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Nutrient Budgeting Using NUTMON - Toolbox in an Irrigated Farm of Semi Arid Tropical Region in India - A Micro and Meso Level Modeling Study

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Abstract: Mining of nutrients from soil is a major problem causing soil degradation and threatening long-term food production in developing countries. In present research, an attempt was made for carrying out nutrient budgeting, which includes the calculation of nutrient balance at micro (plot / field) and meso (farm) level and evaluation of trends in nutrient mining / enrichment. A nutrient budget is an account of inputs and outputs of nutrients in an agricultural system. NUTrient MONitoring (NUTMON) is a multiscale approach that assess the stocks and flows of N, P and K in an well defined geographical unit based on the inputs *viz.,* mineral fertilizers, manures, atmospheric deposition and sedimentation and outputs of harvested crop produces, residues, leaching, denitrification and erosion losses. The nutrient budgeting research in an irrigated farm at Coimbatore district revealed that the nutrient management practices are not appropriate and sustainable. Soil nutrient pool has to offset the negative balance of N and K, hence there is an expected mining of nutrient from the soil reserve in the research area. The management options / policy interventions to mitigate this mining by manipulating all inputs and outputs in a judicious way with an integrated system approach are suggested and one of the ways for redefining the fertilizer recommendation based on site specific using DSSIFER (Decision Support System for Integrated Fertilizer Recommendation) was worked out.

Key words: Nutrient balance % inputs % outputs % fertilizers % NUTMON % nutrient mining

INTRODUCTION

In a densely populated country like India agricultural research was mainly focused on increasing the production during the green revolution erea. The overall performance in food grain production spurred by green revolution is worthy and propelled India towards self-sufficiency in food production. This growth, kick started by introduction of high yielding varieties, extension of irrigated areas, use of high analysis NPK fertilizers and increase in cropping intensity, lost its momentum during the last decade. A worrying factor is that over the last four years, the annual production is hovering close to 200 mt only. This fanatic policy of attaining higher production without giving due emphasize on sustainability and soil health can be clearly visualized from the stagnating yield and decline in annual compound yield growth rate (CGR) of 1.31 during 2001 from 2.56 during 1991 for all principal crops that are grown in India [1]. The system has shown a sign of fatigue in production despite the use of heavy inputs, largely because of nutrient imbalance and depletion.

In spite of the phenomenal rise in fertilizer use the nutrient addition generally falls short of requirements or crop removal [2]. Scientists in the recent past have reported that there is mining of N, P and K from soil reserves in almost all the agro-climatic zones across India [3-6]. The results from Coimbatore center of Long Term Fertilizer Experiment (LTFE) proved beyond doubt that the K depletion still proceed even in plots receiving fertilizer K at 150% of the recommended level [7].

The capacity of the soil resource to perform the critical function of life support system is undergoing unabated degradation of different kinds and deterioration due to nutrient depletion. Soil fertility decline does not get the same public attention as that of drought, pests and disease outbreak, since it is a gradual process not associated with catastrophic feature and mass starvation and hence farmers and policy makers are unable to

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perceive it. Changes in soil fertility level should be monitored to provide early caveat on adverse trends and to identify the problem areas.

Nutrient monitoring is a method that quantifies a system's nutrient inflows and outflows resulting in nutrient balance. Nutrient balance can be determined at spatial scales ranging from field level to national level. A nutrient balance determined at the level of individual activities within a farm serves as a useful indicator to provide insight into magnitude of losses of nutrients from the system and the causes for such losses, which ultimately enables target interventions.

But so far the field research in agriculture has been largely empirical and site specific and conducted without the active help of agricultural system models. Integration of this system models with field research will make easy interpretation of results and will eliminate the critical knowledge gaps. Field research will not be complete unless the results are analyzed and interpreted with a system approach. In this context, a Decision Support System (DSS) will be an effective tool for decision makers to solve complex agricultural problems.

Decision support tools known as NUTrient MONitoring-Toolbox (NUTMON-Toolbox) [8] and Decision Support System for Integrated fertilizer Recommendation (DSSIFER) [9] have been constructed to solve these agricultural problems and increase crop yields and at the same time maintain soil fertility. These DSSs assist in farm decision-making processes by enabling to choose the optimal mix of options when many options are available for a single problem.

