1)^n(1-\gamma_2)^n}{1-(1-\gamma_1)(1-\gamma_2)}\right]\{(1-\gamma_1)(E_2-c_2)+(E_1-c_1)\}$$

for n=i,

$$M_{(i,1)} = (1-\gamma_1)^i(1-\gamma_2)^i M_{(0,1)}$$

$$+\left[\frac{1-(1-\gamma_1)^i(1-\gamma_2)^i}{1-(1-\gamma_1)(1-\gamma_2)}\right]\{(1-\gamma_1)(E_2-c_2)+(E_1-c_1)\} \tag{9}$$

In long run, the status of nutrient in soil can be measured by taking limit i→∞, we get

$$M_1 = \left[\frac{(1-\gamma_1)(E_2 - c_2) + (E_1 - c_1)}{1-(1-\gamma_1)(1-\gamma_2)} \right] \tag{10}$$

where M_1 denotes the steady state of nutrient in soil after first crop due to constant fertilization.

Similarly by using equation (5) in (6), we find

$$M_{(i,2)} = (1-\gamma_1)^i (1-\gamma_2)^i M_{(0,2)} + \left[\frac{1-(1-\gamma_1)^i (1-\gamma_2)^i}{1-(1-\gamma_1)(1-\gamma_2)} \right] \{(1-\gamma_2)(E_1 - c_1) + (E_2 - c_2)\} \tag{11}$$

In long run, the status of nutrient in soil can be measured by taking limit i→∞, we get

$$M_2 = \left[\frac{(1-\gamma_2)(E_1 - c_1) + (E_2 - c_2)}{1-(1-\gamma_1)(1-\gamma_2)} \right] \tag{12}$$

where M_2 represents the steady state of nutrient in soil after second crop due to constant fertilization.

6.4 VALIDITATION OF DATA

Observed and predicted status of soil nutrient can be examined by using reliability index given by Leggett [125]. This index interprets that our model predictions agrees with observations within a factor of k. k_g and k_s are based on geometric and statistical techniques. These indices k_g and k_s are given by,

$$k_g = \frac{1 + \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left[\frac{1 - y_i / x_i}{1 + y_i / x_i} \right]^2}}{1 - \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left[\frac{1 - y_i / x_i}{1 + y_i / x_i} \right]^2}}$$

and $k_s = \exp\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\log\frac{y_i}{x_i}\right)^2}$

where x_i is the predicted value using model while y_i is corresponding observed values respectively. If $k_g = k_s = 1$, then model is perfect.

Application of the Model to Field Data

The above prescribed model was applied on investigation entitled "Integrated Nutrient Management in blackgram (Phaseolus mungo L.)" was conducted during 2003-04 and 2004-05 at RCA, Udaipur [126]. Initially, to ascertain various characteristics of the experimental field, soil samples were taken upto 15 cm depth contained 268.40 kg N ha^{-1}, 19.50 kg P ha^{-1} and 370.80 kg K_2O ha^{-1}. This experiment was consisted of thirty two treatment combinations, out of these we are using here only five which are

i. Control
ii. 50% P (20 kg P_2O_5 ha^{-1}) or (P-20)
iii. 75% P (30 kg P_2O_5 ha^{-1}) or (P-30)
iv. 100% P (40 kg P_2O_5 ha^{-1}) or (P-40)
v. FYM

The expected soil nutrient efficiency parameter was calculated by

$$\gamma = \frac{\sum U_i^0 M_{i-1}^0}{\sum (M_{i-1}^0)^2}$$

where U_i^0 and M_{i-1}^0 are uptake and soil available nutrient values of control plots respectively.

Results

Estimation of γ, E and c for macronutrient nitrogen under different treatments and different crop are presented in table 6.1. Soil N efficiency about P-40 and FYM are significantly high in comparison to control for blackgram. For wheat soil N efficiency is 17% higher P-40 whereas for P-30 and FYM it is approx 10% higher over control. The amount of nitrogen mobilized from unaccounted sources (c) is almost same for all treatment and for blackgram it varies from 1.94 to 1.57 kg/ha and for wheat it varies from 10.86 to 11.09 kg/ha.

The value of *E* in table 6.1 shows that there is build up about all treatments. For blackgram nitrogen build up for P-40 and FYM are almost 90% in comparison to control and for wheat almost same for all treatments. The predicted steady state soil N status for different treatments and crops are presented in table 6.2. For blackgram it is 16% higher about P-40 and FYM in comparison to control and for wheat it is same for all treatments.

Table 6.1: Estimation of γ, *E* and *c* for macronutrient N for different crops in sequence

Treatment	BLACKGRAM			WHEAT		
	γ_1	E_1 ($kgNha^{-1}$)	c_1 ($kgNha^{-1}$)	γ_2	E_2 ($kgNha^{-1}$)	c_2 ($kgNha^{-1}$)
Control	0.20	49.64	1.94	0.36	103.05	10.86
P-20	0.22	76.79	1.23	0.38	97.75	13.06
P-30	0.24	85.92	1.92	0.40	104.58	12.87
P-40	0.27	93.64	1.73	0.42	112.03	11.15
FYM 5	0.26	95.36	1.57	0.40	102.28	11.09

Table 6.2: Predicted steady state of soil N status for different crops in sequence

Treatment	BLACKGRAM ($kgNha^{-1}$)	WHEAT (kgNha-1)
Control	249.05	250.57
P-20	276.20	256.99
P-30	280.42	259.49
P-40	287.80	266.58
FYM 5	290.87	266.50

Comparison of predicted soil N status for different crops and different treatments are presented in table 6.3 and table 6.4.

Table 6.3: Observed and predicted value of soil N status (kg ha^{-1}) after harvesting of Blackgram year wise

Treatment	2003-04		2004-05	
	Observed	Predicted	Observed	Predicted
Control	258.61	258.94	278.95	254.10
P-20	293.61	272.40	289.92	274.35
P-30	295.95	274.97	293.41	277.95
P-40	296.93	279.59	296.38	284.32
FYM 5	301.18	280.85	298.99	286.40

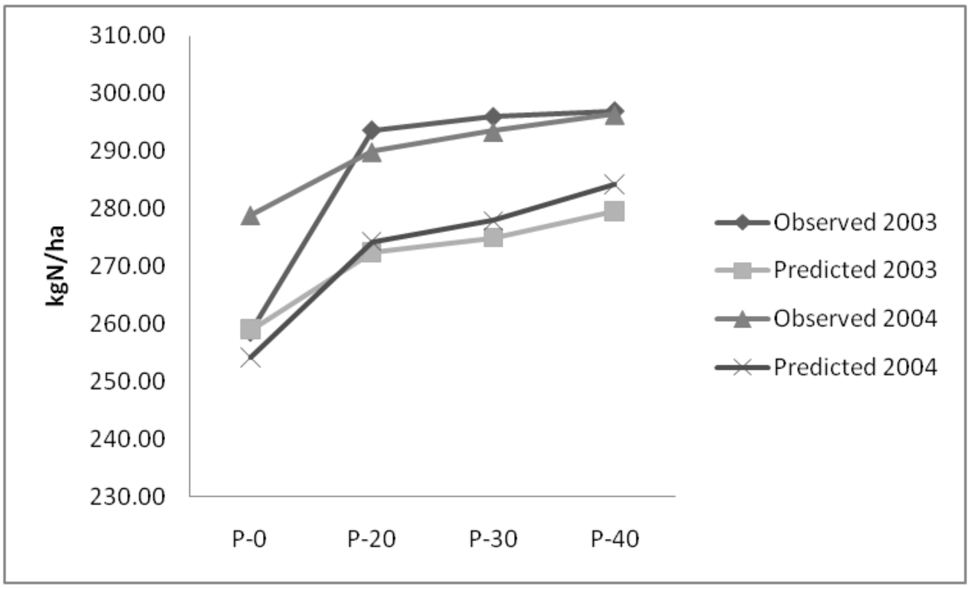

Figure 6.1: Status of N after Blackgram

Figure 6.1 and 6.2 show that the declined in status of N is maximum in control over other application. Soil N status increases with the increased rate of P applied.

In long run significant increase in N status was measured about high p fertilization.

Table 6.4: Observed and predicted value of soil N status (kg ha^{-1}) after harvesting of Wheat year wise

Treatment	2003-04		2004-05	
	Observed	Predicted	Observed	Predicted
Control	276.96	254.68	271.85	252.67
P-20	282.21	274.82	277.14	265.68
P-30	283.05	276.00	278.63	266.97
P-40	284.03	279.42	281.60	272.01
FYM 5	285.15	281.96	281.06	273.39

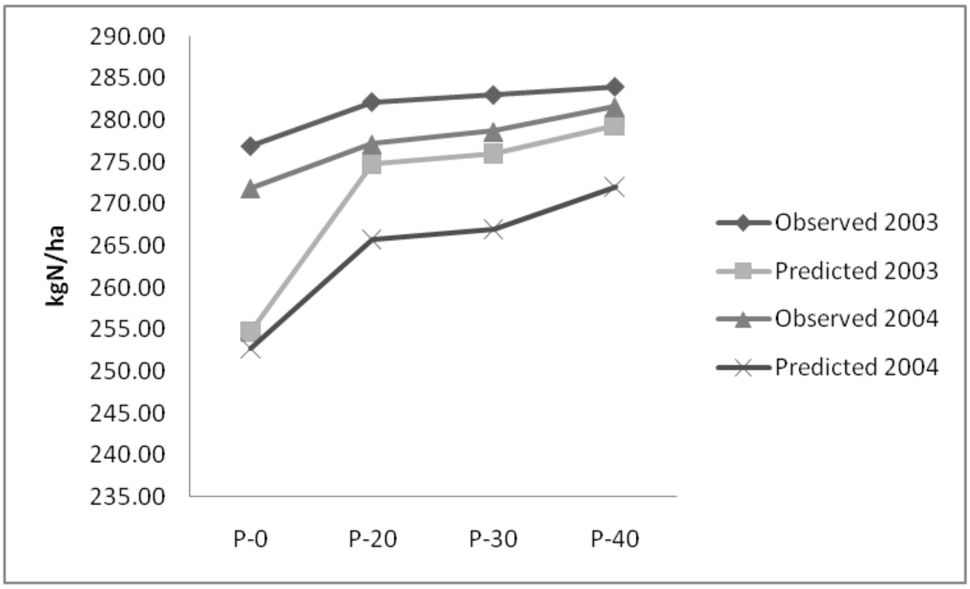

Figure 6.2: Status of N after Wheat

Figure 6.3 represent the observed and predicted soil N status after blackgram and wheat crop under the application of FYM. It shows soil N status about FYM is very similar to the status about high P fertilization.

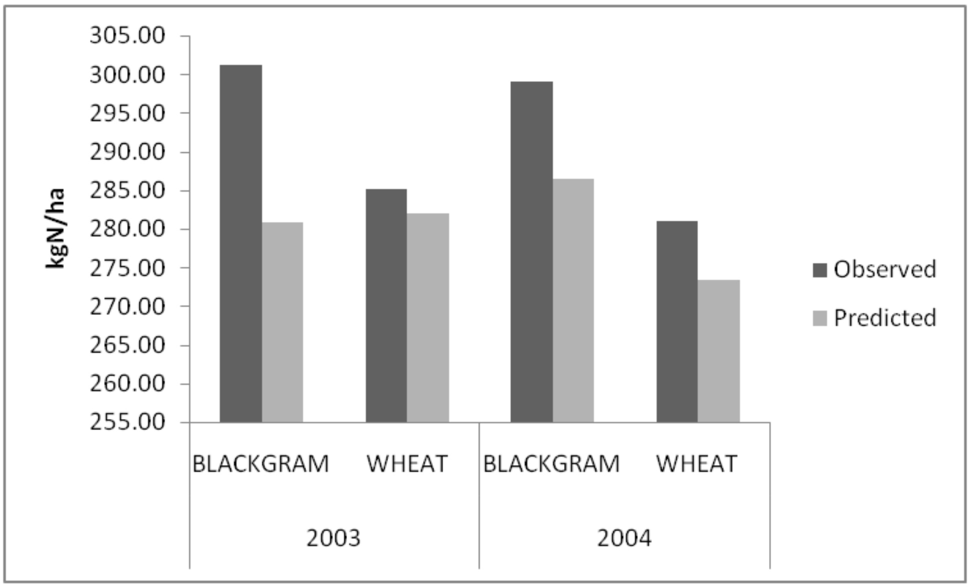

Figure 6.3: Soil N status after Blackgram and Wheat under FYM application

The reliability indices showing the agreement between observed and predicted soil nitrogen status in table 6.5. It shows, under all treatment and for both crops the predicted values closely agreed with observed values.

Table 6.5: Reliability indices for the proposed model for N

Treatment	k_g		k_s	
	BLACKGRAM	WHEAT	BLACKGRAM	WHEAT
P-0	1.0682	1.0819	1.0682	1.0819
P-20	1.0680	1.0359	1.0680	1.0359
P-30	1.0667	1.0357	1.0667	1.0357
P-40	1.0531	1.0275	1.0531	1.0275
FYM 5	1.0597	1.0213	1.0597	1.0213

Estimation of γ, E and c for macronutrient potassium under different treatments and different crop are presented in table 6.6. Soil K efficiency about P-40 and FYM are approximately 20% high in comparison to control for blackgram. For wheat soil K efficiency is 25% higher than control about P-40, for P-30 and FYM it is almost same. The amount of potassium mobilized from unaccounted pool (c) is almost same for all treatment and for blackgram and for wheat it varies from 0.58 to 0.79 kg/ha.

The value of E in table 6.6 shows build up in K due to unaccounted sources about all treatments. For blackgram, potassium build up for P-40 and FYM are almost 150% higher in comparison to control and for wheat no significant difference in E were measured for all treatments. The predicted steady state soil K status for different treatments and crops are presented in table 6.7. For blackgram it is 18% higher about P-40 and FYM in comparison to control and for wheat it is almost 15% higher about P-40 and FYM in comparison to control.

Table 6.6: Estimation of γ, E and c for macronutrient K for different crops in sequence

Treatment	BLACKGRAM			WHEAT		
	γ_1	E_1 (kgKha^{-1})	c_1 (kgKha^{-1})	γ_2	E_2 (kgKha^{-1})	c_2 (kgKha^{-1})
Control	0.06	10.21	0.10	0.25	68.29	0.79
P-20	0.07	18.69	0.09	0.28	74.52	0.60
P-30	0.08	22.28	0.09	0.30	83.62	0.57
P-40	0.08	26.42	0.08	0.32	91.01	0.54
FYM	0.08	27.35	0.09	0.29	80.01	0.58

Table 6.7: Predicted steady state of soil K status for different crops in sequence

Treatment	BLACKGRAM (kg K ha^{-1})	WHEAT (kg K ha^{-1})
Control	247.65	253.03
P-20	265.76	265.58
P-30	278.35	277.12
P-40	293.07	289.85
FYM	287.49	282.87

Comparison of predicted soil K status for different crops and different treatments are presented in table 6.8 and table 6.9.

Table 6.8: Observed and predicted soil K status (kg ha^{-1}) after harvesting of Blackgram year wise

Treatment	2003-04		2004-05	
	Observed	Predicted	Observed	Predicted
Control	359.06	334.27	327.28	308.57
P-20	364.49	336.26	335.96	313.08
P-30	366.75	337.94	338.52	316.76
P-40	370.48	341.73	343.43	323.54
FYM	370.84	341.72	343.34	322.80

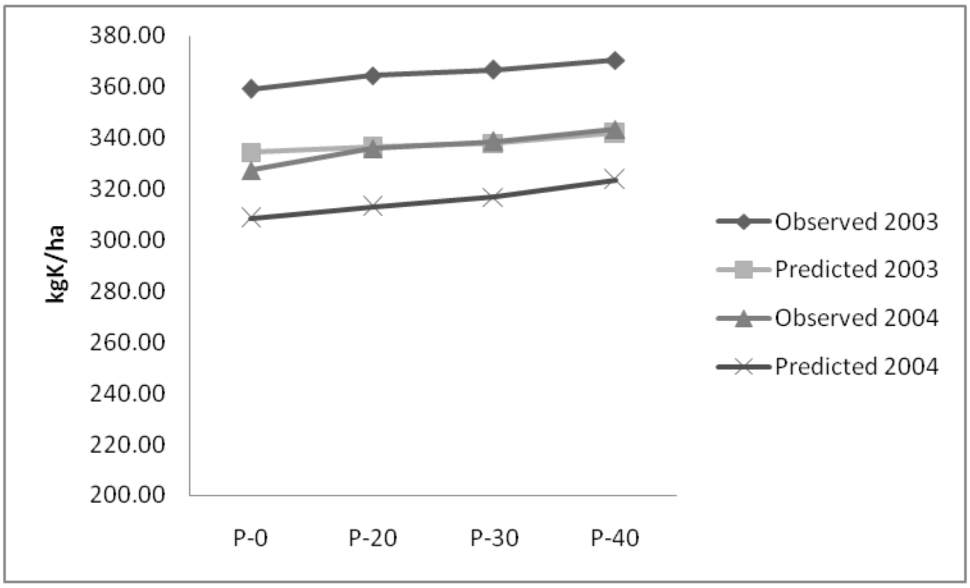

Figure 6.4: Status of K after Blackgram

Figure 6.4 and 6.5 represent decline in K status but not significant. Soil K status remain same about all P practices for blackgram whereas for wheat it is bit higher about P-40.

Table 6.9: Observed and predicted soil K status (Kg ha^{-1}) after harvesting of Wheat year wise

Treatment	2003-04		2004-05	
	Observed	Predicted	Observed	Predicted
Control	338.76	327.61	310.43	305.48
P-20	341.89	331.97	311.11	310.14
P-30	344.15	334.89	313.67	314.35
P-40	347.73	340.33	318.88	321.45
FYM	346.26	340.14	317.99	320.15

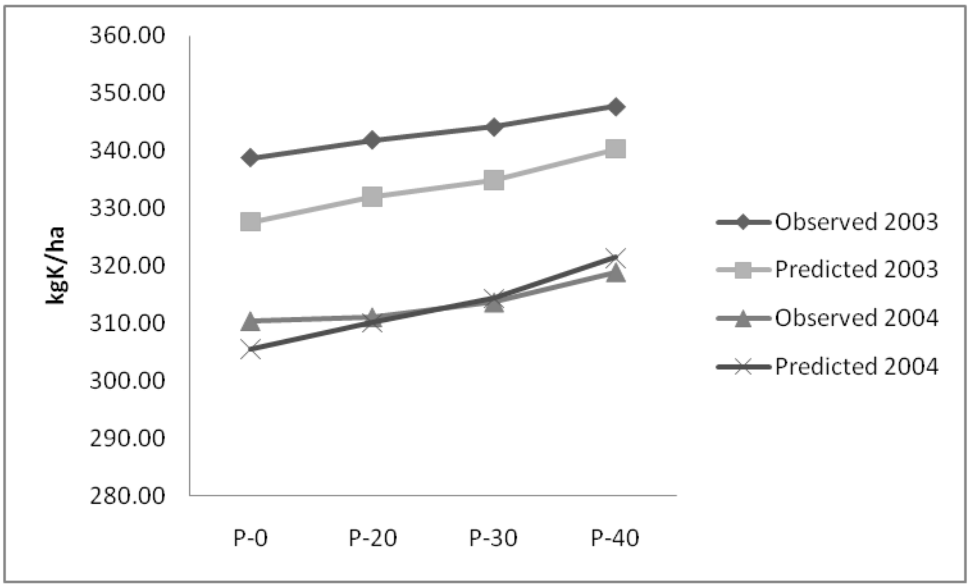

Figure 6.5: Status of K after Wheat

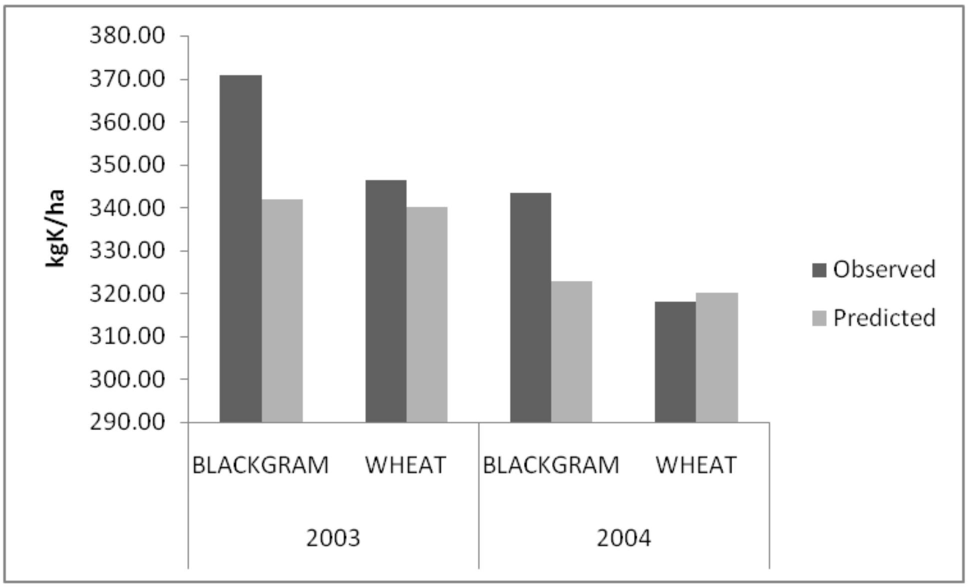

Figure 6.6: Soil N status after Blackgram and Wheat under FYM application

Figure 6.6 represent comparative study of predicted and observed soil K status about FYM application

The reliability indices showing the agreement between observed and predicted soil potassium status in table 6.10. It shows, under all treatment and for both crops the predicted values closely agreed with observed values.

