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INTEGRATED NUTRIENT MANAGEMENT IN PERENNIAL BASED HIGH DENSITY CROPPING THROUGH SYSTEM APPROACH—A THEORETICAL CONSIDERATION

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ABSTRACT

An effort has been made to propose theoretical models to evaluate integrated nutrient management in a mixed perennial crop stand through a system approach. Soil and crop communities are the system components of the model. Soil nutrient enrichment and nutrient depletion models are suggested. The soil nutrient pool constituting the solution, exchange and solid phases to be enriched by the enriching components are considered under the nutrient enrichment model. Various components of nutrition depletion are identified and used in the depletion model. The difference between enrichment and depletion is expected to give a nutrient balance sheet which could be used profitably in nutrient budgeting of multispace high density cropping system.

INTRODUCTION

Nutrient management in a high density multispecies cropping system is a difficult task owing to the involvement of varying nutrient requirements of different crops and crop communities, differential crop responses and crop residue additions. Incidentally nutrient cycling becomes the interesting concern as its engulfs the fluxes reaching and leaving the system. Plant-soil ecosystem represents a three dimensional cut out of vegetation, cover and root zone (Nair, 1979) and a complexity of such a system is seen in the high density cropping, especially with perennials. As studies of eco-components of individual crop species can be misleading, an integrated approach taking the entire eco-processes occurring simultaneously has been attempted in the succeeding text. An effort has been made to propose theoretical models to evaluate integrated nutrient management in a mixed perennial crop stand, through a system approach. Khanna and Nair (1977) in a coconut based system and Ulrich (1971) and Ulrich et al. (1973, 1977) in a forest system outlined the system approach in studying nutrient fluxes.

SYSTEM COMPONENTS

In the proposed model the system components are mainly the soil that support the system and the aerial components, namely, the crop communities. Further, these major components are divided into various sub-components which are to be evaluated separately and integrated to the main components.

Two phases of major activity, namely nutrient enrichment and nutrient depletion of the soil, are considered. The soil nutrient pool constituting the solution phase, exchange phase and solid phase to be enriched by the enriching components that is, rainwater, fertiliser (and organic manures), organic recycling, crop residue addition and native soil nutrients are considered under the nutrient enrichment model. While the soil nutrient depletion mainly takes place through leaching, volatalisation, microbial immobilisation, fixation and plant produce utilisation, the soil matrix with its dynamic equilibrium in maintaining the labile pool of the nutrients is also the main seat of leaching. The resultant difference between enrichment and depletion tend to yield the nutrient balance in the given system which could profitably be used in nutrient budgeting.

BOUNDARY CONDITION

Despite the fact that enrichment and depletion are taking place simultaneously in one form or the other in soil-plant continuum, the following boundary conditions are assumed in the proposed system analysis model:

1) It is an open system which is characterised by materials entering and leaving it across the boundary. However, it is necessary to adjust the system boundary, so that the relevant parts of components are included in the system. This sort of adjustment is illustrated conceptually in the figures.

2) Although nutrient cycling is done to the extent possible, the losses of nutrients from the system take place primarily by: (i) product utilisation loss wherein the nutrients present in the edible parts like nuts, tuber, fruits, berries and vegetative parts are withdrawn from the system permanently and these nutrients under no circumstances are recycled; and (ii) the uncontrolled leaching through soil profile which cannot be checked, though reasonable estimates can be made, and the process is characterised by the movement of sufficiently high quantity of nutrients out of the feeding zone or to the ground water along with the downward transmission of rain water under saturated conditions.

3) The system attains more or less a dynamic equilibrium at a given time for the purpose of studies despite the fact that equilibrium frequently changes due to continuous inflow and outflow of the nutrients in the system.

Key note on the abbreviations used in the models are as follows:

Enrichment rate (Er)		*Soil Nutrient Depletion rate* (Dr)	
Solution phase	— (epsilon) E_1	Solution phase	— E_2
Exchange phase	— (zeta) ζ_1	Exchange phase	— ζ_2
Solid phase	— (et) η_1	Solid phase	— η_2
Rain water	— (alpha) α	Leaching loss	— κ
Fertilisers	— (beta) β	Volatalisation loss	— ν
Soil nutrients (native)	— (gamma) γ		
Organic recycle	— (lambda) λ	Microbial immobilisation loss	ρ
Crop residues	— (psi) ψ	Fixation loss	ω
Microbial addn.	— (chi) χ	Plant utilisation	Φ

SOIL NUTRIENT ENRICHMENT MODEL

Soil nutrient enrichment under a high density cropping system is a complex process to judge, as multiple crop components requiring varying input demands are involved. Thus estimation of elemental cycling requires a complete inventory of the input fluxes to the system (Ulrich et al., 1981). To consider this, soil enrichment has been classified into two categories.