Unless and until one is able to understand the nutrient balance at each crop activity level within the farm and at farm level, agricultural policy decisions for planning at these levels will not be accurate and inaccurate policies will never help to break the crop yield barrier and to sustain the production system. To address the importance of these problems, the present research undertaken by employing reliable tools *viz.*, NUTMON-Toolbox and DSSIFER to assess the nutrient balance at field (crop activity) and farm level in Coimbatore district, Western Agro-climatic Zone of Tamil Nadu, India.

MATERIALS AND METHODS

Research site: The research area of Coimbatore district is located in the Western Agro-climatic Zone of Tamil Nadu in the southern part of India. Usually dry climate prevails in most part of the district except western part, which has a semidry climate. The soils of these districts mostly belong to Alfisols and Vertisols and found best suited for crops like *Oryza sativa* (paddy), *Arachis hypogea* (groundnut), *Curucuma longa* (turmeric), *Sacharaum officinarum* (sugarcane) and pulses. Somayanur, Pichanur, Peelamedu, Irugur, Palathurai, Periyanaickenpalayam, Noyyal, Chavadiparai, Dasarapatti, Palladam and Anaimalai series [10] covers a major part of the soil series in the research area.

Model description:

Structure of NUTMON-Toolbox: NUTMON-Toolbox is a user friendly computerized software for monitoring nutrient flows and stock especially in tropical soils [8]. "NUTMON-Toolbox" enables the assessment of trends based on the local knowledge on soil fertility management and the calculation of nutrient balances. Utilizing these results one can easily identify the factors limiting crop production in the farm or region and propose possible solutions for adoption and testing. Farm-NUTMON is a tool encompassing a structured questionnaire, a database and two simple static models (NUTCAL for calculation of nutrient flows and the ECCAL for calculation of economic parameters). Finally, a user-interface facilitates data entry and extraction of data from the database to produce input for both models. The tool calculates flows and balances of the macronutrients-N, P and K through independent assessment of major inputs and outputs using the following equation.

$$\text{Net soil nutrient balance} = \Sigma\,(\text{Nutrient INPUTS}) - \Sigma\,(\text{Nutrient OUTPUTS}) \quad \ldots (1)$$

This is based on a set of five inflows (IN 1-5 mineral fertilizer, organic inputs, atmospheric deposition, biological nitrogen fixation and sedimentation), five outflows (OUT 1-5 farm products, other organic outputs, leaching, gaseous losses, erosion and human excreta) and six internal flows (consumption of external feeds, household waste, crop residues, grazing, animal manure and home consumption of farm products).

Components of NUTMON-Toolbox: The NUTMON-Toolbox includes four modules and two databases that together facilitate nutrient monitoring at the level of individual farmers' fields and farms as a whole.

Modules :

- A set of Questionnaires to collect the required farm-specific information on inventory and monitoring. They are a structured guide used to gather and record information during an interview with one or more members of the farm regarding farm environment, farm management, farm household, soils and climate.

- A Data entry module that facilitates entry of the data from the questionnaires into the computer.
- A background data module, storing non-farm-specific information on crops, crop residues, animals, inputs and outputs.
- A data processing module that calculates nutrient flows, nutrient balances and economic indicators, based on the farm-specific data from the questionnaires and general data from the background database, using calculation rules and assumptions.

Databases :

- A background database containing non-farm-specific information on, for instance, nutrient contents of crop and animal products, crop and livestock parameters, as well as calibration factors of local units of measurement.
- A Farm Database in which information about a particular farm are stored.

The diagnostic phase was carried out at farm level where, soil and crop management decisions are made through farmer participatory analysis of the current situation in the farm regarding nutrient flows into and out of the farm and their economic performance. The quantification of nutrient inflows and outflows had been done using farm inventory and farm monitoring. Farm inventory is to identify the important features of the farm to be studied. Basically, the inventory entails a simplification of the real farm in order to make it fit into the conceptual framework and is done by means of a one-off inventory of the farm. Monitoring identifies the material flows within and outside the farm over a period of time.