Table 6.10: Reliability indices for the proposed model for Potassium

Treatment	Kg		Ks	
	BLACKGRAM	WHEAT	BLACKGRAM	WHEAT
P-0	1.0677	1.0266	1.0677	1.0266
P-20	1.0787	1.0212	1.0787	1.0212
P-30	1.0774	1.0195	1.0774	1.0195
P-40	1.0736	1.0164	1.0736	1.0164
FYM	1.0751	1.0136	1.0751	1.0136

The theoretical approach given by the above suggested mathematical model is valid as it helps in the prediction of soil macronutrient within the permitted limit of difference.

Estimated value of E, γ and c for various micronutrients (Zn, Cu, Mn and Fe) presented in tables from 6.11 to 6.14 respectively under various fertilization practices.

The values of E_1 and E_2 in the table 6.11 to 6.14 show that there is build up of all micronutrients about all fertilization practices. In table 6.12, E_1 for Cu shows build up is almost same for different P-fertilization which is approx 3 gm/ha while about FYM it was measured 25% higher in comparison of control P, for wheat Cu buildup ranges from 96.28 to 135.43. From table 6.11 and 6.13, it was found that build up increased slightly as the dose of P fertilizers increased. For FYM the buildup of Zn is soil were measured 14% extra and Mn were 35% extra than control P whereas table 6.14 shows a slight reduction of Fe about different P fertilizer practices in comparison of P control. Tables 6.11 to 6.14 show significant increment in build up all micronutrients about P fertilizer. Build up in Zn for blackgram was in the range of 196.14 – 213.5 gm/ha whereas for wheat it ranges from 152.06 to 209.07 gm/ha. Build up in Mn for blackgram is lie in the range of 280.7 to 325.7 gm/ha whereas for wheat it is 57.38-75.24 gm/ha. Build up in Fe measured declined for blackgram but maintained through the application of fertilizers whereas buildup for wheat in the range of 1004.99-1221.38 gm/ha.

E_2 shown in all table 6.11 to 6.14 that there is significant increment in buildup of all micronutrients after wheat crop for P fertilization.

Table 6.11: Estimation of γ , E and c for micronutrient Zn for different crops in sequence

	BLACKGRAM			WHEAT		
	γ_1	E_1	c_1	γ_2	E_2	c_2
P-0	0.16	196.14	0.89	0.30	152.06	30.89
P-20	0.18	204.35	2.11	0.34	174.26	27.21
P-30	0.20	212.32	2.67	0.37	194.23	26.28
P-40	0.22	213.43	4.26	0.40	209.07	28.65
FYM 5	0.21	225.50	1.48	0.36	190.22	29.25

Table 6.12: Estimation of γ , E and c for micronutrient Cu for different crops in sequence

	BLACKGRAM			WHEAT		
	γ_1	E_1	c_1	γ_2	E_2	c_2
P-0	0.06	32.03	3.69	0.22	96.28	25.00
P-20	0.07	31.02	4.32	0.25	111.79	24.73
P-30	0.07	31.05	5.17	0.28	126.62	25.66
P-40	0.08	31.54	6.18	0.30	135.43	24.99
FYM 5	0.08	40.97	4.79	0.27	123.13	26.01

Table 6.13: Estimation of γ , e and c for micronutrient Mn for different crops in sequence

	BLACKGRAM			WHEAT		
	γ_1	E_1	c_1	γ_2	E_2	c_2
P-0	0.03	280.97	0.53	0.07	57.38	36.72
P-20	0.03	311.70	1.10	0.07	60.65	30.78
P-30	0.03	319.59	2.50	0.08	69.37	25.52
P-40	0.04	325.70	4.09	0.09	75.24	25.90
FYM 5	0.04	368.72	0.97	0.08	67.47	29.11

Table 6.14: Estimation of γ , E and c for micronutrient Fe for different crops in sequence

	BLACKGRAM			WHEAT		
	γ_1	E_1	c_1	γ_2	E_2	c_2
P-0	0.15	955.18	0.07	0.40	1004.99	97.41
P-20	0.17	916.94	1.36	0.47	1144.57	97.45
P-30	0.18	942.77	1.81	0.52	1255.18	89.59
P-40	0.20	948.81	7.60	0.56	1341.12	85.94
FYM 5	0.19	781.34	3.65	0.48	1221.38	96.71

For blackgram, significant increment in soil micronutrient efficiency for Zn and Fe as were observed as the amount of added P fertilizer were increased in soil, but soil micronutrient efficiency for Mn and Cu remain same for different application of P fertilizer whereas for wheat, soil micronutrient efficiency for Mn remains same while soil micronutrient efficiency Zn, Cu and Fe were measured increasing about different P fertilization.

For wheat, uptake amount of micronutrients due to unaccounted sources i.e *c* were measured less about different P fertilizer application in comparison of control P application whereas it was observed higher about FYM application. For blackgram, it was measured higher about different P fertilization practices in comparison of control P application. Predicted soil steady state level of Zn, Cu, Mn and Fe for different crops and different fertilization practices is presented in tables from 6.15a to 6.15d.

Table 6.15a: Predicted steady state of soil Zn (gm ha^{-1}) for different crops in sequence

	BLACKGRAM	WHEAT
P-0	719.45	625.60
P-20	697.70	607.73
P-30	688.64	600.68
P-40	656.25	572.66
FYM 5	708.15	615.07

Table 6.15b: Predicted steady state of soil Cu (gm ha^{-1}) for different crops in sequence

	BLACKGRAM	WHEAT
P-0	358.77	350.69
P-20	360.57	357.35
P-30	362.34	362.67
P-40	358.33	361.26
FYM 5	391.80	385.07

Table 6.15c: Predicted steady state of soil Mn (gm ha^{-1}) for different crops in sequence

	BLACKGRAM	WHEAT
P-0	3316.20	3120.62
P-20	3309.66	3095.58
P-30	3166.91	2951.91
P-40	3028.28	2813.13
FYM 5	3664.84	3420.96

Table 6.15d: Predicted steady state of soil Fe (gm ha^{-1}) for different crops in sequence

	BLACKGRAM	WHEAT
P-0	3537.17	3023.22
P-20	3212.21	2752.60
P-30	3140.61	2687.68
P-40	3023.11	2591.24
FYM 5	2932.65	2645.67

Comparison between predicted and observed soil status for micronutrient Zn, is presented in tables 6.16a and 6.16b.

Table 6.16a: Observed and predicted value of soil Zn status (gm ha^{-1}) after harvesting of Blackgram year wise.

	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	655.00	619.90	637.50	660.97
P-20	645.00	618.19	627.50	654.90
P-30	640.00	619.17	625.00	653.83
P-40	632.50	606.67	610.00	633.11
FYM 5	657.50	628.33	635.00	667.86

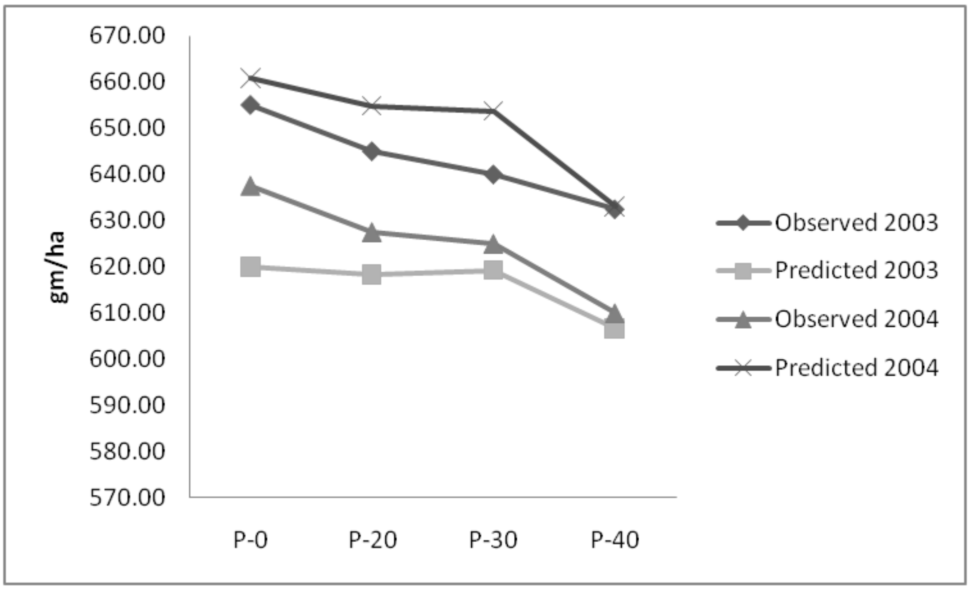

Figure 6.7: Status of Zn after Blackgram

Figure 6.7 and 6.8 represent slight decrease in Zn over the year, reduction maintained for different practices whereas bit more reduction measured about P-40. same results were measured through model.

Table 6.16b: Observed and predicted value of soil Zn status (gm ha^{-1}) after harvesting of Wheat year wise.

	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	610.75	642.87	598.75	635.75
P-20	598.25	627.79	589.75	618.53
P-30	594.50	620.38	588.25	610.55
P-40	587.25	600.58	572.50	585.69
FYM 5	611.00	636.49	597.25	625.88

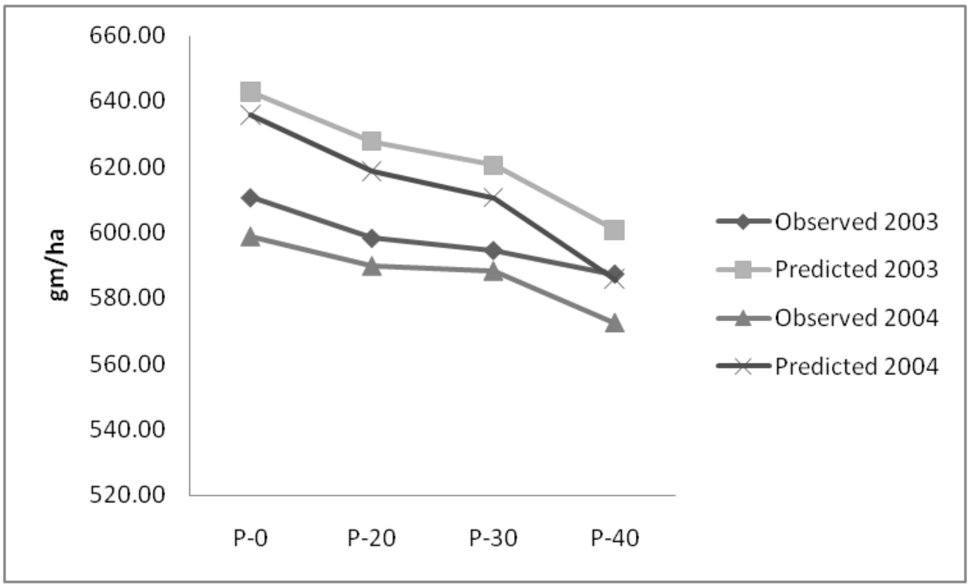

Figure 6.8: Status of Zn after Wheat

Comparative study of observed and predicted status of zinc under the application of FYM is presented in figure 6.9.

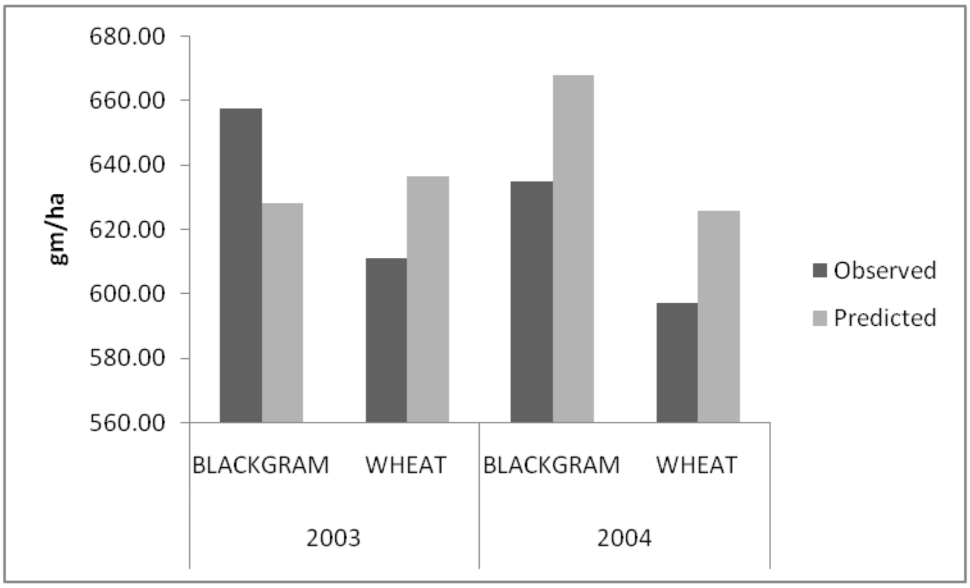

Figure 6.9: Soil Zn status after Blackgram and Wheat under FYM application

Comparison between predicted and observed soil status for micronutrient Cu, is presented in tables 6.17a and 6.17b.

Table 6.17a: Observed and predicted value of soil Cu status (gm ha^{-1}) after harvesting of Blackgram year wise

	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	595.00	550.47	590.00	499.44
P-20	592.50	542.27	577.50	487.83
P-30	587.50	534.99	570.00	478.03
P-40	572.50	527.15	565.00	467.25
FYM 5	600.00	546.69	585.00	496.93

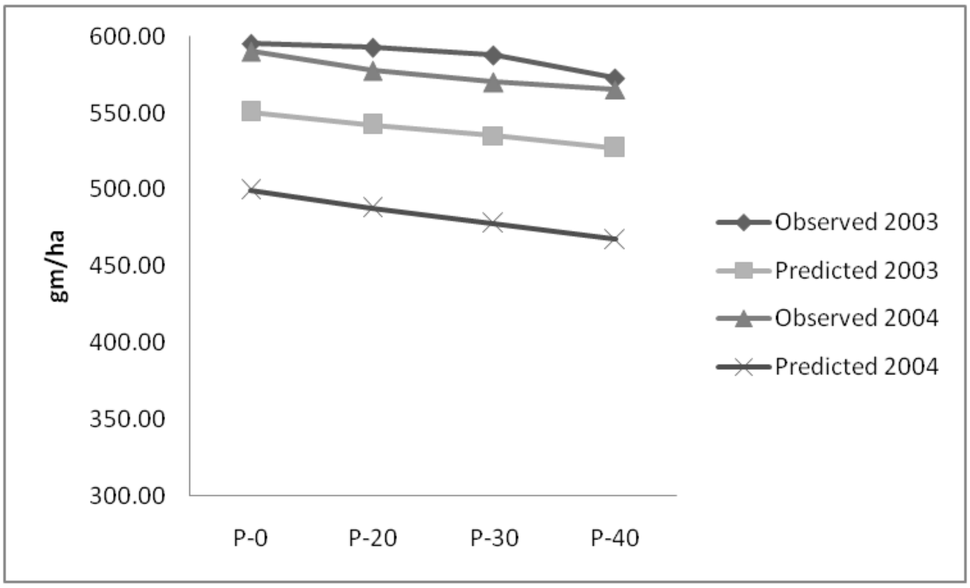

Figure 6.10: Status of Cu after Blackgram

Table 6.17b: Observed and predicted value of soil Cu status (gm ha^{-1}) after harvesting of Wheat year wise

	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	570.00	529.97	545.25	482.25
P-20	566.25	522.04	533.75	472.70
P-30	561.25	513.32	527.25	463.61
P-40	546.50	497.55	520.25	449.19
FYM 5	574.75	530.95	541.75	484.09

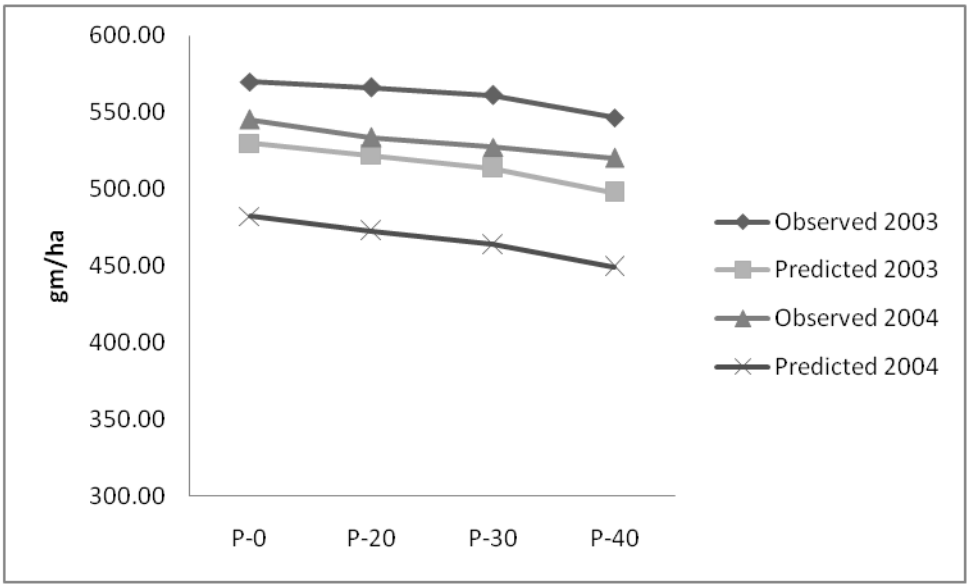

Figure 6.11: Status of Cu after Wheat

No significant difference in status of cu were measured about different fertilization practices shown in figure 6.10 - 6.12

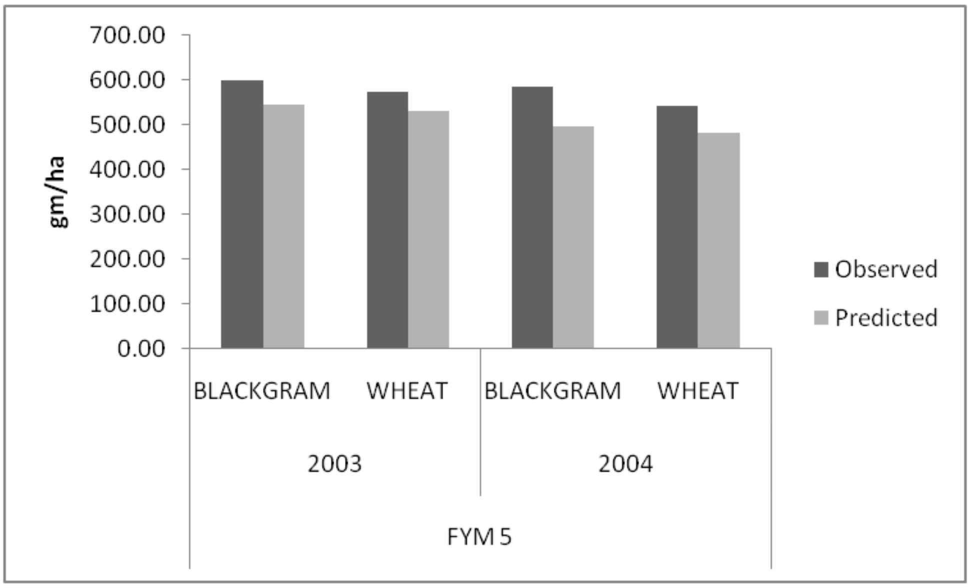

Figure 6.12: Soil Cu status after Blackgram and Wheat under FYM application

Comparison between predicted and observed soil status for micronutrient Mn, is presented in tables 6.18a and 6.18b.