a) soil enrichment without cropping, and

b) soil enrichment under multispecies cropping.

a) Soil enrichment without cropping

Schematic representation of processes governing soil enrichment without cropping is shown in Fig. 1. The enrichment is limited to additions through rain water and organic cycling. Rain water through the filtering process brings down soluble metabolities from the crop stand to the soil in addition to the atmospheric input. As conditioned by the interaction of nutrient

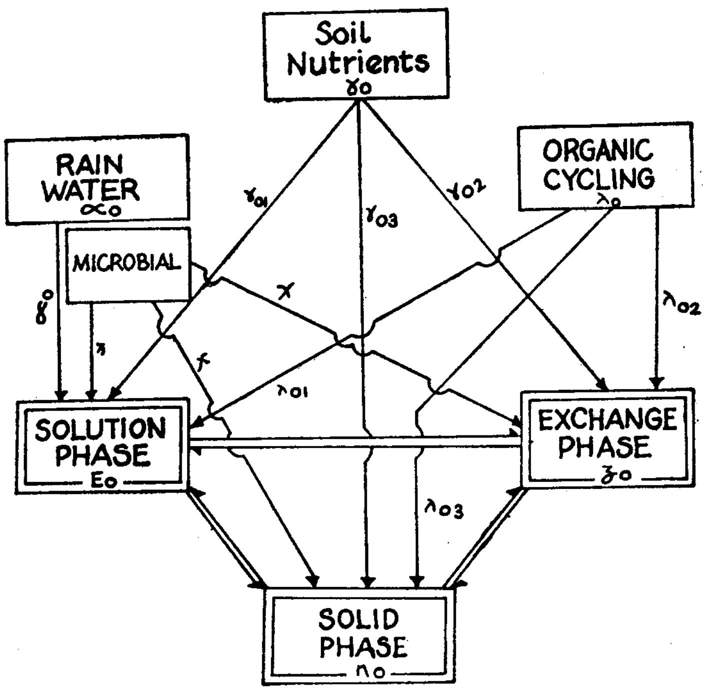

Fig. 1

addition through organic recycling and rain water, changes are brought out in the dynamic equilibrium between solution, exchange and solid phase. Weathering action on the solid phase also enriches the nutrient pool. The equilibrium changes and a static level is maintained. Methods of studying these and the difficulties experienced have been indicated by Ulrich et al. (1981).

The lower half of the diagram exhibiting interplay between the three phases in the soil holds good for all the nutrients except those that are not capable of undergoing exhange in the soil (NO_3^- and SO_4^{2-}). For phosphorus it may be modified as below since surface absorbed phosphate is used by plants (Venkateswarlu, 1976).

Nutrient in mineral or soild phase	$\rightleftharpoons$	Nutrient in exchangeable or surface	$\rightleftharpoons$	Nutrient in solution
	$\rightleftharpoons$ SLOW	:	$\rightleftharpoons$ RAPID	

b) Soil enrichment under multispecies cropping

The incoming fluxes of nutrient under a multispecies cropping system is through the agencies of rain water and fertilisers inputs to the individual crop communities, and the organic addition through crop and weed growth. The addition of elements by crop growth of weeds is partly an internal turnover of the nutrients absorbed by the roots from the soil. The contribution from roots as biomass addition and through nutrient cycling will be enormous and estimations by soil monolith analysis (Karizumi, 1968) and allometric analysis (Kira and Ogawa, 1968) have been proposed. The soil enrichment is gradual along with the growth of the crop community in the system, though various stages of nutrient enrichment by the bio-elements are observed, namely initial stages, active growth stage and the equilibrium stage. The direct and indirect effects of microbial organisms also enrich the nutrient pool. The attainment of the equilibrium stage may be after four to five years of the reproductive phase of 75 per cent of the crop communities concerned. The elemental input is dependent upon the season (Ando, 1970; Pavlov, 1972) and annual variation (Rodin and Bazilevich, 1967).