Table 6.18a: Observed and predicted value of soil Mn status (gm ha^{-1}) after harvesting of Blackgram year wise

	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	3032.50	2676.28	2877.50	2734.27
P-20	3025.00	2684.02	2912.50	2748.21
P-30	2937.50	2675.42	2917.50	2731.20
P-40	2932.50	2663.17	2910.00	2707.67
FYM 5	3060.00	2728.71	3002.50	2832.09

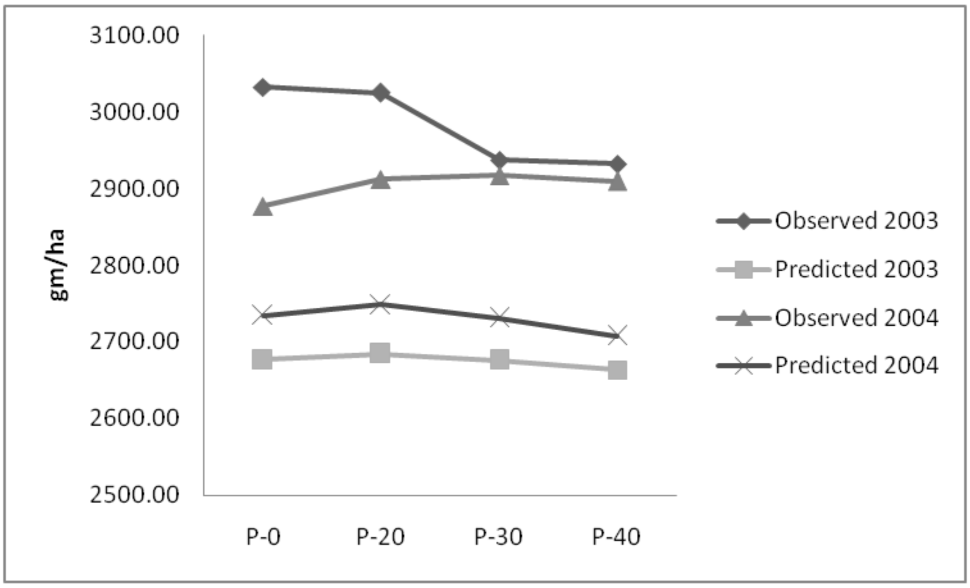

Figure 6.13: Status of Mn after blackgram

Table 6.18b: Observed and predicted value of soil Mn status (gm ha^{-1}) after harvesting of Wheat year wise

	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	2885.00	3040.49	2752.50	3047.75
P-20	2872.50	3032.24	2747.50	3038.74
P-30	2790.00	2939.14	2725.00	2940.58
P-40	2782.50	2917.95	2700.00	2905.18
FYM 5	2912.50	3099.86	2817.50	3135.32

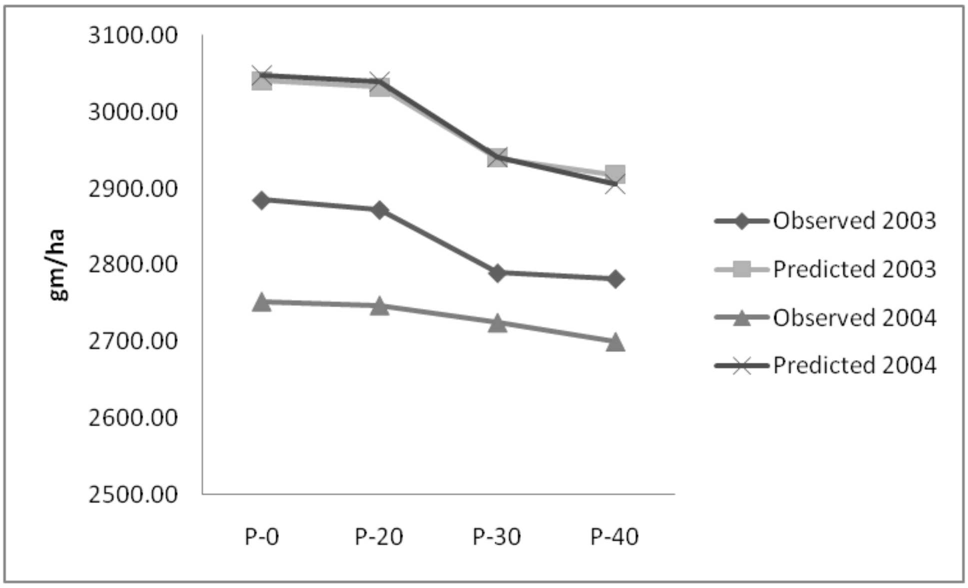

Figure 6.14: Status of Mn after Wheat

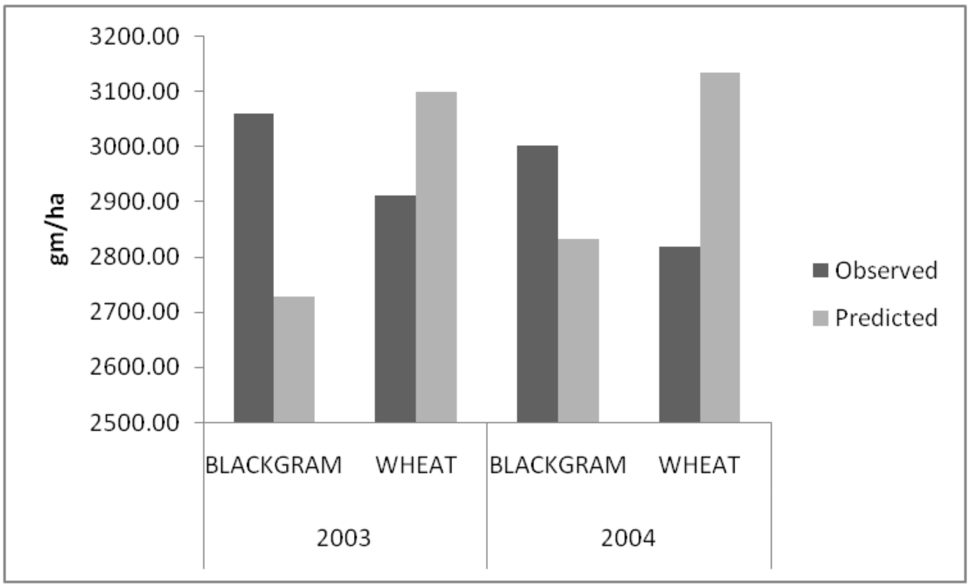

Figure 6.15: Soil Mn status after Blackgram and Wheat under FYM application

Comparison between predicted and observed soil status for micronutrient Fe, is presented in tables 6.19a and 6.19b.

Table 6.19a: Observed and predicted value of soil Fe status (gm ha^{-1}) after harvesting of Blackgram year wise

	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	2537.50	2854.09	2827.50	3188.23
P-20	2517.50	2763.82	2662.50	3013.58
P-30	2505.00	2767.52	2642.50	2992.62
P-40	2457.50	2730.84	2595.00	2919.33
FYM 5	2607.50	2624.47	2765.00	2803.02

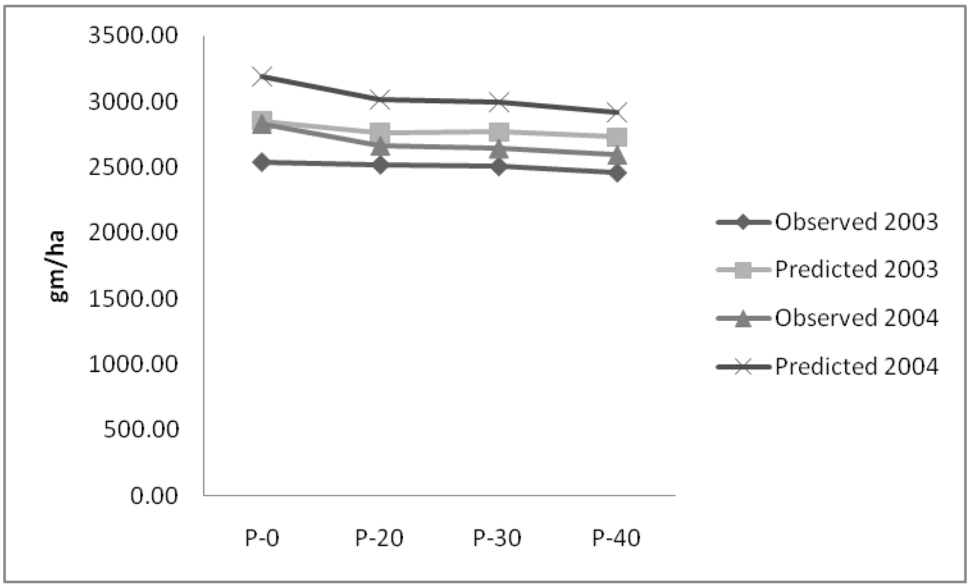

Figure 6.16: Status of Fe after Blackgram

Table 6.19b: Observed and predicted value of soil Fe status (gm ha^{-1}) after harvesting of Wheat year wise

	Observed 2003	Predicted 2003	Observed 2004	Predicted 2004
P-0	2462.50	2775.10	2767.50	2896.47
P-20	2442.50	2648.46	2602.50	2706.47
P-30	2430.00	2615.22	2580.00	2658.94
P-40	2382.50	2543.75	2537.50	2574.38
FYM 5	2532.50	2629.61	2702.50	2638.91

Figure 6.16 and 6.17 represent that predicted status of soil Fe is very similar to observed status also soil Fe status remain almost same of slight changed about different P fertilization practices and same results are shown in figure 6.18 about FYM applications.

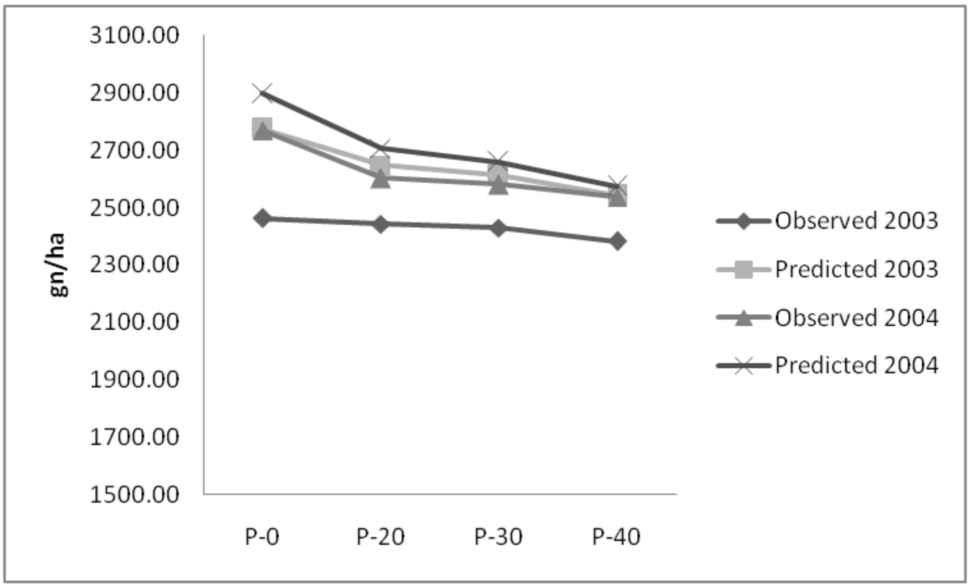

Figure 6.17: Status of Fe after Wheat

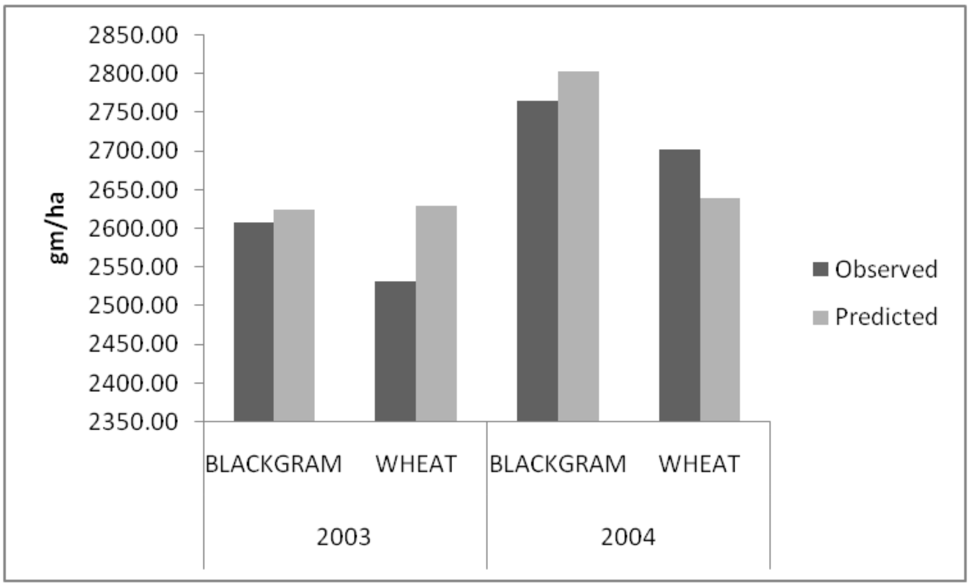

Figure 6.18: Soil Fe status after Blackgram and Wheat under FYM application

Reliability indices k_g and k_s are given in following tables 6.20 and 6.21 for different micronutrient and both crops. It shows that observed and predicted data agree closely.

Table 6.20: Reliability index k_g of Zn, Cu, Mn and Fe for the proposed model

Micronutrients	CROP	Treatment				
		P-0	P-20	P-30	P-40	FYM
Zn	BLACKGRAM	1.0477	1.0435	1.0403	1.0403	1.0492
	WHEAT	1.0574	1.0491	1.0408	1.0229	1.0449
Cu	BLACKGRAM	1.1388	1.1442	1.1513	1.1576	1.1420
	WHEAT	1.1062	1.1089	1.1171	1.1311	1.1022
Mn	BLACKGRAM	1.1001	1.0985	1.0842	1.0888	1.0952
	WHEAT	1.0844	1.0842	1.0674	1.0637	1.0914
Fe	BLACKGRAM	1.1262	1.1159	1.1193	1.1183	1.0107
	WHEAT	1.0946	1.0656	1.0577	1.0486	1.0320

Table 6.21: Reliability index k_s of Zn, Cu, Mn and Fe for the proposed model

Micronutrients	CROP	Treatment				
		P-0	P-20	P-30	P-40	FYM
Zn	BLACKGRAM	1.0477	1.0435	1.0403	1.0403	1.0492
	WHEAT	1.0574	1.0491	1.0408	1.0229	1.0449
Cu	BLACKGRAM	1.1389	1.1443	1.1514	1.1577	1.1420
	WHEAT	1.1062	1.1089	1.1171	1.1312	1.1022
Mn	BLACKGRAM	1.1002	1.0986	1.0843	1.0888	1.0952
	WHEAT	1.0844	1.0842	1.0674	1.0637	1.0914
Fe	BLACKGRAM	1.1262	1.1159	1.1193	1.1183	1.0107
	WHEAT	1.0946	1.0657	1.0578	1.0486	1.0320

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Chapter 7

MODELLING ASSESSMENT OF REGIONAL SOIL & GROUNDWATER CONTAMINATION DUE TO EMISSIONS OF COMPONENT OF FERTILIZER

7.1 INTRODUCTION

Soil and water both are vast natural resource on which the life supporting systems and socio-economic development depends. For living a healthy life it's must to have healthy or atleast nontoxic intake which is totally depend on water and soil. Assessment of physicochemical properties of soil and water to make sure the quality of these in a specific region, play an important role. Organic matter is one of the most important constituents of soil, a good amount of organic carbon / matter in soil increase soil fertility. Continuous land use for harvesting results in the reduction of soil organic carbon and soil nutrient status further it enhance soil erosion and salinity hence it affect adversely soil affect soil physical properties. The soil fertility status of Gharsana tehsil anticipate problems in successful maintenance of irrigated agriculture under cultivation due to majority of soils were found strongly alkaline and calcareous in nature and organic carbon is very low (< 0.50%) [136]. In Chiraigaon (Varanasi), a positive correlation was reported between organic carbon and available essential nutrients in a experiment to analyze soil physico-chemical properties [137]. In Prathapgadh district of Rajasthan, work on study of available soil nutrients (micro and macro) status and their behavior with various physio-chemical properties has been done by Singh and Rathore [138]. Similar work was done by Meena, Sharma and Rawat to assess the status of soil macro and micro nutrient status in Tonk district [139]. Agricultural management i.e. application different practices of fertilizer and manure to achieve maximum crops results into water contamination.

In the present study we tried to find out various physico-chemical properties of different soil and groundwater bodies at some blocks of Bhilwara district (Rajasthan). It helps to predict the status of pH, EC, OC and available P in soil and the condition of groundwater that is it ready to use as drinking water in different blocks of Bhilwara district of Rajastha. Further it helps to choose suitable recommendations to improve level of soil and water in area.

7.2 DATA COLLECTION

Bhilwara is situated at 25.35°N 74.63°E. Its average elevation is of 421 metres or 1381 feet. Bhilwara consists of 12 blocks namely Asind, Suwana, Jahazpur, Kotri, Mandal, Mandalgarh, Shahpura, Raipur, Beejoliya, Banera, Sahara and Hurda. Its climate is humid and has average annual temperature approx 22 degree Celsius whereas average rainfall of Bhilwara district is 635.1 mm annually. Soils of Bhilwara district can be classified in four ways- (i) Clay loam (medium black) - Such type of soil is usually found in the hilly areas of central parts of the district, (ii) Loam- This type of soil is found in almost entire district, (iii) Sand and sandy loam- This type of soil can be seen near the banks of rivers in the district and (iv) Loam (pebbly & stony)- This type of soil can be found in eastern hilly area of the district.

Soil and water data were collected from soil testing lab, Bhilwara, where soil samples of different villages and almost all blocks/ tehsil of Bhilwara were examined to know the status of soil characteristics like its pH, status of organic carbon, soluble salt content, availability of soil micronutrients and macronutrients etc. The soil samples were mixed thoroughly before analysis after that approx 500 gram material was taken for analysis from sample. Then this 500gm sample was analyzed for different nutrients using standard procedures. Available phosphorus was extracted by sodium bicarbonate extractable phosphorus [115]. The organic matter content was determined by Walkey and Black method [116].

We were provided data about soil OC, EC, pH and available status of P of different soil and NO_3, TDS, pH, availability of Ca, Mg and Cl in water of some tehsil of Bhilwara.

7.3 ASSESSMENT OF SOIL

7.3.1 Physico-Chemical Properties

Soil is said to be of neutral in reaction if its pH lies in the range of 6.5-7.4, slightly alkaline if it lies in 7.5-8.5 and strongly alkaline if soil pH belongs to 8.6-10 [140]. If the status of organic carbon in soil is less than 0.5%, soil is said to be low in OC, if it is 0.5%-0.75% OC in soil is medium and if it is more than 0.75% then soil OC level is high[141]. Tables 7.1 to 7.10 represent the various soil properties and Figure 7.1 to 7.10 represent status of pH, EC, OC and Phosphorus in ten different blocks of Bhilwara districts.

Table 7.1: Soil properties in Asind block

Parameters	pH	EC	OC	P
Range	7-8.9	0.1-1.2	0.15-0.9	18-60
Mean	7.881	0.361	0.403	33.790
S.D	0.400	0.200	0.207	12.120
C.V(%)	5.075	55.387	51.420	35.868

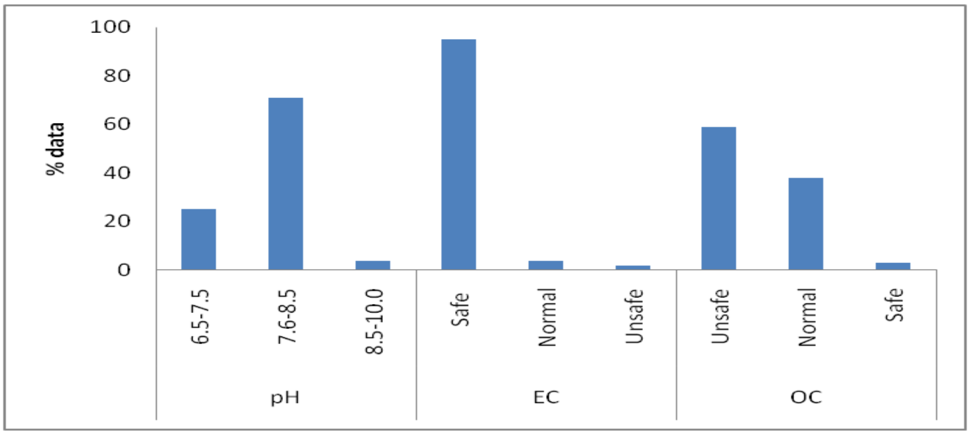

Figure 7.1: Status of various parameters of Asind block

Figure 7.1 shows that most of the soil in Asind block is of slightly alkaline type and very few of strongly alkaline, soil OC status is low as approx 60% field are in unsafe range whereas EC condition of soil is good.

Table 7.2: Soil properties in Suwana block

Parameters	pH	EC	OC	P
Range	6.1-9.5	0.12-1.7	0.15-1.05	8.0-52.0
Mean	7.853	0.521	0.299	26.169
S.D	0.537	0.310	0.200	7.771
C.V(%)	6.835	59.513	66.862	29.696

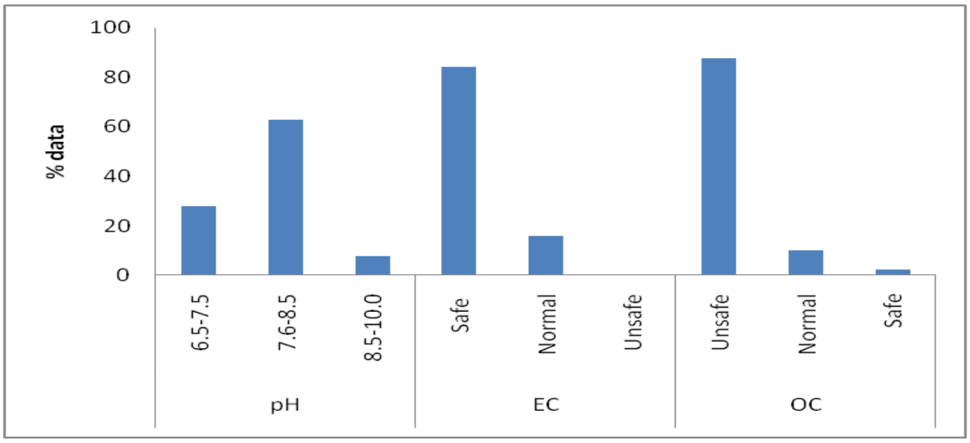

Figure 7.2: Status of various parameters of Suwana block

Figure 7.2 shows electrical conductivity in Suwana block is in good condition, most of the soil is of alkaline medium and organic carbon level of soil is very poor.

Table 7.3: Soil properties in Jahazpur block

Parameters	pH	EC	OC	P
Range	7.6-8.7	0.1-0.7	0.15-0.9	20-52
Mean	7.972	0.421	0.452	30.340
S.D	0.237	0.142	0.193	8.123
C.V(%)	2.969	33.777	42.669	26.773

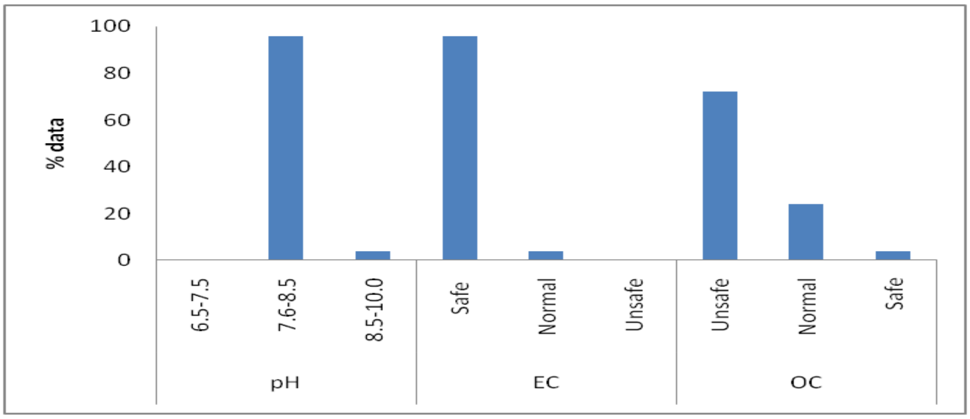

Figure 7.3: Status of various parameters of Jahazpur block

In jahazpur block most of the soil is slightly alkaline, electrical conductivity of soil in block is in safe range and approx 30% soil have good organic carbon level i.e. OC level is not good.

Table 7.4: Soil properties in Kotri block

Parameters	pH	EC	OC	P
Range	6.4-8.5	0.2-1.1	0.15-1.0	18-48
Mean	7.735	0.367	0.429	26.159
S.D	0.423	0.157	0.207	5.923
C.V(%)	5.466	42.944	48.288	22.644

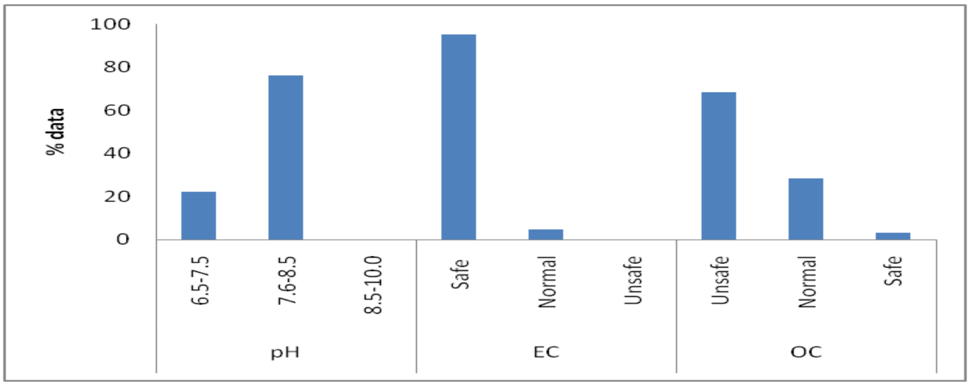

Figure 7.4: Status of various parameters of Kotri block

Figure 7.4 shows pH level varies neutral to slightly alkaline medium, electrical conductivity is good whereas OC level is not good.

Table 7.5: Soil properties in Mandal block

Parameters	pH	EC	OC	P
Range	7.0-9.0	0.17-2.0	0.15-1.05	20-62
Mean	8.391	0.414	0.573	35.927
S.D	0.483	0.385	0.225	13.419
C.V(%)	5.755	93.028	39.354	37.350

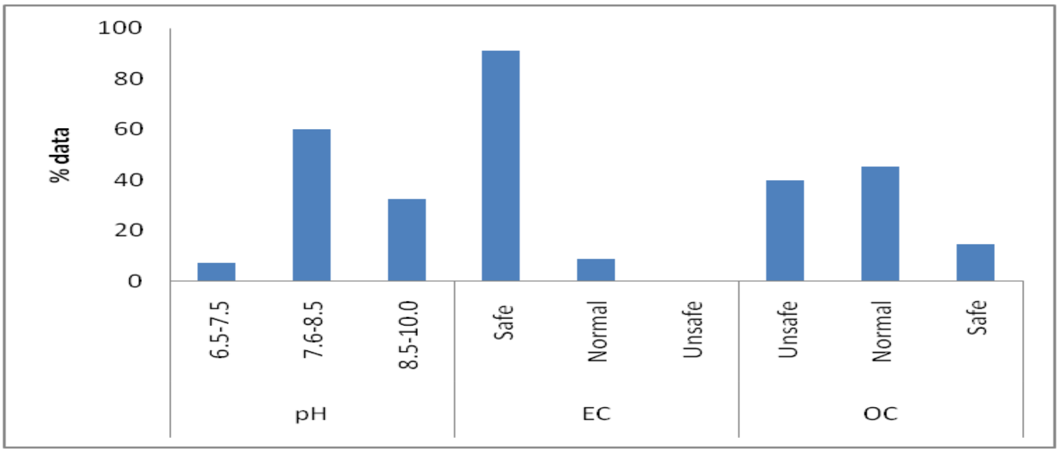

Figure 7.5: Status of various parameters of Mandal block

It is shown in figure 7.5 that organic carbon level of Mandal block is far better than other block of district approx 55% soil has sufficient quantity of OC, electrical conductivity is also good while soil pH varies slightly to strongly alkaline medium.

Table 7.6: Soil properties in Mandalgarh block

Parameters	pH	EC	OC	P
Range	8.3-8.6	0.18-0.96	0.15-1.05	18-64
Mean	7.942	0.340	0.521	34.073
S.D	0.398	0.144	0.204	10.417
C.V(%)	5.012	42.264	39.159	30.571

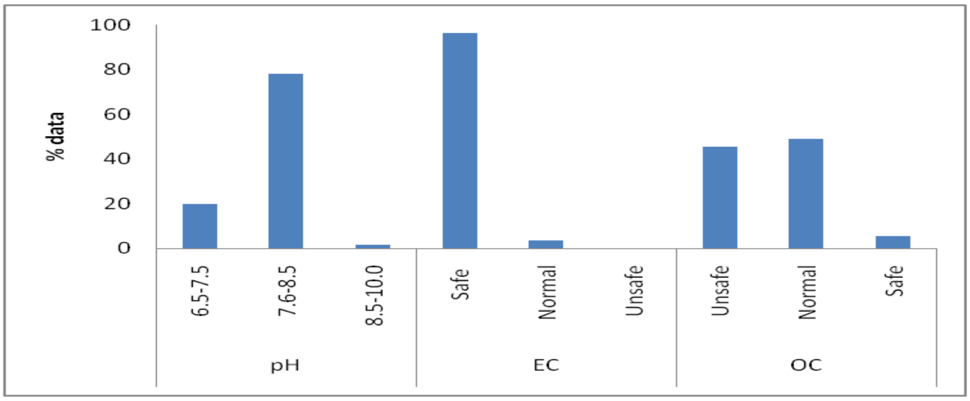

Figure 7.6: Status of various parameters of Mandalgarh block

As shown in figure 7.6, soil OC level is good in the block in overall comparison, electrical conductivity is also good whereas soil pH varies from neutral to slightly alkaline medium.

Table 7.7: Soil properties in Sahara block

Parameters	pH	EC	OC	P
Range	7.0-9.0	0.25-1.7	0.15-1.35	8.0-64.0
Mean	7.869	0.481	0.614	34.982
S.D	0.579	0.235	0.359	11.415
C.V(%)	7.362	48.840	58.458	32.632

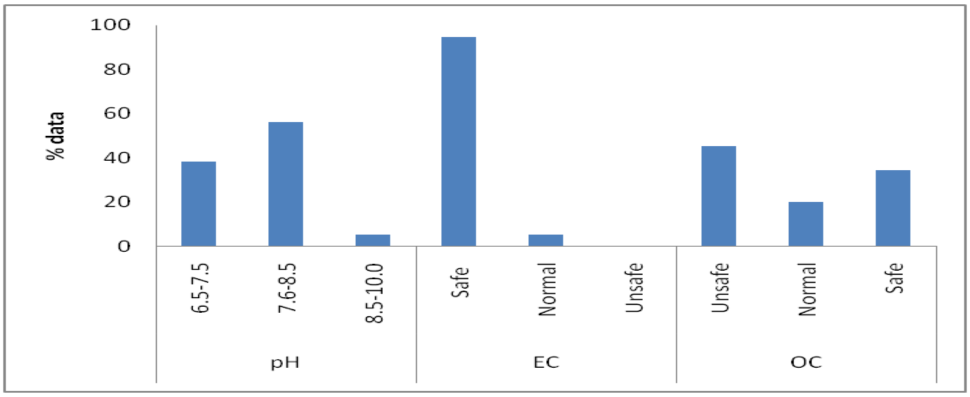

Figure 7.7: Status of various parameters of Sahara block

Figure 7.7 shows organic carbon contained in is rich in Sahara block, soil pH varies from neutral to slightly alkaline few field found having strongly alkaline medium and soil electrical conductivity found good.

Table 7.8: Soil properties in Shahpura block

Parameters	pH	EC	OC	P
Range	7.2-8.8	0.18-2.1	0.1-1.05	18-50
Mean	8.136	0.584	0.374	31.486
S.D	0.257	0.417	0.231	7.166
C.V(%)	3.153	71.312	61.802	22.760

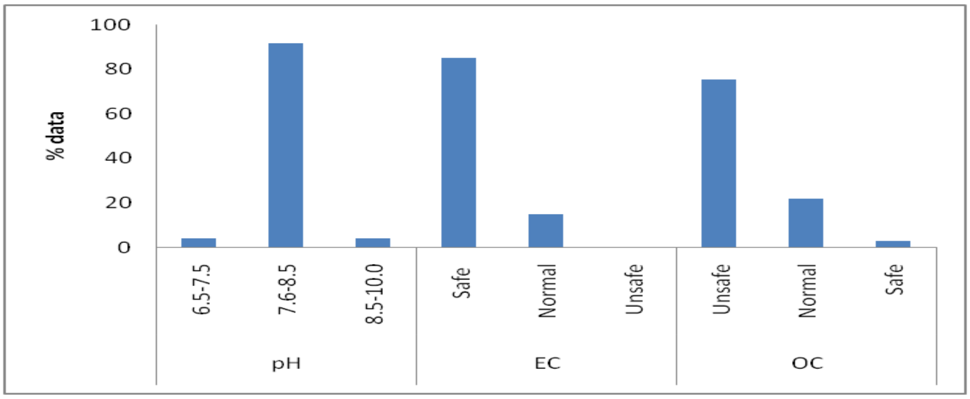

Figure 7.8: Status of various parameters of Shahpura block

In Shahpura block contain pH in slightly alkaline medium, EC level is good and OC level found in critical condition

Table 7.9: Soil properties in Raipur block

Parameters	pH	EC	OC	P
Range	7-8.7	0.28-9.2	0.1-0.9	20-64
Mean	7.920	1.395	0.350	34.800
S.D	0.431	2.273	0.188	12.490
C.V(%)	5.445	162.927	53.605	35.891

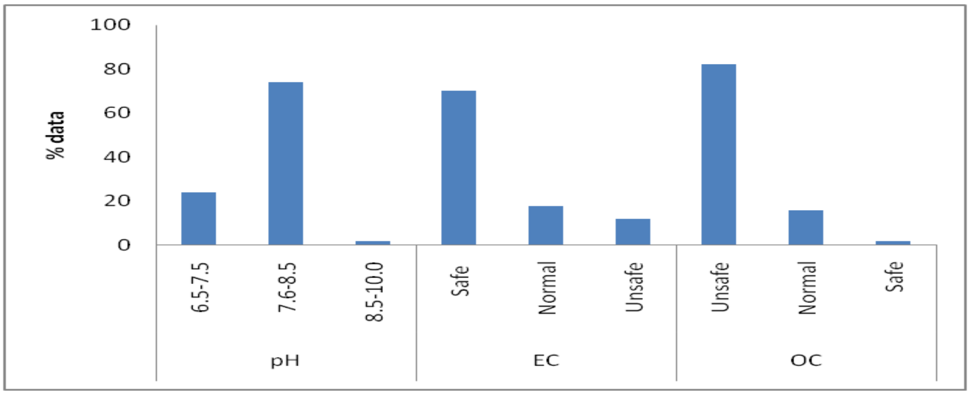

Figure 7.9: Status of various parameters of Raipur block

It is shown in figure 7.9 that mostly soil is of slightly alkaline medium, EC is comparatively poor than other blocks also OC level is poor.

Table 7.10: Soil properties in Beejoliya block

Parameters	pH	EC	OC	P
Range	6-8.3	0.2-0.48	0.3-1.2	20-60
Mean	7.642	0.331	0.742	35.564
S.D	0.336	0.067	0.224	11.078
C.V(%)	4.391	20.121	30.219	31.149

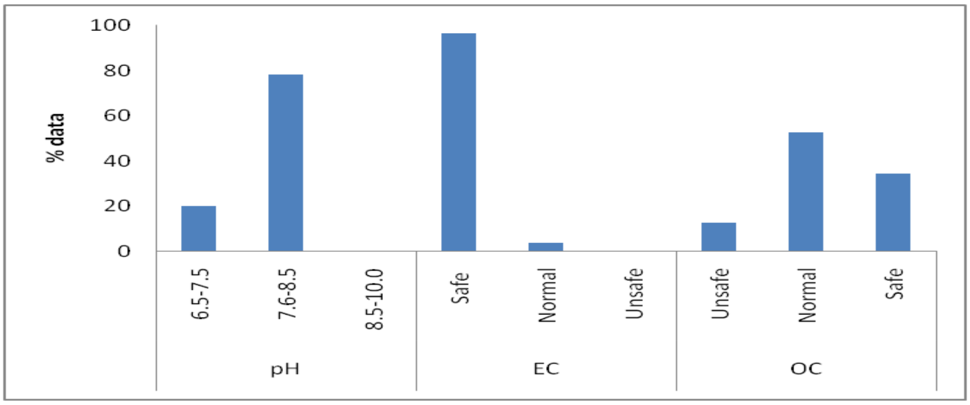

Figure 7.10: Status of various parameters of Beejoliya block

It is shown in figure 7.10 that the soil condition is good approx 80% have good soil organic carbon level, most of the soil is of good condition and soil pH moves to neutral to slightly alkaline condition.

➢ Soil pH

In Asind block pH varies from 7.0 to 8.9 with average of 7.89. Approx 25% soil data found neutral, 71 % soil data were found slightly alkaline and 4% soil data was found of strongly alkaline in reaction. In Suwana block 1.12% of soil data were of slight acidic and 28.09 % data found of neutral, 62.92% data found of slightly alkaline and approx 7.87% soil data found of strongly alkaline in reaction. In Kotri and Beejoliya 1.59% and 1.82% of soil data were of slight acidic respectively. In these blocks 22.2% and 20% data were of neutral and soil data of slightly alkaline were 76.19% and 78.18% respectively. In Kotri and Beejoliya blocks, no data was of strongly alkaline in reaction. In Raipur and Mandalgarh blocks approx 2% soil data were strongly alkaline in reaction. 74% were slightly alkaline in Raipur and 78.18% in Mandalgarh whereas 24% and 20% data were neutral in reaction in these blocks respectively. Maximum neutral data 38.18% were found in Sahara block here 56.36% data found slightly whereas 5.5% found strongly alkaline in reaction. Maximum strongly alkaline soil data were found in Jahazpur block it was 96% followed by 91.89% in Shahpura block. In Jahazpur and Shahpura approx 4% soil data were of strongly alkaline in reaction whereas 4% were neutral in Shahpura and no data were found of neutral in reaction in Jahazpur block. In Mandal, approx 7.27% data were of neutral and 60% soil data were found slightly alkaline in reaction whereas approx 5% data were of strongly alkaline in reaction. Similar results have also been reported for Mandal block [142]. Figure 7.11 represents the comparative study of pH soil status in different blocks in Bhilwara district.

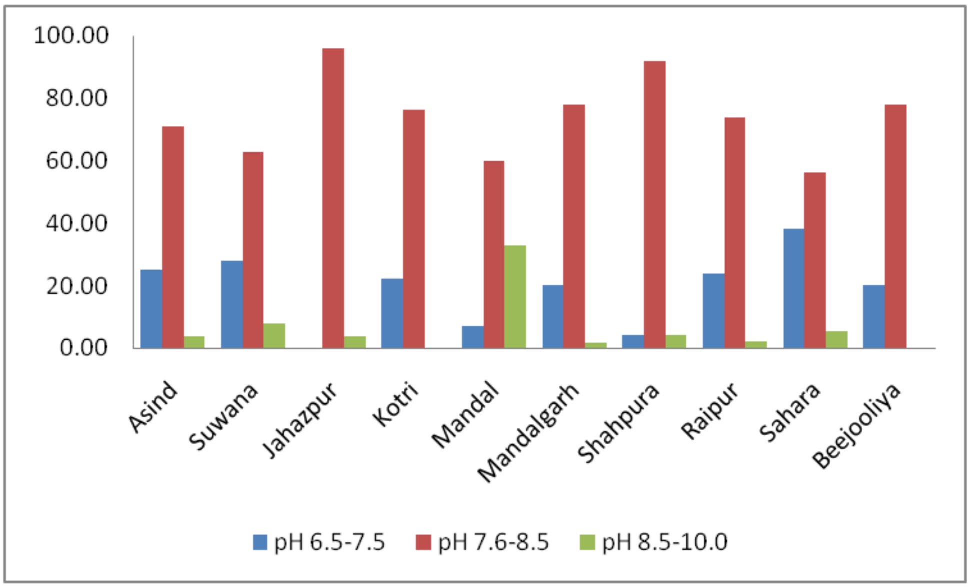

Figure 7.11: pH status block wise

➢ Electrical Conductivity (EC) in soil

Jahazpur, Mandalgarh and Beejoliya can be considered safe blocks as EC was found less than 1in these blocks. In Jahazpur EC varied 0.1 to 0.7, in Mandalgarh it varied from 0.18 to 0.96 and in Beejoliya it varied 0.2 to0.48. But in Raipur maximum approx12% soil data were found which are in critical range or not safe as EC point of view. In some soil data EC was found tremendously high. Here 70% soil data were found in safe region whereas approx 18% was in normal range. In Asind 95% soil data were belonged to safe range and 4% in normal range only 1% was found unsafe range. In Suwana and Shahpura approx 95% soil data were found in safe range and approx 15% was in normal range whereas in Mandal block 90.9% soil data were found to be safe and approx 9.1% were in normal range. In Kotri and Sahara blocks more than 95% soil data were in safe range and 5% were in normal range. Figure 7.12 shows overall status of EC in different blocks.

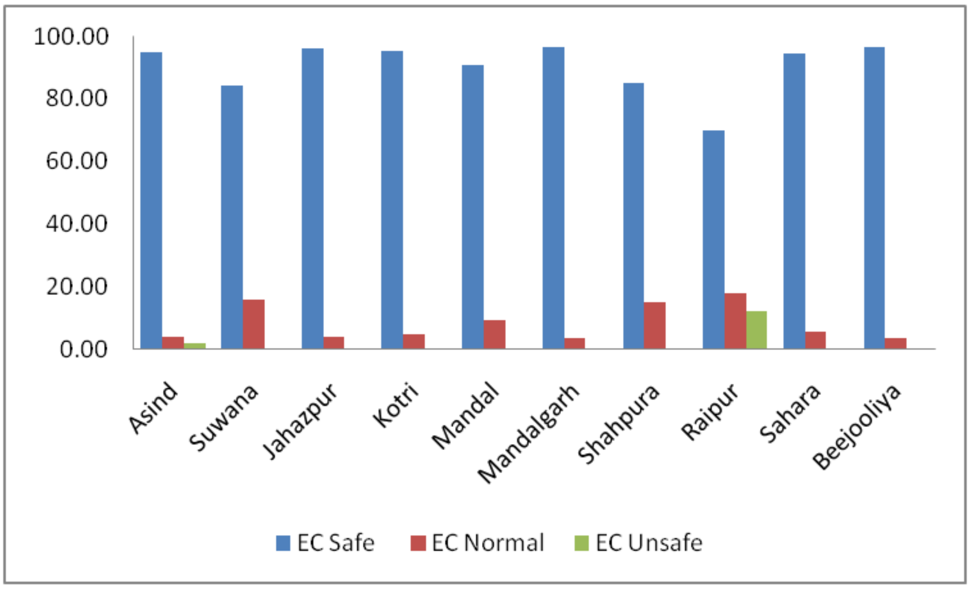

Figure 7.12: Electrical Conductivity level block wise

- Organic Carbon Status in soil

As per organic carbon status considered, soil condition was tremendous. More than 50% soil data of six blocks were found in low OC percent region. In Suwana almost 87.64% soil data were in low OC present soil followed by Raipur block with 82% data were in low OC percent soil. In Shahpura, Jahazpur, Kotri and Asind approx 75.6%, 72%, 68.25% and 59% data were in low OC percent soil respectively. In Beejoliya, Mandalgarh and Mandal 52.73%, 49.1% and 45.45%

data were in medium OC percent region. In Sahara and Beejoliya, Maximum 35% of data were found in safe OC percent region. In other blocks 2% to 5% data were present in safe OC percent range. Thus majority of the soil data in different blocks are low to medium and few soil data were high in organic carbon percent due to the use of manure or crop residues. Figure 7.13 shows the comparison of status of OC in different blocks of Bhilwara.