A schematic diagram of nutrient enrichment phase (Fig. 2) indicates the additional enrichment components over those seen

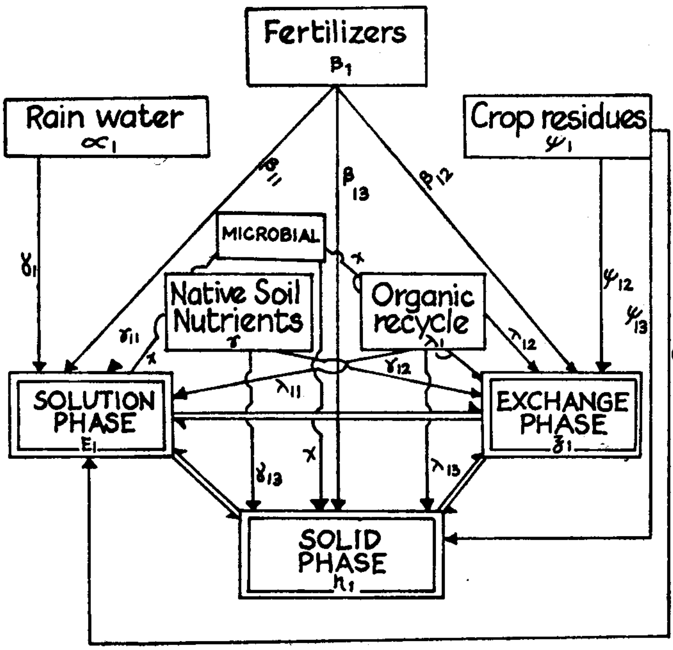

Fig. 2

in (Fig. 1) and their interrelationship on the soil matrix. Soil, more precisely the solid phase is considered as the reservoir of nutrients and is in dynamic equilibrium with the exchange and solution phase.

The reaction governing the nutrient enrichment by agencies within and between the three phases are indicated by three numerical equations (1, 2, 3)

$$\epsilon_1 - \epsilon_0 = \int_i^f \left(\frac{\delta\epsilon}{\delta\alpha}\right) d\alpha + \int_i^f \left(\frac{\delta\epsilon}{\delta\beta}\right) d\beta + \int_i^f \left(\frac{\delta\epsilon}{\delta}\right) d\gamma + \int_i^f \left(\frac{\delta\epsilon}{\delta\lambda}\right) d\lambda + \int_i^f \left(\frac{\delta\epsilon}{\delta\Psi}\right) d\Psi + \int_i^f \left(\frac{\delta\epsilon}{\delta\varkappa}\right) \delta\lambda \tag{1}$$

$$z_1 - z_0 = \int_i^f \left(\frac{\delta z}{\delta\beta}\right) d\beta + \int_i^f \left(\frac{\delta z}{\delta\gamma}\right) d\gamma + \int_i^f \left(\frac{\delta z}{\delta\lambda}\right) d\lambda + \int_i^f \left(\frac{\delta z}{\delta\Psi}\right) d\Psi + \int_i^f \left(\frac{\delta z}{\delta\varkappa}\right) d\lambda \tag{2}$$

$$\eta_1 - \eta_0 = \int_i^f \left(\frac{\delta\eta}{\delta\beta} \right) d\beta + \int_i^f \left(\frac{\delta\eta}{\delta\gamma} \right) d\gamma + \int_i^f \left(\frac{\delta\eta}{\delta\lambda} \right) d\lambda + \int_i^f \left(\frac{\delta\eta}{\delta\Psi} \right) d\Psi + \int_i^f \left(\frac{\delta\eta}{\delta\chi} \right) d\chi \qquad (3)$$

The various symbols indicate (refer key) different components taking part in enrichment steps each being a rate limiting step and are in equilibrium with the other phases. The differences between the enrichment under cropping and without cropping gives the enrichment profile of the respective nutrient pool. However, the net gain or loss of the nutrient from the pool would be a resultant effect of enrichment of solution, exchange and solid phase fractions. To comprehend the individual steps in the process is rather difficult, and one usually estimates the resultant effect of interactions. Studies of sequential extraction type (Silveir and Sommers, 1977) may give information on fractionated portion of the nutrient continuum on soil matrix.

SOIL NUTRIENT DEPLETION

Under barren soil conditions nutrient depletion from the soil will mainly be through leaching, weed growth, grazing and through mechanical loss by erosion, if unchecked. In monocropping and multiple cropping systems, the integrated interaction effect of crop on soil helps in conservation and depletion of nutrients. Depletion in this context refers to the nutrient removal from the system through harvesting of crop produce both edible and non-edible. The aerial storage in lignified tissues (trunk, bark and plant parts)—a system building activity, immobilises a considerable amount of nutrient, a portion of which is activated by photosynthesis. The series of depletion parameters which would act on the soil—the ultimate reservoir of nutrients pool—are outlined in Fig. 3.