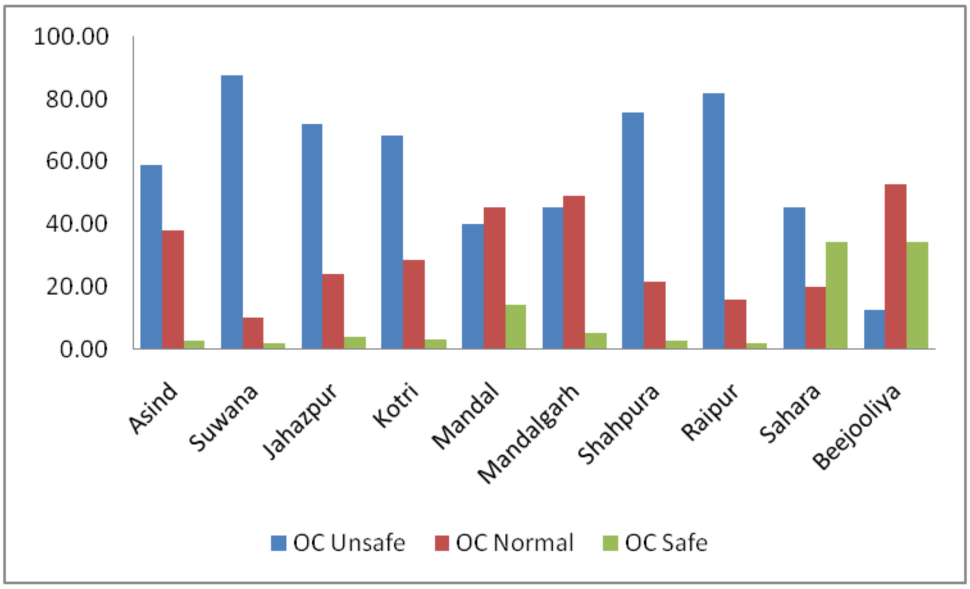

Figure 7.13: Organic Carbon status block wise

➢ Available Phosphorus

Majority of the soil data of different blocks of Bhilwara were medium to high. Maximum 56.18% soil data of Suwana block were found in safe range whereas in same block 42.7% soil data were found in high Phosphorus range and 1.12% soil data were in low phosphorus range. In Kotri, Raipur, Jahazpur and Mandal 47.62%, 32%, 32% and 25.5% soil data of respective blocks found in medium phosphorus range. In Shahpura, Beejoliya and Mandalgarh approx 82% soil data were found in high phosphorus range. More than 70% soil data of Mandal, Sahara, Asind and Jahazpur were found in high phosphorus range. In Kotri, 52.38% soil data were in high phosphorus range.

7.3.2 Correlation between Various Parameters

Tables 7.11 to 7.20 show the pearson's correlation matrix between various parameter of soil in different blocks of Bhilwara.

Table 7.11: Pearson's correlation matrix between various soil parameters at Asind block

	pH	EC	OC	P
pH	1			
EC	0.479	1		
OC	0.329	0.203	1	
P	0.546	0.429	0.478	1

Table 7.12: Pearson's correlation matrix between various soil parameters at Suwana block

	pH	EC	OC	P
pH	1			
EC	-0.288	1		
OC	-0.016	0.094	1	
P	-0.037	-0.108	0.338	1

Table 7.13: Pearson's correlation matrix between various soil parameters at Jahazpur block

	pH	EC	OC	P
pH	1			
EC	0.168	1		
OC	0.047	0.473	1	
P	0.295	0.137	0.121	1

Table 7.14: Pearson's correlation matrix between various soil parameters at Kotri block

	pH	EC	OC	P
pH	1			
EC	-0.047	1		
OC	0.168	0.203	1	
P	-0.242	0.149	0.306	1

Table 7.15: Pearson's correlation matrix between various soil parameters at Mandal block

	pH	EC	OC	P
pH	1			
EC	0.390	1		
OC	0.105	-0.117	1	
P	0.156	-0.149	0.513	1

Table 7.16: Pearson’s correlation matrix between various soil parameters at Mandalgarh block

	pH	EC	OC	P
pH	1			
EC	0.013	1		
OC	0.135	0.512	1	
P	0.140	0.413	-0.010	1

Table 7.17: Pearson’s correlation matrix between various soil parameters at Sahara block

	pH	EC	OC	P
pH	1			
EC	0.367	1		
OC	0.661	0.345	1	
P	-0.202	0.308	0.121	1

Table 7.18: Pearson’s correlation matrix between various soil parameters at Shahpura block

	pH	EC	OC	P
pH	1			
EC	0.028	1		
OC	-0.004	0.059	1	
P	-0.104	0.231	0.457	1

Table 7.19: Pearson's correlation matrix between various soil parameters at Raipur block

	pH	EC	OC	P
pH	1			
EC	0.478	1		
OC	-0.330	-0.271	1	
P	-0.238	-0.114	0.364	1

Table 7.20: Pearson's correlation matrix between various soil parameters at Beejoliya block

	pH	EC	OC	P
pH	1			
EC	-0.332	1		
OC	-0.198	0.209	1	
P	-0.059	0.552	0.108	1

Correlation analysis plays a keen role in the study of environmental problems. They provide a useful way to disclose the relationships between multiple variables and thus have been helpful for understanding the influencing factors as well as the sources of chemical components. Pearson's correlation matrix of various parameters of phyico-chemical properties of soil has been shown.

Soil data of Asind block showed significant positive correlation between pH and EC, similar results were found in Raipur while Mandal and Sahara blocks showed a low degree positive correlation whereas suwana and Beejoliya showed low degree negative correlation between pH and EC. Between pH and OC, soil data of

Sahara and Asind showed significant positive correlation whereas Suwana and Shahpura showed low degree negative correlation and other blocks Jahazpur, Kotri, Mandal and Mandalgarh showed low degree positive correlation between pH and OC. Soil data of Asind block showed significant positive correlation between pH and P also Jahazpur, Mandal and Mandalghadh showed positive correlation, whereas negative shown by other blocks. Soil data of Mandal and Raipur showed significant negative correlation between EC and OC whereas other blocks showed positive correlation. A significant positive correlation was shown between EC and P at Beejoliya, Mandalgarh, Asind and Sahara whereas Suwana and Mandal showed negative correlation between them and other showed low degree positive correlation. Soil data at Mandalgarh showed negative correlation between OC and P and other showed positive correlation between OC and P.

A positive correlation between pH and EC was found when cumulative data of all blocks were studied. In cumulative study of data a positive correlation was found between pH and OC also between pH and P whereas negative correlation excited between EC and OC. A low degree positive correlation existed between EC and P. Similar results have been revealed in the study of physico-chemical properties at Lahar, Bhind (M.P.) [143].

7.4 ASSESSMENT OF GROUNDWATER

7.4.1 Physico-Chemical Properties

For groundwater assessment we collected sample of Raipur and Banera blocks. It was observed that level of NO_3 in both blocks varies in wide range maximum NO_3 level was measured 806 in Banera. Average level of NO_3 in Banera was 128.67 whereas in Raipur it was 103.68. Further 42-43% groundwater source was found highly contaminated by NO_3 as a result of high fertilization practice and in Banera only 11.42% sources have desirable level as per BIS recommendations. F^- varies from 0.3 to 4.3 and more than 50% water bodies are heavlily loaded by floride. Level of Cl^- in 57% and 36.8% groundwater sources measured desirable only 7-8% sources have high chloride level which is due might be due to application of animal manure application in field and in rest of the water bodies level was in permissible range. Significant effect of chloride found on availability of Ca^+ and Mg^+ in ground water. It was found that in both blocks approx 84-85% water bodies have desirable level of Ca^+ while in Banera 91% and in Raipur 85% water bodies have desirable level of Mg^+. Level of SO_4 and pH are also in permissible range in most of the water sources in both blocks. TDS level (Total dissolved solids) was measured tremendously high in both blocks though approx 70-77% sources have permissible TDS level but only 2% have desirable level, it might be due to the industrial wastage which leached into dipper soil. TH (Total hardness) was found unsafe in 28-31% water bodies whereas approx 31-37% have desirable level of TH. Figure shows average status of different physicochemical parameters of groundwater in both blocks.

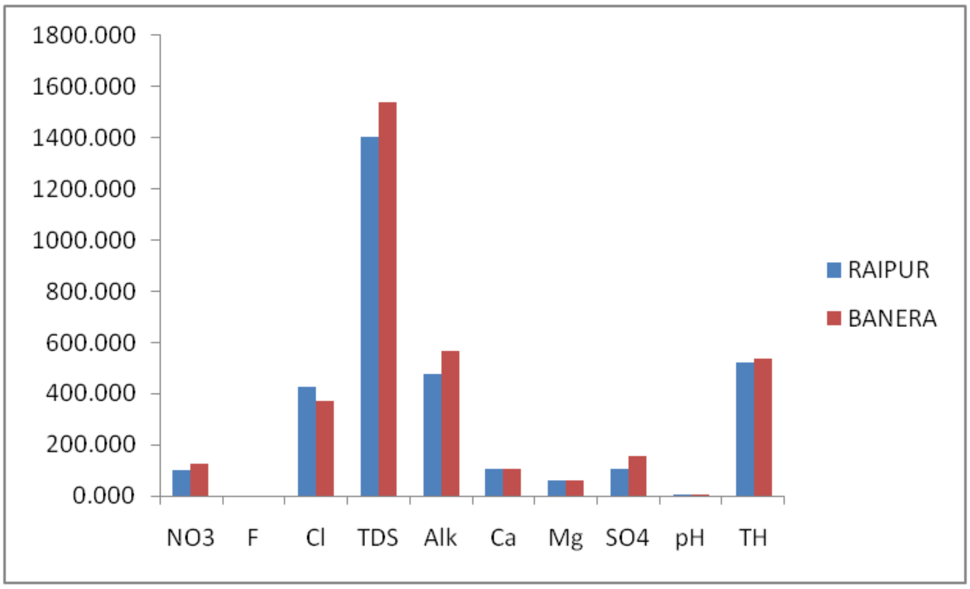

Figure 7.14: Average status of different parameters in Raipur and Banera Blocks

7.4.2 Correlation between Various Parameters:

It was found that Cl showed a high positive correlation with Ca, Mg and TDS while moderate with SO_4. A negative correlation was measured between Cl and pH. F shows slightly negative Ca and Mg. NO_3 shows positive correlation with Cl, Ca, Mg and SO_4 while a slight positive correlation was shown between pH and NO_3. Correlation coefficient among various parameters are shown in following tables.

Table 21: Correlation coefficient between various groundwater parameters in Raipur

	NO3	F	Cl	Ca	Mg	pH	SO4	TDS
NO3	1							
F	-0.021	1						
Cl	0.381	-0.045	1					
Ca	0.299	-0.313	0.722	1				
Mg	0.298	-0.238	0.791	0.767	1			
pH	-0.021	0.286	-0.209	-0.500	-0.221	1		
SO4	0.269	0.038	0.299	0.322	0.226	0.260	1	
TDS	0.541	0.027	0.700	0.613	0.562	-0.288	0.370	1

Table 22: Correlation coefficient between various groundwater parameters in Banera

	NO3	F	Cl	Ca	Mg	pH	SO4	TDS
NO3	1							
F	0.068	1						
Cl	0.242	-0.194	1					
Ca	0.222	-0.545	0.541	1				
Mg	0.266	-0.331	0.878	0.725	1			
pH	0.068	0.271	-0.202	-0.682	-0.356	1		
SO4	0.339	-0.168	0.752	0.407	0.837	-0.066	1	
TDS	0.287	-0.039	0.744	0.582	0.583	-0.422	0.354	1

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Chapter 8

RESULT

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DISCUSSION

Result of this study indicate that the theoretical approach used in proposed mathematical model is valid as the reliability indices shows agreement between observed and predicted soil nutrient status. In Clay loam soil, average soil phosphorus efficiency was measured 0.278 and 0.921 for greengram and wheat respectively whereas average fertilizer phosphorus efficiency was measured about different dose of P similarly average soil nutrients efficiency were measured for different macro and micro nutrient under the influence of phosphorus. Results shows that in Bhilwara soil pH is of alkaline in medium, soil organic matter is of poor level whereas electrical conductivity of soil is safe. Positive correlation exists between soil pH, EC, OC and P while negative correlation exists between EC and P. It was observed that approx 43% sources of groundwater in Banera and approx 42% were found contaminated with nitrogen and average NO_3 in groundwater was found between 103.6 to 128.67.

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Chapter 9

SUMMARY

SUMMARY

Soil is the most fundamental resource which is required to meet the various requirements of human being. Now a days, soil deterioration or soil pollution as a result of either excessive or unbalanced fertilization practices or continuous exhaust of soil nutrients and not replenished in long run or nutrient loss due to runoff, have been become a serious concern. Without a healthy soil it not possible to take non toxic or healthy crops and a sustainable crop system. Soil health is directly depends on soil fertility i.e. the capacity to produce optimize crops under favorable environmental conditions. Soil fertility is highly influenced by the chemical, physical and biological conditions of soil and by the quantity and balance of essential nutrients present in it. It is necessary that removed nutrients from soil to plants must be restored by proper application of organic and inorganic fertilizers to maintain soil fertility but the Intensive application of synthesized fertilizer may results into soil acidification and decline in soil organic matter further reduce crop harvest. Excessive use of nitrogen contaminates ground water sources.

An understanding of the factors that affect the status of available plant required nutrients in soil and their effect of availability of soil nutrients and their contamination in groundwater is important for many applications. An understanding of these factors will also help in identification of suitable remediation methods. To design and control the operation of soil ecosystem model the mathematical modeling can play an important role. Mathematical based environmental models are comparatively less expensive also work more rapid than other experimental approach, and it can be taken as an effective tool in the decision making. The present work entitled "A mathematical model on effect of fertilizer in soil fertility" has been designed to achieve the purpose with the objectives as follows:

- Formulate mathematical model for prediction of status nutrients in soil.
- Find its solution under specific fertilizer applications.

- Estimation of soil macro- and micronutrients status under specific fertilizer application.
- Predict the steady state level of soil macro- and micronutrients under the long run fertilizer practices.
- Assessment of soil physico-chemical properties and regional groundwater status in different blocks of Bhilwara district in Rajasthan and established correlation between them.

To predict the status of nutrients in soil the following equation was considered as governing equation

$$M_i = M_{i-1} + F_i - U_i + E \tag{1}$$

where M_i represent the soil nutrient status after i^{th} crop, F_i shows input fertilizer, U_i shows uptake through plants or crop and E is build up through unaccounted sources.

In general, we take crops in a continuous cropping system i.e. in a year producer or farmer take two or more than two crops. In a continuous crop system if one of the crop is legumes like greengram, blackgram or beans etc. which require additional phosphorus through fertilizers but after harvesting there is sufficient phosphorus in soil that we can take some other crop like wheat without additional application of phosphorus fertilizers. To convert this problem in mathematical form we use difference equation

$$P_{(i,B)} = P_{(i-1,W)} + F_{i,B} - U_{iB} - F_r + E_B \tag{2}$$

$$P_{(i,W)} = P_{(i,B)} - U_{iW} + E_W \tag{3}$$

Where $P_{(i,B)}$ shows the phosphorus level in soil after the blackgram crop in ith year, $F_{i,B}$ shows the amount of fertilizer applied to ith crop of blackgram only, U_{iB} shows the amount of phosphorus uptake by ith crop of blackgram, $P_{(i,W)}$ shows the phosphorus level in soil after the wheat crop in ith year U_{iW} shows the amount of phosphorus uptake by i[th] crop of wheat, F_r runoff amount of fertilizer applied, E_B and E_W are the built-up level of phosphorus due to the factor other than considered in basic equations. Equation (2) shows the status of phosphorus after blackgram (with added phosphorus) whereas equation (3) shows status of Phosphorus after wheat (without added phosphorus) i.e. residual effect of application of P on soil status for wheat crop.

It was assumed that uptake is function of available phosphorus in soil and of fertilizer (if added). So U_{iB} and U_{iW} were given by

$$U_{iB} = \gamma_B P_{(i-1,W)} + \delta_B F_{iB} + C_B \tag{4}$$

$$U_{iW} = \gamma_W P_{(i,B)} + C_W \tag{5}$$

Where constant γ is the average soil phosphorus nutrient efficiency $\left(0 \le \gamma \le 1\right)$, δ is aveage fertilizer nutrient efficiency $\left(0 \le \delta \le 1\right)$ for crops and C shows the uptake of phosphorus from unaccounted sources by crop $\left(C \ge 0\right)$.

If a constant amount of fertilizer ($F_{i,B} = F_B$) is used every year then the solution of the equation (2) is given by

$$\begin{aligned} P_{(i,B)} &= (1-\gamma_B)^i (1-\gamma_W)^i P_0 + (1-\delta_B) F_B \left[\frac{1-(1-\gamma_B)^i (1-\gamma_W)^i}{1-(1-\gamma_B)(1-\gamma_W)} \right] \\ &\quad + \{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\} \\ &\quad \times \left[\frac{1-(1-\gamma_B)^i (1-\gamma_W)^i}{1-(1-\gamma_B)(1-\gamma_W)} \right] \end{aligned} \tag{6}$$

and the steady state level of phosphorus after blackgram is given by

$$P_{(\infty,B)} = \frac{(1-\delta_B) F_B}{1-(1-\gamma_B)(1-\gamma_W)}$$

$$+\frac{\{(1-\gamma_B)(E_W-C_W)+E_B-C_B-F_r\}}{1-(1-\gamma_B)(1-\gamma_W)} \tag{7}$$

Similarly the solution of equation (3) is given by

$$P_{(i,W)}=(1-\gamma_W)^i(1-\gamma_B)^i P_0+(1-\gamma_W)(1-\delta_B)F_B\left[\frac{1-(1-\gamma_w)^i(1-\gamma_B)^i}{1-(1-\gamma_w)(1-\gamma_B)}\right]$$

$$+\{(1-\gamma_W)(E_B-C_B-F_r)-C_W+E_W\}$$

$$\times\left[\frac{1-(1-\gamma_w)^i(1-\gamma_B)^i}{1-(1-\gamma_w)(1-\gamma_B)}\right] \tag{8}$$

and the steady state level of phosphorus after wheat is given by

$$P_{(\infty,W)}=\left[\frac{(1-\gamma_W)(1-\delta_B)F_B}{1-(1-\gamma_w)(1-\gamma_B)}\right]$$

$$+\left[\frac{(1-\gamma_W)(E_B-C_B-F_r)-C_W+E_W}{1-(1-\gamma_w)(1-\gamma_B)}\right] \tag{9}$$

To verify the validity of the model equation we use reliability indices k_g and k_s depends upon geometric and statistical techniques. They are given by

$$k_g=\frac{1+\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1-y_i/x_i}{1+y_i/x_i}\right]^2}}{1-\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1-y_i/x_i}{1+y_i/x_i}\right]^2}} \tag{10}$$

and $k_s=\exp\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\log\frac{y_i}{x_i}\right)^2}$ (11)

where x_i and y_i are predicted and observed values respectively. Predicted value is perfect if $k_g = k_s = 1$.

This model was applied to an available data of an experiment conducted on a continuous cropping blackgram and wheat. The experiment consist of following treatments

i. Control or (P-0)

ii. 50% P (20 kg P_2O_5 ha^{-1}) or (P-20)

iii. 75% P (30 kg P_2O_5 ha^{-1}) or (P-30)

iv. 100% P (40 kg P_2O_5 ha^{-1}) or (P-40)

v. FYM

γ and δ were calculated by

$$\gamma = \frac{\sum U_t^0 P_{t-1}^0}{\sum (P_{t-1}^0)^2} \qquad \text{and} \qquad \delta = \frac{U_t - U_t^0}{F} \text{ respectively}$$

where U_t^0 is uptake and P_{t-1}^0 is soil available phosphorus from control plots and U_t is uptake form a plot of some treatment.

The estimation of various parameters γ, δ, C and E for each crop and for each treatment were measured. Soil phosphorus efficiency (γ) is very high (0.921) for wheat than blackgram. Fertilizer phosphorus efficiency (δ) are approximately same for 20 and 30 kg P ha^{-1}, while for 40 kg P ha^{-1} is approx 18% higher. Uptake from unaccounted sources is very less (0.2243) for blackgram than wheat which is very high (4.034). Maximum depletion were observed about 100% P treatment for blackgram crop than 50% P and 75% P treatment if built up in soil for blackgram assumed constant as in control then fertilizer run off (F_r) calculated maximum 87% for 100% P treatment and approx 86% for 50% P and 75% P treatment. Maximum built up as the residual effect of 100% P treatment applied for blackgram seen for wheat crop. While built up about 50% P and 75% P treatment are moderate as a residual effect over wheat crop. Accumulation of phosphorus in soil is maximum about both crop about 100% P. The reliability indices show observed and predicted data from model are approximately same and for the treatment 100% P are closely agreed.

To show the influence of applied phosphorus on status of soil nutrient (macro and micro) other than phosphorus in a cropping system with two crops per year, we use following equations

$$M_{(i,1)} = M_{(i-1,2)} - U_{(i,1)} + E_1 \tag{12}$$

and $$M_{(i,2)} = M_{(i,1)} - U_{(i,2)} + E_2 \tag{13}$$

where $M_{(i,1)}$ and $M_{(i,2)}$ are the level of a nutrient in soil after first and second crop in ith year respectively. Here we assume that a fixed amount $U_{(i,1)}$ and $U_{(i,2)}$ are uptake of nutrient by first and second crop respectively in ith year.

Nutrient uptake by crop $U_{(i,1)}$ and $U_{(i,2)}$ are given by

$$U_{(i,1)} = \gamma_1 M_{(i-1,2)} + c_1 \tag{14}$$

and $$U_{(i,2)} = \gamma_2 M_{(i,1)} + c_2 \tag{15}$$

where γ is expected soil nutrient efficiency and c shows the uptake of nutrient from unaccounted sources by crops.

Solution of equation (12) is given by

$$M_{(i,1)} = (1-\gamma_1)^i (1-\gamma_2)^i M_{(0,1)}$$

$$+ \left[\frac{1-(1-\gamma_1)^i (1-\gamma_2)^i}{1-(1-\gamma_1)(1-\gamma_2)} \right] \{(1-\gamma_1)(E_2 - c_2) + (E_1 - c_1)\} \tag{16}$$

and steady state level nutrient for first crop is given by

$$M_1 = \left[\frac{(1-\gamma_1)(E_2 - c_2) + (E_1 - c_1)}{1-(1-\gamma_1)(1-\gamma_2)} \right] \tag{17}$$

Similarly the solution for second crop is

$$M_{(i,2)} = (1-\gamma_1)^i (1-\gamma_2)^i M_{(0,2)}$$

$$+\left[\frac{1-(1-\gamma_1)^i(1-\gamma_2)^i}{1-(1-\gamma_1)(1-\gamma_2)}\right]\{(1-\gamma_2)(E_1-c_1)+(E_2-c_2)\} \qquad (18)$$

and steady state level nutrient for second crop is given by

$$M_2 = \left[\frac{(1-\gamma_2)(E_1-c_1)+(E_2-c_2)}{1-(1-\gamma_1)(1-\gamma_2)}\right] \qquad (19)$$

using equation (10) and (11) we check the validity of model. The model was applied on above mentioned available data under same treatment. The influence of phosphorus was measured over macronutrients (Nitrogen and Potassium) and micronutrients (Zink, Copper, Manganese and Ferus).

Estimation of γ, E and c for Nitrogen under different treatments and different crop were calculated. Soil N efficiency about P-40 and FYM are significantly high in comparison to control for blackgram. For wheat soil N efficiency is 17% higher P-40 whereas for P-30 and FYM it is approx 10% higher over control. The amount of nitrogen mobilized from unaccounted sources (c) is almost same for all treatment and for blackgram it varies from 1.94 to 1.57 kg/ha and for wheat it varies from 10.86 to 11.09 kg/ha.For blackgram nitrogen build up for P-40 and FYM are almost 90% in comparison to control and for wheat almost same for all treatments. For blackgram it is 16% higher about P-40 and FYM in comparison to control and for wheat it is same for all treatments.

Estimation of γ, E and c for macronutrient potassium under different treatments and different crop were calculated. Soil K efficiency about P-40 and FYM are approximately 20% high in comparison to control for blackgram. For wheat soil K efficiency is 25% higher than control about P-40, for P-30 and FYM it is almost same. The amount of potassium mobilized from unaccounted pool (c) is almost same for all treatment and for blackgram and for wheat it varies from 0.58 to 0.79 kg/ha.For blackgram, potassium build up for P-40 and FYM are almost 150% higher in comparison to control and for wheat no significant difference in E were measured for all treatments. For blackgram it is 18% higher about P-40 and FYM in comparison to control and for wheat it is almost 15% higher about P-40 and FYM in comparison to control.

E_1 for Cu shows build up is almost same for different P-fertilization which is approx 3 gm/ha while about FYM it was measured 25% higher in comparison of control P, for wheat Cu buildup ranges from 96.28 to 135.43. It was found that build up increased slightly as the dose of P fertilizers increased. For FYM the buildup of Zn is soil were measured 14% extra and Mn were 35% extra than control P whereas a slight reduction of Fe about different P fertilizer practices in comparison of P control. A significant increment in build up all micronutrients about P fertilizer. Build up in Zn for blackgram was in the range of 196.14 – 213.5 gm/ha whereas for wheat it ranges from 152.06 to 209.07 gm/ha. Build up in Mn for blackgram is lie in the range of 280.7 to 325.7 gm/ha whereas for wheat it is 57.38-75.24 gm/ha. Build up in Fe measured declined for blackgram but maintained through the application of fertilizers whereas buildup for wheat in the range of 1004.99-1221.38 gm/ha.

For blackgram, significant increment in soil micronutrient efficiency for Zn and Fe as were observed as the amount of added P fertilizer were increased in soil, but soil micronutrient efficiency for Mn and Cu remain same for different application of P fertilizer whereas for wheat, soil micronutrient efficiency for Mn remains same while soil micronutrient efficiency Zn, Cu and Fe were measured increasing about different P fertilization.

For wheat, uptake amount of micronutrients due to unaccounted sources i.e *c* were measured less about different P fertilizer application in comparison of control P application whereas it was observed higher about FYM application. For blackgram, it was measured higher about different P fertilization practices in comparison of control P application. Predicted soil steady state level of Zn, Cu, Mn and Fe for different crops and different fertilization practices were calculated. Reliability indices k_g and k_s show that observed and predicted data agree closely.

Assessment of soil physico-chemical properties at different blocks of Bhilwara, Rajasthan.

Soil pH: Maximum neutral data 38.18% were found in Sahara block here 56.36% data found slightly. Maximum strongly alkaline soil data were found in Jahazpur block it was 96% followed by 91.89% in Shahpura block. In Jahazpur and Shahpura approx 4% soil data were of strongly alkaline in reaction. In Mandal, approx 7.27% data were of neutral and 60% soil data were found slightly alkaline in reaction whereas approx 5% data were of strongly alkaline in reaction. In Kotri and Beejoliya 22.2% and 20% data were of neutral and soil data of slightly alkaline were 76.19% and 78.18% respectively.

Soil Electrical Conductivity: Jahazpur, Mandalgarh and Beejoliya can be considered safe blocks as EC was found less than 1in these blocks. In Jahazpur EC varied 0.1 to 0.7, in Mandalgarh it varied from 0.18 to 0.96 and in Beejoliya it varied 0.2 to0.48. But in Raipur maximum approx12% soil data were found which are in critical range or not safe as EC point of view. In Suwana and Shahpura approx 95% soil data were found in safe range and approx 15% was in normal range whereas in Mandal block 90.9% soil data were found to be safe and approx 9.1% were in normal range.

Soil Organic Carbon: As per organic carbon status considered, soil condition was tremendous. More than 50% soil data of six blocks were found in low OC percent region. In Suwana almost 87.64% soil data were in low OC present soil followed by Raipur block with 82% data were in low OC percent soil. In Shahpura, Jahazpur, Kotri and Asind approx 75.6%, 72%, 68.25% and 59% data were in low OC percent soil respectively. In Beejoliya, Mandalgarh and Mandal 52.73%, 49.1% and 45.45% data were in medium OC percent region. In Sahara and Beejoliya, Maximum 35% of data were found in safe OC percent region.

Available Phosphorus: Majority of the soil data of different blocks of Bhilwara were medium to high. Maximum 56.18% soil data of Suwana block were found in safe range whereas in same block 42.7% soil data were found in high Phosphorus range and 1.12% soil data were in low phosphorus range. In Kotri, Raipur, Jahazpur and Mandal 47.62%, 32%, 32% and 25.5% soil data of respective blocks found in medium phosphorus range.

Correlation between Various Parameters

A significant positive correlation between pH and EC were measured at Asind and Raipur while at Mandal and Sahara it was of low degree positive correlation. Between pH and OC, soil data of Sahara and Asind showed significant positive correlation whereas Suwana and Shahpura showed low degree negative correlation. Soil data of Asind block showed significant positive correlation between pH and P also Jahazpur, Mandal and Mandalghadh showed positive correlation, whereas negative shown by other blocks. Soil data of Mandal and Raipur showed significant negative correlation between EC and OC whereas other blocks showed positive correlation coefficient. A positive correlation between pH and EC was found when cumulative data of all blocks were studied. In cumulative study of data a positive correlation was found between pH and OC also between pH and P whereas negative correlation excited between EC and OC. A low degree positive correlation existed between EC and P.

Groundwater assessment in different blocks of Bhilwara, Rajasthan

It was observed that approx 43% sources of groundwater in Banera and approx 42% were found contaminated with nitrogen and average NO_3 in groundwater was found between 103.6 to 128.67. As per the level of chloride is concerned it was found approx 36% to 57% sources was in desirable range only7-8% was in unsafe range. Level of Ca and Mg in water was found in desirable range in most of groundwater sources. TDS of ground water is very high, only 2-3% sources of groundwater lies in desirable range whereas approx 77% are in permissible level and 20% water sources are highly contaminated and shows high TDS. Level of SO_4 in 86% groundwater sources of Raipur is desirable only 2% is unsafe whereas in Banera 5% sources are not safe as per SO_4 level is concerned. pH of ground water in almost all sources is in permissible level.

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Chapter 10

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A mathematical model to predict soil phosphorus status under varying fertilizer practices and its residual effects on soil phosphorus status for another continuous crop

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ABSTRACT

A mathematical model has been proposed to predict the changes in phosphorus level in soil under varying fertilizer practices and its residual effect on soil phosphorus status for another continuous crop. The model also enabled the prediction of the steady state of soil nutrients for specified fertilizer practice.

The model was applied to two years phosphorus availability data of four fertilizer practices in blackgram crop whose residual effect were studied over wheat crop followed in the field experiment entitled "Integrated nutrient management in blackgram " and their residual effect on succeeding wheat was conducted Rajasthan College of Agriculture, Udaipur, Rajasthan, India. The agreement between the predicted soil phosphorus status by the model and the actual was proved by employing reliability index.

Keywords: Mathematical Model, Nutrient Management , Residual Effect, Phosphorus Status.

I. INTRODUCTION

Excessive use of chemical fertilizers is harmful for the biological power of soil, which must be prevented as all nutrient transformations are performed by soil microflora. Organic matter is a big energy source for the soil microflora and organic carbon content is considered to be the soil health index. Nutrient management is a better approach to minimize the use of chemical sources of nutrient along with maximization of their efficiency and economic profit of farmer. Finck[1] discussed that the nutrient supply, the flows and the nutrient added must be managed properly to achieve good amount of yield while minimizing environmental pollution.

Phosphorus (P) is one of the most essential element of modern agro-system. Fertilization of crops comprises the largest proportion of P used in agriculture. Phosphorous use has become increasingly prevalent in last few decades due to its depletion in soils used for crop. Although the benefits of P on agricultural production are evident, but Schröder[2] examined that it can also be a harmful polluting agent of surface waters and can promote eutropication.

So the level of soil P must be managed at that concentration which allows to good crop production, prevents the escape of P to surface water bodies and adequate animal waste disposal. This paper provides the description of a mathematical model for such a prediction of soil p level for a rotational crop system. Sen[3] and Ahmed[4] examined that in rotation, legumes increases the availability of several nutrients for succeeding crops. Legume cultivation leads to increase soil available P probably ascribed to development of P-solubilizing organisms in root zone of legumes. Usherwood[5] found with nitrogen P significantly contributes to optimum crop yield and nitrogen use efficiency. A preliminary verification of data of fertilizer experiment is also presented here.

II. THE MODEL

For predicting the steady state of phosphorus levels in plots which have received the same fertilizer treatments over the years, the following balance equations are taken as basic equation to show the status behavior of phosphorus in soil after fertilization and its residual effect on soil phosphorus status respectively,

$$P_{(i,B)} = P_{(i-1,W)} + F_{i,B} - U_{iB} - F_r + E_B \tag{1}$$

$$P_{(i,W)} = P_{(i,B)} - U_{iW} + E_W \tag{2}$$

Where $P_{(i,B)}$ shows the phosphorus level in soil after the blackgram crop in ith year, $F_{i,B}$ shows the amount of fertilizer applied to ith crop of blackgram only, U_{iB} shows the amount of phosphorus uptake by ith crop of blackgram, $P_{(i,W)}$ shows the phosphorus level in soil after the wheat crop in ith year U_{iW} shows the amount of phosphorus uptake by ith crop of wheat, F_r runoff amount of fertilizer applied, E_B and E_W are the built-up level of phosphorus due to the factor other than considered in basic equations.

We assume that uptake of phosphorus U_{iB} by blackgram crop depends on the phosphorus available in soil after the previous wheat crop $P_{(i-1,W)}$ and the applied fertilizer $F_{i,B}$,

$$U_{iB} = f(P_{(i-1,W)}, F_{i,B})$$

Or it can be written as,

$$U_{iB} = \gamma_B P_{(i-1,W)} + \delta_B F_{iB} + C_B \tag{3}$$

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Where constant γ_B shows the expected soil phosphorus nutrient efficiency $(0 \le \gamma_B \le 1)$ for blackgram crop, δ_B shows expected fertilizer nutrient efficiency $(0 \le \delta_B \le 1)$ for blackgram crop and C_B shows the uptake of phosphorus from unaccounted sources by blackgram crop $(C_{\mathbf{B}} \ge 0)$.

Similarly the uptake of phosphorus U_{iW} by wheat crop depends on the phosphorus available in soil after the previous blackgram crop $P_{(i-1,B)}$ only as fertilization practice is not applied on wheat crop,

$$U_{iW} = g(P_{(i,B)})$$

Or it can be written as,

$$U_{iW} = \gamma_W P_{(i,B)} + C_W \quad (4)$$

Where constant γ_W shows the expected soil phosphorus nutrient efficiency $(0 \le \gamma_W \le 1)$ for wheat crop, and C_W shows the uptake of phosphorus from unaccounted sources by wheat crop $(C_W \ge 0)$.

III. SOLUTION OF MODEL

Using (3) in (1), we get

$$P_{(i,B)} = P_{(i-1,W)} + F_{i,B} - (\gamma_B P_{(i-1,W)} + \delta_B F_{i,B} + C_B) - F_r + E_B$$

Or $$P_{(i,B)} = (1-\gamma_B)P_{(i-1,W)} + (1-\delta_B)F_{i,B} - F_r + E_B - C_B \quad (5)$$

Using (4) in (2), we get

$$P_{(i,W)} = P_{(i,B)} - (\gamma_W P_{(i,B)} + C_W) + E_W$$

Or $$P_{(i,W)} = (1-\gamma_W)P_{(i,B)} - C_W + E_W \quad (6)$$

Using (6) in (5), we get

$$P_{(i,B)} = (1-\gamma_B)(1-\gamma_W)P_{(i-1,B)} + (1-\delta_B)F_{i,B} + \{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\} \quad (7)$$

Using iteration in (7), we have

$$P_{(i,B)} = (1-\gamma_B)^2(1-\gamma_W)^2 P_{(i-2,B)} + (1-\delta_B)[(1-\gamma_B)(1-\gamma_W)F_{i-1,B} + F_{i,B}]$$

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$$+\{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\}[(1-\gamma_B)(1-\gamma_W)+1] \tag{8}$$

Iterating the right hand side of the above equation, we get

$$P_{(i,B)} = (1-\gamma_B)^n (1-\gamma_W)^n P_{(i-n,B)} + (1-\delta_B)\sum_{j=0}^{n-1}(1-\gamma_B)^j (1-\gamma_W)^j F_{i-j,B}$$

$$+\{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\}\left[\frac{1-(1-\gamma_B)^n(1-\gamma_W)^n}{1-(1-\gamma_B)(1-\gamma_W)}\right] \tag{9}$$

This equation shows relationship of $P_{(i,B)}$ with the available soil phosphorus status at the end of (i-n) th crop and the amount of fertilizer nutrient applied from n to i th crop.

Equation (9) can be reduced to the equation to predict $P_{(i,B)}$ from initial value like P_0 by taking n=i

$$P_{(i,B)} = (1-\gamma_B)^i (1-\gamma_W)^i P_0 + (1-\delta_B)\sum_{j=0}^{i-1}(1-\gamma_B)^j (1-\gamma_W)^j F_{i-j,B}$$

$$+\{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\}\left[\frac{1-(1-\gamma_B)^i(1-\gamma_W)^i}{1-(1-\gamma_B)(1-\gamma_W)}\right] \tag{10}$$

If a constant amount of fertilizer($F_{i,B} = F_B$) is used every year then the above equation can be reduced in,

$$P_{(i,B)} = (1-\gamma_B)^i (1-\gamma_W)^i P_0 + (1-\delta_B)F_B\left[\frac{1-(1-\gamma_B)^i(1-\gamma_W)^i}{1-(1-\gamma_B)(1-\gamma_W)}\right]$$

$$+\{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\}\left[\frac{1-(1-\gamma_B)^i(1-\gamma_W)^i}{1-(1-\gamma_B)(1-\gamma_W)}\right] \tag{11}$$

The phosphorus status in the soil in the long run can also be predicted by taking limit as $i \to \infty$ in above equation. If $P_{(\infty,B)}$ denotes the steady state of phosphorus status due to constant fertilization, then above equation becomes,

$$P_{(\infty,B)} = \frac{(1-\delta_B)F_B}{1-(1-\gamma_B)(1-\gamma_W)} + \frac{\{(1-\gamma_B)(E_W - C_W) + E_B - C_B - F_r\}}{1-(1-\gamma_B)(1-\gamma_W)} \tag{12}$$

Now solution for residual effects on soil phosphorus status for another continuous crop.

Using equation(5)in (6), we get

$$P_{(i,W)} = (1-\gamma_W)(1-\gamma_B)P_{(i-1,W)} + (1-\gamma_W)(1-\delta_B)F_{i,B} + (1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W \quad (13)$$

Using iteration in (13), we haves

$$P_{(i,W)} = (1-\gamma_W)^2(1-\gamma_B)^2 P_{(i-2,W)} + (1-\gamma_W)(1-\delta_B)[(1-\gamma_W)(1-\gamma_B)F_{i-1,B} + F_{i,B}]$$

$$+\{(1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W\}\{1+(1-\gamma_w)(1-\gamma_B)\}$$

Iterating the right hand side of the above equation, we get

$$P_{(i,W)} = (1-\gamma_W)^n(1-\gamma_B)^n P_{(i-n,W)} + (1-\gamma_W)(1-\delta_B)\sum_{j=0}^{n-1}(1-\gamma_W)^j(1-\gamma_B)^j F_{i-j,B}$$

$$+\{(1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W\}\left[\frac{1-(1-\gamma_w)^n(1-\gamma_B)^n}{1-(1-\gamma_w)(1-\gamma_B)}\right] \quad (14)$$

by taking n=i this Equation reduced to the equation to predict $P_{(i,B)}$ from initial value like P_0

$$P_{(i,W)} = (1-\gamma_W)^i(1-\gamma_B)^i P_0 + (1-\gamma_W)(1-\delta_B)\sum_{j=0}^{i-1}(1-\gamma_W)^j(1-\gamma_B)^j F_{i-j,B}$$

$$+\{(1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W\}\left[\frac{1-(1-\gamma_w)^i(1-\gamma_B)^i}{1-(1-\gamma_w)(1-\gamma_B)}\right] \quad (15)$$

When constant amount of fertilizer($F_{i,B} = F_B$) is used every year then the above equation can be reduced in,

$$P_{(i,W)} = (1-\gamma_W)^i(1-\gamma_B)^i P_0 + (1-\gamma_W)(1-\delta_B)F_B\left[\frac{1-(1-\gamma_w)^i(1-\gamma_B)^i}{1-(1-\gamma_w)(1-\gamma_B)}\right]$$

$$+\{(1-\gamma_W)(E_B - C_B - F_r) - C_W + E_W\}\left[\frac{1-(1-\gamma_w)^i(1-\gamma_B)^i}{1-(1-\gamma_w)(1-\gamma_B)}\right] \quad (16)$$

As $i \to \infty$, $P_{(\infty,W)}$ denotes the steady state of phosphorus status due to residual effect of constant fertilization, then above equation becomes

$$P_{(\infty,W)}=\left[\frac{(1-\gamma_W)(1-\delta_B)F_B}{1-(1-\gamma_w)(1-\gamma_B)}\right]+\left[\frac{(1-\gamma_W)(E_B-C_B-F_r)-C_W+E_W}{1-(1-\gamma_w)(1-\gamma_B)}\right] \tag{17}$$

IV. VALIDITATION OF MODEL

Soil phosphorus levels (observed and predicted from the model) can be tested by computing a reliability index as suggested by Leggett[6]. This index denoted by k interpret that the model predictions agree with observations within a factor of k. The index is defined using geometric approach and is justified through agreement with another index developed using statistical techniques. These indices denoted, respectively, by k_g and k_s are given by,

$$k_g=\frac{1+\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1-y_i/x_i}{1+y_i/x_i}\right]^2}}{1-\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1-y_i/x_i}{1+y_i/x_i}\right]^2}}$$

and $$k_s=\exp\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\log\frac{y_i}{x_i}\right)^2}$$

where X_i and Y_i are the predicted values using model and corresponding observed values respectively. For a perfectly predicting model, $k_g = k_s = 1$.