Nutrient depletion in high density cropping is a dynamic process and the nutrient pool will be unevenly tapped for resources by the companion crops. Losses due to leaching, drain of native soil nutrient contents, microbial immobilisation and nutrient fixation (especially phosphorus) are soil bound and plant utilisation is an aerial bound nutrient loss. As nutrient enrichment changes

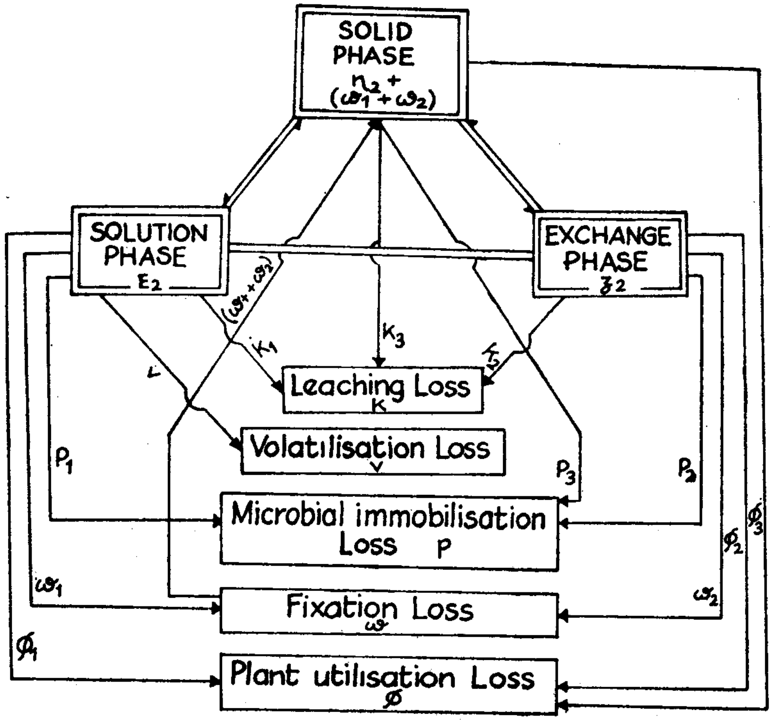

Fig. 3

the equilibrium, nutrient depletion also changes the equilibrium of soil store. The changes as influenced by different compoments modify the nutrient pool and are given by three numerical equations (4, 5, 6) as follows:

$$\epsilon_2 - \epsilon_0 = \int_i^f \left(\frac{\delta\epsilon}{\delta k}\right) dk + \int_i^f \left(\frac{\delta\epsilon}{\delta k}\right) \delta\gamma + \int_i^f \left(\frac{\delta\epsilon}{\delta p}\right) dp + \int_i^f \left(\frac{\delta\epsilon}{\delta\phi}\right) d\phi \quad (4)$$

$$z_2 - z_0 = \int_i^f \left(\frac{\delta z}{\delta k}\right) dk + \int_i^f \left(\frac{\delta z}{\delta w}\right) dw + \int_i^f \left(\frac{\delta z}{\delta p}\right) dp + \int_i^f \left(\frac{\delta z}{\delta\phi}\right) d\phi \quad (5)$$

$$\eta_2 - \eta_0 = \int_i^f \left(\frac{\delta\eta}{\delta k}\right) dk + \int_i^f \left(\frac{\delta\eta}{\delta p}\right) dp + \int_i^f \left(\frac{\delta\eta}{\delta\phi}\right) d\phi + \int_i^f \left(\frac{\delta\eta}{\delta w}\right) dw \quad (6)$$

The difference between the summation of natural depletion rate under an adjacent barren land (E_0, Z_0, and n_0) and the summation of depletion of nutrients under a cropping system (E_2 Z_2, and n_2) will provide information on net nutrient depletion from the system.

NUTRIENT BUDGETING AND BALANCE

Nutrient balance in the strict sense of the term means the difference between the input and the output of nutrients in various forms. Under a high density cropping system the difference between nutrient enrichment and depletion is expected to give the nutrient balance which may be positive, negative or equal. In a perennial based system we opine that the nutrient balance (budgeting and tailoring to needs) can be studied at equilibrium: (1) after four to five years of the reproductive phase of 75 per cent of crop communities concerned; and (2) when the system is fully mature.

$$\left.\begin{array}{l}\text{Nutrient balance in}\\\text{respective phase}\end{array}\right\} Er^{(1,2,3)} - Dr^{(3,4,5)}$$

Such information helps to understand the nutrient profile in the system and evokes measures to regulate inputs.

ACKNOWLEDGEMENTS

The authors are thankful to Shri K. Vijayakumar, Statistics section for the help in preparing mathematical models.

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DISCUSSION

Q : The paper presented by you suggests only a theoretical model. Will this be of any practical use in nutrient management?

Ans: This theoretical model forms the basis for further work on integrated nutrient management.

Q : Is this model same as that one proposed by Ulrich?

Ans: Ulrich's outlined the system approach in a forest system and not in high density cropping systems.

Q : Could you quantify any boundary conditions in your study?

Ans: This paper gives the assumptions on boundary conditions.