V. THE SOURCE OF DATA

The above prescribed model was applied on investigation entitled "Integrated nutrient management in blackgram (Phaseolus mungo L.)" was conducted during 2003-04 and 2004-05 by Rathore[7] at RCA, Udaipur. The region lies under typical sub-humid climatic conditions average annual rainfall 637 mm, soil of the experimental field was clay loam in texture. Initially, to ascertain various characteristics of the experimental field, soil samples were taken upto 15 cm depth contained 268.40 kg N ha-1 using Alkaline permanganate method by Subbiah[8], 19.50 kg P ha-1 using Olsen's method by Olsen[9], 370.80 kg K_2O ha^{-1} using Extraction with 1 N neutral ammonium acetate at pH 7.0 and estimated by Flame photometer method by Richards[10]. This experiment was consisted of thirty two treatment combinations, out of these we are using here only four which are

i. No phosphorus
ii. 50% P (20 kg P_2O_5 ha^{-1})

iii. 75% P (30 kg P_2O_5 ha^{-1})

iv. 100% P (40 kg P_2O_5 ha^{-1})

Phosphorus entirely was drilled through Di-Ammonium-Phosphate (DAP) before sowing of the crop also uniform application of nitrogen @ 15 kg N ha^{-1} was done as basal through DAP + urea.

After harvest of blackgram, every experimental plot was prepared without disturbing original plan of layout and only N was given using urea @ 90 kg N ha^{-1} in two equal splits at sowing and at first irrigation. After harvesting soil sample taken from each plot upto 15 cm depth and analyzed also plant analysis for nitrogen using Nessler's reagent, spectrophotometrically method by Snell[11] and phosphorus using Vanadomolybdate phosphoric acid yellow colour method by Jackson[12] were done.

The average soil nutrient efficiency parameter was estimated using the uptake and soil available phosphorus values of control plots. If these are respectively U_t^0 and P_{t-1}^0, then

$$\gamma = \frac{\sum U_t^0 P_{t-1}^0}{\sum (P_{t-1}^0)^2}$$

The average fertilizer nutrient efficiency parameter of applied phosphorus was calculated by using difference of uptake in treatment and control and unit of applied P fertilizer. If uptake from control plot is U_t^0 and form a plot of some treatment is U_t and applied amount of fertilizer is F unit, then

$$\delta = \frac{U_t - U_t^0}{F}$$

VI. RESULT AND DISCUSSION

The estimation of various parameter Υ, δ, C and E for each crop and for each treatment is presented in table 1. Soil phosphorus efficiency (Υ) is very high (0.9215304) for wheat than blackgram. Fertilizer phosphorus efficiency (δ) are approximately same for 20 and 30 kg P ha^{-1}, while for 40 kg P ha^{-1} is approx 18% higher. Uptake from unaccounted sources is very less (0.2243)for blackgram than wheat which is very high(4.0349). Table 1 shows that maximum depletion took place about 100% P treatment for blackgram crop than 50% P and 75% P treatment if built up in soil for blackgram assumed constant as in control then fertilizer run off (F_r) calculated maximum 87% for 100% P treatment and approx 86% for 50% P and 75% P treatment. Maximum built up; as the residual effect of 100% P treatment applied for blackgram seen for wheat crop. While built up about 50% P and 75% P treatment are moderate as a residual effect over wheat crop.

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Table 1. Estimates of Υ, δ, C and E-F_r for phosphorus for the crops in the sequence

Parameter	Crop	
	Blackgram	Wheat
Υ	278322	0.9215304
δ		
50% P (20 kg P_2O_5 ha^{-1})	0.052	
75% P (30 kg P_2O_5 ha^{-1})	0.055167	
100% P (40 kg P_2O_5 ha^{-1})	0.06175	
C(kg P ha^{-1})	0.22433	4.0349
E-Fr(kg P ha^{-1})		
Control	7.905	16.2
50% P (20 kg P_2O_5 ha^{-1})	-9.41	17.52
75% P (30 kg P_2O_5 ha^{-1})	-17.93	18.65
100% P (40 kg P_2O_5 ha^{-1})	-27.065	20.58

Predicted soil phosphorus status of long term practices about various treatment is shown in table2. Accumulation of phosphorus in soil is maximum for both crop about 100% P. Comparison between predicted and observed phosphorus soil level is presented in table 3 and 4 for both crops respectively. The reliability indices show observed and predicted data from model are approximately same and for the treatment 100% P are closely agreed.

Table 2. Predicted steady state soil phosphorus levels for the crops in the sequence

Treatment	Crop	
	Blackgram	Wheat
Control	17.4480334	13.5342402
50% P (20 kg P_2O_5 ha^{-1})	20.20158118	15.07030999
75% P (30 kg P_2O_5 ha^{-1})	21.9829562	16.34009378
100% P (40 kg P_2O_5 ha^{-1})	23.51240722	18.39010919

Table 3. Observed and predicted soil phosphorus status after the harvest of each crop of Blackgram

Treatment	year 2003-04		year 2004-05	
	Predicted	Observed	Predicted	Observed
Control	17.39434647	18.4	16.51286942	20.56
50% P (20 kg P_2O_5 ha^{-1})	19.99196143	21.7	20.18971046	22.35
75% P (30 kg P_2O_5 ha^{-1})	21.67245757	22.83	21.96537273	23.33
100% P (40 kg P_2O_5 ha^{-1})	23.11529611	23.77	23.4899189	23.43

Table 4. Observed and predicted soil phosphorus after the harvest of each crop of Wheat

Treatment	year 2003-04		year 2004-05	
	Predicted	Observed	Predicted	Observed
Control	13.70219054	16.8	13.54375119	18.89
50% P (20 kg P_2O_5 ha^{-1})	15.15127303	18.6	15.07489491	19.18
75% P (30 kg P_2O_5 ha^{-1})	16.34914923	18.98	16.34060659	19.41
100% P (40 kg P_2O_5 ha^{-1})	18.28307271	19.92	18.38404774	19.52

Table 5. Reliability indices for the proposed model

Index	Treatment			
	Control	50% P (20 kg P_2O_5 ha^{-1})	75% P (30 kg P_2O_5 ha^{-1})	100% P (40 kg P_2O_5 ha^{-1})
k_g	1.252297931	1.18635304	1.128133841	1.055642337
k_s	1.252982397	1.18662048	1.128240143	1.055655801

VII. CONCLUSION

Thus the theoretical basis provided by this proposed mathematical model is valid since it enables the prediction of soil phosphorus level within permissible limit of variation. It is also useful in establishing estimates on the steady state of soil phosphorus status for a specific fertilizer treatment apply on one and not other in a continuous cropping system.

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Mathematical Model to Predict the Soil Macronutrients Status under the Influence of Phosphorus and Manure for Continuous Cropping System

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Abstract— In the present work we studied, how phosphorus fertilizer and manure affect the soil status of other macronutrients like nitrogen and potassium using mathematical model. By knowing the status of nutrients availability, a producer can manage things and get high crop yield. The model was applied to five fertilizer practices of a two year field experiment entitled "Integrated nutrient management in blackgram", conducted in Rajasthan College of Agriculture, Udaipur, Rajasthan, India.

Keywords- phosphorus, mathematical model, macronutrients, nitrogen soil status, potassium soil status

I. INTRODUCTION

A proper combination of nutrients is required by plants to grow, live and reproduce. Excess or lacking of any nutrient may cause problems. Soil is the major source to supply most of the essential nutrients, required by plants. Removing of nutrients by one crop and not replaced for next subsequent crop production will result in decreased yield accordingly. The requirements of fertilizers containing NPK (Nitrogen–Phosphorous–Potassium) have been increased in last few decades [1]. The importance of Fertilizers is to determine the nutritional content [2].

Producer or farmer can manage fertilizer application if he knows results of soil analysis i.e. the accurate amount of nutrient removed and replaced for crop production statistics. By using soil analysis producer can determine the level of nutrients available in soil and estimate the amount of nutrients needed to supplement in soil. These nutrients are of specific function and should be supplied to plants in right time and right quantity. Insufficient amounts of nutrients result into poor crop growth and low yield [3]. Excess supply of nutrients never helps in producing higher crop yield, even leads wastages as in addition of leaching, washing and many times raise serious causes for human health. The nitrate available in the plants may cause methemoglobinaemia disease in new born babies and creates problems in the intestine and stomach like abnormal acid secretion [4]. That's why, it is recommended to consume fruits or vegetables containing less nitrate [5].

To take high crop production, the supply of essential macronutrients is required. N is abundantly present in nature, but plants can't take it directly from the air. In addition to providing a place for crops to grow, soil is the only source for most of the essential nutrients required by the crop. When N is deficient in soil, cropping systems require N inputs [6]. Most of the available crop production technologies are based upon increasing the availability of N to crops. The augmentation of soil N is accomplished by various sources for supplying N to crops [7]. Inorganic fertilization is a option to alleviate its deficiency but it is expensive. Manure obtained from livestock could be a cheap source of nutrients, but it is required in bulk amount to satisfy plant nutrient requirements [8]. In West African countries the various type of organic manure like ruminant dung and poultry dropping are very popular for crop production and to improve agricultural practice. It helps to provide a good amount of nutrients needed in the soil and improve the physical condition of soil. Organic fertilizer plays an important role as a major contributor to supply plant macronutrients. It works as a storehouse for cation and improves their exchange capacity also reduces undesirable pH fluctuation [9].

In last few decades several studies have taken place to measure effect of various type of inorganic and organic fertilizer over soil and plant. Integrated Nutrient Management (INM) refers as the process to maintain the soil fertility and nutrient supply to plant for achieving an optimum level of productivity by optimizing the benefits from all possible sources of biological, inorganic and organic components in an integrated manner.

In a study of combined effect of phosphorus and nitrogen on soyabean plant, it was found that growth, yield potential of soybean and an increase N_2 fixation can be achieved by using inoculation of *B. japonicum* and P with small dose of N fertilizer application. The highest improvement of 34.77% was obtained when 11.5 kg ha^{-1} N and 46 kg ha^{-1} P_2O_5 were combined with *B japonicum* [10]. At El-Khattara, in a field experiment on sandy soil it was found that combined application of different levels of N and P fertilizer with or without compost; influenced various attributes like growth and yield of okra plants significantly [11].
Combined or individual fertilization of N and P improve plant growth in saline soil. It was found that shoot dry weight of wheat crop in sandy soil was significantly affected by N and P individually and in combinations with and without salinity [12]. At south-western Ethiopia, in a field experiment there was a measure significant increase in the grain yield of food barley and observed significant improvement in most of the physico-chemical properties of soil under the application of FYM combined with different levels of inorganic N and P over the application of 100% mineral NP alone and the control [13]. A treatment of 5 t FYM ha^{-1} in combination with 75% recommended rates of inorganic N and P increased soil organic carbon content and available P.
In a long-term experiment it was found that combination of FYM and inorganic NP enhanced grain yield of maize, improve soil chemical properties and water use efficiency significantly as compared to the use of inorganic N and P fertilizers only [14]. In Udaipur of Rajasthan, results of a field experiment in clay loam soil has shown higher seed/grain and stover/straw yields of blackgram and wheat under the integrated use of 5 t FYM, 40 kg P_2O_5 and dual inoculation of PSB (*Bacillus megathereum* var.phosphaticum) and VAM (*Glomous faciculatum*) [15]. It shows that, INM involving both inorganic and organic fertilizer combinedly is the more effective and feasible approach to maintain a productive and healthy soil [16, 17].
In present work a mathematical model is developed and applied to available experimental data. Section 1 includes introduction, in section 2 we present mathematical model and steady state solution, section 3 contains validation of model, in next section 4 we present application of model and section 5 is devoted to result and discussion while in section 6 we present conclusion and future scope of work.

II. MODEL

In our previous work [7], we used a mathematical model to predict phosphorus status in soil on some available data to study the effect of P fertilizer and its residual effect on soil. In this paper we extend that study to find the status of other macronutrients in presence of P fertilizer for continuous cropping system under the assumption that no other macronutrients fertilizers were added to soil. So we modify the basic equation of previous model, as

$$M_{(i,1)} = M_{(i-1,2)} - U_{(i,1)} + E_1 \tag{1}$$

$$M_{(i,2)} = M_{(i,1)} - U_{(i,2)} + E_2 \tag{2}$$

if we take two crops in a year.
where $M_{(i,1)}$ and $M_{(i,2)}$ are the level of a macronutrient in soil after first and second crop in i^{th} year respectively. Here we assume that a fixed amount $U_{(i,1)}$ and $U_{(i,2)}$ are uptake of macronutrient by first and second crop respectively in i^{th} year. E_1 and E_2 are the built-up level of macronutrient due to the factor other than considered in basic equations for first and second crop respectively.
We assume that uptake of macronutrient $U_{(i,1)}$ by first crop depends on the macronutrient available in soil after the previous second crop $M_{(i-1,2)}$ i.e.

$$U_{(i,1)} = f(M_{(i-1,2)})$$

or
$$U_{(i,1)} = \gamma_1 M_{(i-1,2)} + c_1 \tag{3}$$

where γ_1 shows the expected soil macronutrient efficiency $(0 \le \gamma_1 \le 1)$ for first crop and c_1 shows the uptake of macronutrient from unaccounted sources by first crop $(c_1 \ge 0)$.

Also uptake of macronutrient $U_{(i,2)}$ by second crop depends on the macronutrient available in soil after the previous first crop $M_{(i,1)}$ i.e.

$$U_{(i,2)} = g(M_{(i,1)})$$

or $$U_{(i,2)} = \gamma_2 M_{(i,1)} + c_2 \quad (4)$$

where γ_2 shows the expected soil macronutrient efficiency $(0 \le \gamma_2 \le 1)$ for second crop and c_2 shows the uptake of macronutrient from unaccounted sources by second crop $(c_2 \ge 0)$.

SOLUTION OF MODEL

Putting (3) in (1), we get

$$M_{(i,1)} = (1-\gamma_1)M_{(i-1,2)} + E_1 - c_1 \quad (5)$$

Using (4) in (2), we get

$$M_{(i,2)} = (1-\gamma_2)M_{(i,1)_2} + E_2 - c_2 \quad (6)$$

Using (6) in (5), we have

$$M_{(i,1)} = (1-\gamma_1)(1-\gamma_2)M_{(i-1,1)} + (1-\gamma_1)(E_2 - c_2) + (E_1 - c_1) \quad (7)$$

Using iteration in (7), we get

$$M_{(i,1)} = (1-\gamma_1)^2(1-\gamma_2)^2 M_{(i-2,1)} + [(1-\gamma_1)(1-\gamma_2)+1]\{(1-\gamma_1)(E_2 - c_2) + (E_1 - c_1)\}$$

Again iterating, we get

$$M_{(i,1)} = (1-\gamma_1)^n(1-\gamma_2)^n M_{(i-n,1)} + \left[\sum_{j=0}^{n-1}(1-\gamma_1)^j(1-\gamma_2)^j\right]\{(1-\gamma_1)(E_2 - c_2) + (E_1 - c_1)\} \quad (8)$$

This equation shows the relationship of macronutrient in soil of $M_{(i,1)}$ and available soil macronutrient status at the end of (i-n)th crop

or $$M_{(i,1)} = (1-\gamma_1)^n(1-\gamma_2)^n M_{(i-n,1)} + \left[\frac{1-(1-\gamma_1)^n(1-\gamma_2)^n}{1-(1-\gamma_1)(1-\gamma_2)}\right]\{(1-\gamma_1)(E_2 - c_2) + (E_1 - c_1)\}$$

for n=i,

$$M_{(i,1)} = (1-\gamma_1)^i(1-\gamma_2)^i M_{(0,1)} + \left[\frac{1-(1-\gamma_1)^i(1-\gamma_2)^i}{1-(1-\gamma_1)(1-\gamma_2)}\right]\{(1-\gamma_1)(E_2 - c_2) + (E_1 - c_1)\} \quad (9)$$

In long run, the status of macronutrient in soil can be measured by taking limit i→∞, we get

$$M_1 = \left[\frac{(1-\gamma_1)(E_2 - c_2) + (E_1 - c_1)}{1-(1-\gamma_1)(1-\gamma_2)}\right] \quad (10)$$

where M_1 denotes the steady state of macronutrient in soil after first crop due to constant fertilization.

Similarly by using equation (5) in (6), we find

$$M_{(i,2)} = (1-\gamma_1)^i(1-\gamma_2)^i M_{(0,2)} + \left[\frac{1-(1-\gamma_1)^i(1-\gamma_2)^i}{1-(1-\gamma_1)(1-\gamma_2)}\right]\{(1-\gamma_2)(E_1 - c_1) + (E_2 - c_2)\} \quad (11)$$

In long run, the status of macro nutrient in soil can be measured by taking limit i→∞, we get

$$M_2 = \left[\frac{(1-\gamma_2)(E_1 - c_1) + (E_2 - c_2)}{1-(1-\gamma_1)(1-\gamma_2)}\right] \quad (12)$$

where M_2 represents the steady state of macronutrient in soil after second crop due to constant fertilization.

III. VALIDITATION OF DATA

Soil macronutrient status (observed and predicted from the model) can be tested by computing a reliability index as suggested by Leggett [19]. This index interprets that our model predictions agrees with observations within a factor of *k*. The index k_g is defined by using geometric approach and is justified with another index k_s developed by using statistical techniques. These indices k_g and k_s are given by,

$$k_g = \frac{1+\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1-y_i/x_i}{1+y_i/x_i}\right]^2}}{1-\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1-y_i/x_i}{1+y_i/x_i}\right]^2}}$$

and $$k_s = \exp\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\log\frac{y_i}{x_i}\right)^2}$$

where x_i is the predicted value using model while y_i is corresponding observed values respectively. If $k_g = k_s = 1$, then model is perfect.

IV. APPLICATION OF THE MODEL TO FIELD DATA

The above prescribed model was applied on investigation entitled "Integrated Nutrient Management in blackgram (Phaseolus mungo L.)" was conducted during 2003-04 and 2004-05 at RCA, Udaipur [15]. The region lies under typical sub-humid climatic conditions average annual rainfall 637 mm, soil of the experimental field was clay loam in texture. Initially, to ascertain various characteristics of the experimental field, soil samples were taken upto 15 cm depth contained 268.40 kg N ha^{-1}, 19.50 kg P ha^{-1} and 370.80 kg K_2O ha^{-1}. This experiment was consisted of thirty two treatment combinations, out of these we are using here only five which are

i. Control
ii. 50% P (20 kg P_2O_5 ha^{-1}) or (P-20)
iii. 75% P (30 kg P_2O_5 ha^{-1}) or (P-30)
iv. 100% P (40 kg P_2O_5 ha^{-1}) or (P-40)
v. FYM

The expected soil macronutrient efficiency parameter was calculated by $\gamma = \frac{\sum U_i^0 M_{i-1}^0}{\sum (M_{i-1}^0)^2}$

where U_i^0 and M_{i-1}^0 are uptake and soil available macronutrient values of control plots respectively.

V. RESULT AND DISCUSSION

Estimation of γ, E and c for macronutrient nitrogen under different treatments and different crop are presented in table 1. soil N efficiency about P-40 and FYM are significantly high in comparison to control for blackgram. For wheat soil N efficiency is 17% higher than control about P-40, for P-30 and FYM it is almost same. The amount of nitrogen mobilized from unaccounted sources (c) is almost same for all treatment and for blackgram it varies from 1.94 to 1.57 and for wheat it varies from 10.86 to 11.09 kg/ha.

The value of *E* in table shows the there is build up about all treatments. For blackgram nitrogen build up for P-40 and FYM are almost 90% in comparison to control and for wheat almost same for all treatments. The predicted steady state soil N status for different treatments and crops are presented in table 2. For blackgram it is 16% higher about P-40 and FYM in comparison to control and for wheat it is same for all treatments.

Table 1. Estimation of γ , E and c for macronutrient N for different crops in sequence

Treatment	BLACKGRAM			WHEAT		
	γ_1	E_1 (Kg N ha^{-1})	C_1 (Kg N ha^{-1})	γ_2	E_2 (Kg N ha^{-1})	C_2 (Kg N ha^{-1})
Control	0.20	49.64	1.94	0.36	103.05	10.86
P-20	0.22	76.79	1.23	0.38	97.75	13.06
P-30	0.24	85.92	1.92	0.40	104.58	12.87
P-40	0.27	93.64	1.73	0.42	112.03	11.15
FYM 5	0.26	95.36	1.57	0.40	102.28	11.09

Table 2. Predicted steady state of soil N status for different crops in sequence

Treatment	BLACKGRAM (Kg N ha^{-1})	WHEAT (Kg N ha^{-1})
Control	249.05	250.57
P-20	276.20	256.99
P-30	280.42	259.49
P-40	287.80	266.58
FYM 5	290.87	266.50

Comparison of predicted soil N status for different crops and different treatments are presented in table 3 and table4. The reliability indices showing the agreement between observed and predicted soil nitrogen status in table 5. It shows, under all treatment and for both crops the predicted values closely agreed with observed values.

Table 3. Observed and predicted value of soil N status (Kg ha^{-1}) after harvesting of Blackgram year wise

Treatment	2003-04		2004-05	
	Observed	Predicted	Observed	Predicted
Control	258.61	258.94	278.95	254.10
P-20	293.61	272.40	289.92	274.35
P-30	295.95	274.97	293.41	277.95
P-40	296.93	279.59	296.38	284.32
FYM 5	301.18	280.85	298.99	286.40

Table 4. Observed and predicted value of soil N status (Kg ha^{-1}) after harvesting of Wheat year wise

Treatment	2003-04		2004-05	
	Observed	Predicted	Observed	Predicted
Control	276.96	254.68	271.85	252.67
P-20	282.21	274.82	277.14	265.68
P-30	283.05	276.00	278.63	266.97
P-40	284.03	279.42	281.60	272.01
FYM 5	285.15	281.96	281.06	273.39

Table5. Reliability indices for the proposed model for N

INDICES	CROP	Treatment				
		CONTROL	P-20	P-30	P-40	FYM
Kg	BLACKGRAM	1.06817904	1.06804499	1.06667663	1.05305363	1.05973600
	WHEAT	1.08187079	1.03589920	1.03571564	1.02746614	1.02133980
Ks	BLACKGRAM	1.06820459	1.06804723	1.06667874	1.05305515	1.05973950
	WHEAT	1.08187160	1.03589991	1.03571651	1.02746683	1.02134021

Estimation of γ, E and c for macronutrient potassium under different treatments and different crop are presented in table 6. soil K efficiency about P-40 and FYM are approximately 20% high in comparison to control for blackgram. For wheat soil K efficiency is 25% higher than control about P-40, for P-30 and FYM it is almost same. The amount of potassium mobilized from unaccounted pool (c) is almost same for all treatment and for blackgram and for wheat it varies from 0.58 to 0.79 kg/ha.

The value of *E* in table shows the there is build up about all treatments. For blackgram potassium build up for P-40 and FYM are almost 150% in comparison to control and for wheat almost same for all treatments. The predicted steady state soil K status for different treatments and crops are presented in table 2. For blackgram it is 18% higher about P-40 and FYM in comparison to control and for wheat it is almost 15% higher about P-40 and FYM in comparison to control.

Table 6. Estimation of γ, *E* and *c* for macronutrient K for different crops in sequence

Treatment	BLACKGRAM			WHEAT		
	γ_1	E_1 (Kg K ha^{-1})	c_1 (Kg K ha^{-1})	γ_2	E_2 (Kg K ha^{-1})	c_2 (Kg K ha^{-1})
Control	0.06	10.21	0.10	0.25	68.29	0.79
P-20	0.07	18.69	0.09	0.28	74.52	0.60
P-30	0.08	22.28	0.09	0.30	83.62	0.57
P-40	0.08	26.42	0.08	0.32	91.01	0.54
FYM	0.08	27.35	0.09	0.29	80.01	0.58

Table 7. Predicted steady state of soil K status for different crops in sequence

Treatment	BLACKGRAM (Kg K ha^{-1})	WHEAT (Kg K ha^{-1})
ontrol	247.65	253.03
P-20	265.76	265.58
P-30	278.35	277.12
P-40	293.07	289.85
FYM	287.49	282.87

Comparison of predicted soil K status for different crops and different treatments are presented in table 8 and table9. The reliability indices showing the agreement between observed and predicted soil potassium status in table 10. It shows, under all treatment and for both crops the predicted values closely agreed with observed values.

Table 8. Observed and predicted soil K status (Kg ha^{-1}) after harvesting of Blackgram year wise

Treatment	2003-04		2004-05	
	Observed	Predicted	Observed	Predicted
Control	359.06	334.27	327.28	308.57
P-20	364.49	336.26	335.96	313.08
P-30	366.75	337.94	338.52	316.76
P-40	370.48	341.73	343.43	323.54
FYM	370.84	341.72	343.34	322.80

Table 9. Observed and predicted soil K status (Kg ha^{-1}) after harvesting of Wheat yearwise

Treatment	2003-04		2004-05	
	Observed	Predicted	Observed	Predicted
Control	338.76	327.61	310.43	305.48
P-20	341.89	331.97	311.11	310.14
P-30	344.15	334.89	313.67	314.35
P-40	347.73	340.33	318.88	321.45
FYM	346.26	340.14	317.99	320.15

Table10. Reliability indices for the proposed model for Potassium

INDICES	CROP	Treatment				
		CONTROL	P-20	P-30	P-40	FYM
Kg	BLACKGRAM	1.06771240	1.07868969	1.07737906	1.07358807	1.07511922
	WHEAT	1.02660787	1.02116469	1.01954005	1.01637368	1.01358304
Ks	BLACKGRAM	1.06771332	1.07869037	1.07738062	1.07359084	1.07512178
	WHEAT	1.02660848	1.02116544	1.01954065	1.01637389	1.01358315

VI. CONCLUSION AND FUTURE SCOPE

The theoretical approach given by the above suggested mathematical model is valid as it helps in the prediction of soil macronutrient within the permitted limit of difference. The model is also helpful for calculation of steady state of soil macronutrient status for a particular fertilizer treatment in a continuous cropping system. This method can also be helpful in the estimation of soil status of other essential nutrient like sulphar and micronutrients like zink, copper etc.

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Assessment of Soil Physico-Chemical Properties in Different Blocks of Bhilwara District

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Abstract- ***Soil characterization in context of evaluation of fertility status of the soils of a region or area is an important aspect as far the sustainable agricultural production is concerned. Present study was conducted from different blocks in Bhilwara district of Rajasthan for assessment of the some characteristics of agriculture land soils. For assessment of soil physico-chemical properties soil data of different fields of various blocks were collected from soil testing lab, Bhilwara. The pH level of soil were observed from neutral, slightly alkaline to strongly alkaline in most of areas but at few places it was found slight acidic also. The EC was safe range for agriculture land. At most of place soil organic matter content (%) was found in low to medium range. Available phosphorus was medium to high in soils almost at all except few.***

Keywords- ***Soil fertility, organic carbon, macronutrients, micronutrients, salinity.***

I. INTRODUCTION

Soil is a component of the lithosphere and biosphere system. It is a vast natural resource on which the life supporting systems and socio-economic development depends. Organic matter is one of the most important constituents of soil, a good amount of organic carbon / matter in soil increase soil fertility. The core constraints in relation to land use include depletion of organic carbon, soil micronutrients and macronutrients, removal of top soil by erosion, change of physical properties and increased soil salinity. The soil fertility status of Gharsana tehsil anticipate problems in successful maintenance of irrigated agriculture under cultivation due to majority of soils were found strongly alkaline and calcareous in nature and organic carbon is very low (< 0.50%).[1] In a experiment conducted at Chiraigaon block of district Varanasi, physico-chemical properties were analysed and a significant positive correlation were found between organic carbon and available primary macronutrients status of soil [2]. In Prathapgadh district of Rajasthan, work on study of available soil nutrients (micro and macro) status and their behavior with various physio-chemical properties has been done by Singh and Rathore [3]. Similar work was done by Mena, Sharma and Rawat to assess the status of soil macro and micro nutrient status in Tonk district [4].

In the present study we tried to find our various physico-chemical properties of different soil at some blocks of Bhilwara district (Rajasthan). Main objective of this study was to assess the Soil reaction (pH) and soluble salt content (EC) in study area and to study the relationship between OC, pH, EC and available phosphorus content through correlation study.

Section I consist of introduction, in Section II material and methods for collecting data were discussed, Section III devoted to result and discussion and section IV presents conclusion.

II. MATERIALS AND METHODS

Bhilwara is situated at 25.35°N 74.63°E. Its average elevation is of 421 metres or 1381 feet. Bhilwara covers the area 10,455 km². This region comes under sub agro ecological Sub Region (ICAR) Northern Plain (And Central Highlands) Including Aravallis, Hot Semi-Arid Eco-Region Agro-Climatic Zone (Planning Commission) Central Plateau and Hills Region (VIII) Agro Climatic Zone (NARP) Sub Humid Southern Plain Zone (RJ-7). Bhilwara consists of 12 blocks namely Asind, Suwana, Jahazpur, Kotri, Mandal, Mandalgarh, Shahpura, Raipur, Beejoliya, Banera, Sahara and Hurda. Its climate is humid and has average annual temperature approx 22 degree Celsius whereas average rainfall of Bhilwara district is 635.1 mm annually. Soils of Bhilwara district can be classified in four ways- (i) Clay loam (medium black) - Such type of soil is usually found in the hilly areas of central parts of the district, (ii) Loam- This type of soil is found in almost entire district, (iii) Sand and sandy loam- This type of soil can be seen near the banks of rivers in the district and (iv) Loam (pebbly & stony)- This type of soil can be found in eastern hilly area of the district.

Data were collected from soil testing lab, Bhilwara, where soil samples of different villages and almost all blocks/ tehsil of Bhilwara were examined to know the status of soil characteristics like its pH, status of organic carbon, soluble salt content, availability of soil micronutrients and macronutrients etc. The soil samples were mixed thoroughly before analysis after that approx 500 gram material was taken for analysis from sample. Then this 500gm sample was analyzed for different nutrients

using standard procedures. Available phosphorus was extracted by sodium bicarbonate extractable phosphorus [5]. The organic matter content was determined by Walkey and Black method [6].
We were provided data about soil OC, EC, pH and available status of P of different soil of some tehsil of Bhilwara.

III. RESULTS AND DISCUSSION

Soil is said to be of neutral in reaction if its pH lies in the range of 6.5-7.4, slightly alkaline if it lies in 7.5-8.5 and strongly alkaline if soil pH belongs to 8.6-10 [7]. If the status of organic carbon in soil is less than 0.5%, soil is said to be low in OC, if it is 0.5%-0.75% OC in soil is medium and if it is more than 0.75% then soil OC level is high[8]. Soil properties are given block wise in Table I and Table II presents Pearson's correlation matrix of various soil properties block wise.

TABLE I: SOILS PROPERTIES OF BHILWARA DISTRICT (BLOCKWISE)

Asind					Suwana				
Parameters	pH	EC	OC	P	Parameters	pH	EC	OC	P
Range	7-8.9	0.1-1.2	0.15-0.9	18-60	Range	6.1-9.5	0.12-1.7	0.15-1.05	8.0-52.0
Mean	7.881	0.361	0.403	33.790	Mean	7.853	0.521	0.299	26.169
S.D	0.400	0.200	0.207	12.120	S.D	0.537	0.310	0.200	7.771
C.V(%)	5.075	55.387	51.420	35.868	C.V(%)	6.835	59.513	66.862	29.696
Jahazpur					Kotri				
Parameters	pH	EC	OC	P	Parameters	pH	EC	OC	P
Range	7.6-8.7	0.1-0.7	0.15-0.9	20-52	Range	6.4-8.5	0.2-1.1	0.15-1.0	18-48
Mean	7.972	0.421	0.452	30.340	Mean	7.735	0.367	0.429	26.159
S.D	0.237	0.142	0.193	8.123	S.D	0.423	0.157	0.207	5.923
C.V(%)	2.969	33.777	42.669	26.773	C.V(%)	5.466	42.944	48.288	22.644
Mandal					Mandalgarh				
Parameters	pH	EC	OC	P	Parameters	pH	EC	OC	P
Range	7.0-9.0	0.17-2.0	0.15-1.05	20-62	Range	8.3-8.6	0.18-0.96	0.15-1.05	18-64
Mean	8.391	0.414	0.573	35.927	Mean	7.942	0.340	0.521	34.073
S.D	0.483	0.385	0.225	13.419	S.D	0.398	0.144	0.204	10.417
C.V(%)	5.755	93.028	39.354	37.350	C.V(%)	5.012	42.264	39.159	30.571
Sahara					Shahpura				
Parameters	pH	EC	OC	P	Parameters	pH	EC	OC	P
Range	7.0-9.0	0.25-1.7	0.15-1.35	8.0-64.0	Range	7.2-8.8	0.18-2.1	0.1-1.05	18-50
Mean	7.869	0.481	0.614	34.982	Mean	8.136	0.584	0.374	31.486
S.D	0.579	0.235	0.359	11.415	S.D	0.257	0.417	0.231	7.166
C.V(%)	7.362	48.840	58.458	32.632	C.V(%)	3.153	71.312	61.802	22.760
Raipur					Beejoliya				
Parameters	pH	EC	OC	P	Parameters	pH	EC	OC	P
Range	7-8.7	0.28-9.2	0.1-0.9	20-64	Range	6-8.3	0.2-0.48	0.3-1.2	20-60
Mean	7.920	1.395	0.350	34.800	Mean	7.642	0.331	0.742	35.564
S.D	0.431	2.273	0.188	12.490	S.D	0.336	0.067	0.224	11.078
C.V(%)	5.445	162.927	53.605	35.891	C.V(%)	4.391	20.121	30.219	31.149

A. Soil pH

In Asind block pH varies from 7.0 to 8.9 with average of 7.89. Approx 25% soil data found neutral, 71 % soil data were found slightly alkaline and 4% soil data was found of strongly alkaline in reaction. In Suwana block 1.12% of soil data were of slight acidic and 28.09 % data found of neutral, 62.92% data found of slightly alkaline and approx 7.87% soil data found of strongly alkaline in reaction. In Kotri and Beejoliya 1.59% and 1.82% of soil data were of slight acidic respectively. In these blocks 22.2% and 20% data were of neutral and soil data of slightly alkaline were 76.19% and 78.18% respectively. In Kotri and Beejoliya blocks, no data was of strongly alkaline in reaction. In Raipur and Mandalgarh blocks approx 2% soil data were strongly alkaline in reaction. 74% were slightly alkaline in Raipur and 78.18% in Mandalgarh whereas 24% and 20% data were neutral in reaction in these blocks respectively. Maximum neutral data 38.18% were found in Sahara block here 56.36% data found slightly whereas 5.5% found strongly alkaline in reaction. Maximum strongly alkaline soil data were found in Jahazpur block it was 96% followed by 91.89% in Shahpura block. In Jahazpur and Shahpura approx 4% soil data were of strongly alkaline in reaction whereas 4% were neutral in Shahpura and no data were found of neutral in reaction in Jahazpur block. In Mandal, approx 7.27% data were of neutral and 60% soil data were found slightly alkaline in reaction whereas approx 5% data were of strongly alkaline in reaction. Similar results have also been reported for Mandal block [9].

B. Electrical Conductivity (EC) in soil

Jahazpur, Mandalgarh and Beejoliya can be considered safe blocks as EC was found less than 1in these blocks. In Jahazpur EC varied 0.1 to 0.7, in Mandalgarh it varied from 0.18 to 0.96 and in Beejoliya it varied 0.2 to0.48. But in Raipur maximum approx12% soil data were found which are in critical range or not safe as EC point of view. In some soil data EC was found tremendously high. Here 70% soil data were found in safe region whereas approx 18% was in normal range. In Asind 95% soil data were belonged to safe range and 4% in normal range only 1% was found unsafe range. In Suwana and Shahpura approx 95% soil data were found in safe range and approx 15% was in normal range whereas in Mandal block 90.9% soil data were found to be safe and approx 9.1% were in normal range. In Kotri and Sahara blocks more than 95% soil data were in safe range and 5% were in normal range.

C. Organic Carbon Status in soil

As per organic carbon status considered, soil condition was tremendous. More than 50% soil data of six blocks were found in low OC percent region. In Suwana almost 87.64% soil data were in low OC present soil followed by Raipur block with 82% data were in low OC percent soil. In Shahpura, Jahazpur, Kotri and Asind approx 75.6%, 72%, 68.25% and 59% data were in low OC percent soil respectively. In Beejoliya, Mandalgarh and Mandal 52.73%, 49.1% and 45.45% data were in medium OC percent region. In Sahara and Beejoliya, Maximum 35% of data were found in safe OC percent region. In other blocks 2% to 5% data were present in safe OC percent range. Thus majority of the soil data in different blocks are low to medium and few soil data were high in organic carbon percent due to the use of manure or crop residues.

D. Available Phosphorus

Majority of the soil data of different blocks of Bhilwara were medium to high. Maximum 56.18% soil data of Suwana block were found in safe range whereas in same block 42.7% soil data were found in high Phosphorus range and 1.12% soil data were in low phosphorus range. In Kotri, Raipur, Jahazpur and Mandal 47.62%, 32%, 32% and 25.5% soil data of respective blocks found in medium phosphorus range. In Shahpura, Beejoliya and Mandalgarh approx 82% soil data were found in high phosphorus range. More than 70% soil data of Mandal, Sahara, Asind and Jahazpur were found in high phosphorus range. In Kotri, 52.38% soil data were in high phosphorus range.

E. Correlation Between Various Parameters

Correlation analyses have been widely applied in environmental studies. They provide a useful way to disclose the relationships between multiple variables and thus have been helpful for understanding the influencing factors as well as the sources of chemical components. Pearson's correlation matrix of various parameters of phyico-chemical properties of soil has been shown in table II block wise.

Soil data of Asind block showed significant positive correlation between pH and EC, similar results were found in Raipur, Mandal and Sahara blocks showed a low degree positive correlation whereas suwana and Beejoliya showed low degree negative correlation between pH and EC. Between pH and OC, soil data of Sahara and Asind showed significant positive correlation whereas Suwana and Shahpura showed low degree negative correlation and other blocks Jahazpur, Kotri, Mandal and Mandalgarh showed low degree positive correlation between pH and OC. Soil data of Asind block showed significant positive correlation between pH and P also Jahazpur, Mandal and Mandalghadh showed positive correlation, where as other shows negative correlation between pH and P. Soil data of Mandal and Raipur showed significant negative correlation between EC and OC whereas other blocks showed positive correlation. A significant positive correlation was shown between EC and P at Beejoliya, Mandalgarh, Asind and Sahara whereas Suwana and Mandal showed negative correlation between them and other showed low degree positive correlation. Soil data at Mandalgarh showed negative correlation between OC and P and other showed positive correlation between OC and P.

TABLE II:PEARSON'S CORRELATION MATRIX OF DIFFERENT SOIL PARAMETERS (BLOCKWISE) OF BHILWARA DISTRICT.

Asind					Suwana				
	pH	EC	OC	P		pH	EC	OC	P
pH	1				pH	1			
EC	0.479	1			EC	-0.288	1		
OC	0.329	0.203	1		OC	-0.016	0.094	1	
P	0.546	0.429	0.478	1	P	-0.037	-0.108	0.338	1
Jahazpur					Kotri				
	pH	EC	OC	P		pH	EC	OC	P
pH	1				pH	1			
EC	0.168	1			EC	-0.047	1		
OC	0.047	0.473	1		OC	0.168	0.203	1	
P	0.295	0.137	0.121	1	P	-0.242	0.149	0.306	1
Mandal					Mandalgarh				
	pH	EC	OC	P		pH	EC	OC	P
pH	1				pH	1			
EC	0.390	1			EC	0.013	1		
OC	0.105	-0.117	1		OC	0.135	0.512	1	
P	0.156	-0.149	0.513	1	P	0.140	0.413	-0.010	1
Sahara					Shahpura				
	pH	EC	OC	P		pH	EC	OC	P
pH	1				pH	1			
EC	0.367	1			EC	0.028	1		
OC	0.661	0.345	1		OC	-0.004	0.059	1	
P	-0.202	0.308	0.121	1	P	-0.104	0.231	0.457	1
Raipur					Beejoliya				
	pH	EC	OC	P		pH	EC	OC	P
pH	1				pH	1			
EC	0.478	1			EC	-0.332	1		
OC	-0.330	-0.271	1		OC	-0.198	0.209	1	
P	-0.238	-0.114	0.364	1	P	-0.059	0.552	0.108	1

A positive correlation between pH and EC was found when cumulative data of all blocks were studied. In cumulative study of data a positive correlation was found between pH and OC also between pH and P whereas negative correlation excited between EC and OC. A low degree positive correlation existed between EC and P. Similar correlation results were found in assessment of physico-chemical characteristics of the soil of Lahar block in Bhind district of Madhya Pradesh [10].

IV. CONCLUSION

It was found that cultivated soil in Bhilwara is slightly alkaline in reaction and pH varies in the range of 6-9.8 also the organic carbon status was found low in most of the blocks with the average of 0.46%. Soil phosphorus level varies from medium to high and electrical conductivity in soil moves safe to medium in majority.

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