Additional information that are needed for the calculations but that cannot be given by the farmer, for instance, nutrient contents of crop products and fertilizers, soil parameters and calibration factors for local units of measurement are gathered from literature reviews that provide data valid for the research area.

Similarly, for some of the crops and other livestock products, input parameters like nutrient contents, which are not stored in the background database, had been analyzed and entered. Soil sampling and their analysis provide information on the current nutrient status of soils. Complete database for crops that are not included in the Toolbox but are grown in the research area are generated afresh.

Farm conceptualization: Farms are conceptualized as a set of dynamic units, which depending on management, form the source and / or destination of nutrient flows and economic flows.

- *Farm Section Unit (FSU)* : Areas within the farm with relatively homogeneous properties

- *Primary Production Unit (PPU) / crop activities* : Piece of land with different possible activities such as one or more crops (annual or perennial), a pasture, a fallow and located in one or more FSUs.

- *Secondary Production Unit (SPU) / livestock activities* : Group of animals within the farm that are treated by the farm household as a single group in terms of feeding, herding and confinement.

- *Redistribution Unit (RU)*: Nutrient storage activities. Location within the farm where nutrients gather and from which they are redistributed, such as manure heaps and compost pits.

- *House Hold (HH)* : Group of people who usually live in the same house or group of houses and who share food regularly.

- *Stock* : The amount of staple crops, crop residues and chemical fertilizers temporarily stored for later use.

- *Outside (EXT)* : The external (nutrient) pool consisting of markets, other families and neighbours, being a source and destination at the same time which itself is not monitored.

Quantification of nutrient balance: In Farm-NUTMON, nutrient flows are quantified in three different ways *viz*., by using primary data, estimates and assumptions. Flows directly related to farm management were quantified by asking the farmers on inputs to and outputs from the different compartments. Nutrient balances were quantified using the in-built transfer functions, equations and assumed values. Detailed equations can be referred from Vlaming *et al*. [8] and Surendran [11].

To make a clear distinction between primary data on the one hand and estimates and assumptions on the other, two different balances were worked out. The partial balance at farm level [(Σ IN1-2) - (Σ OUT1-2)] is made up solely of primary data. The full balance, (Σ *IN* - Σ*OUT*), is a combination of the partial balance and the immissions (atmospheric deposition and nitrogen fixation) and emissions (leaching, gaseous losses, erosion losses and human excreta) from and to the environment.

Farm inventory and farm monitoring regarding nutrient flows into and out of the farm was done using the available questionnaires through farmer participatory analysis. Collected data were fed into the data processing module and the nutrient balance for the individual crop activity (micro) and farm (meso) as a whole were computed using the NUTMON-Toolbox.

RESULTS

Description of the selected farm: This irrigated farm lies in Nathegoundenpudur village in Thondamuthur block of Coimbatore district of Tamil Nadu. The farm has a cultivable area of 2.8 ha. The soil of the farm is well drained and taxonomically belongs to Somayanur series [10]. The source of irrigation is mainly wells, situated in the farm itself. Farms are conceptualized as a set of dynamic units, which depending on management, form the source and / or destination of nutrient flows and economic flows. They are Farm Section Unit (FSU), Primary Production Unit (PPU) / crop activities, Secondary Production Unit (SPU) / livestock activities, Redistribution Unit (RU) / manure heap, House Hold (HH), Stock and Outside (EXT).

This farm comprises of six primary production units within three farm section units. They are sorghum (PPU 1), banana (PPU 2), onion + chillies intercropping (PPU 3), maize (PPU 4), turmeric (PPU 5) and blackgram (PPU 6). Crop activities (PPUs), livestock activities (SPU), manure pit (RUs), household (HH) and irrigation source are depicted in Fig. 1.

On-farm nutrient flow: ways and means: The identified nutrient flows into the selected farms are mineral fertilizer (IN 1) on-farm and off-farm manure (IN 2), atmospheric deposition (IN 3) and biological fixation (IN 4). Nutrients for the farm were mainly through chemical fertilizers and organic manures that are met from external sources besides on-farm generated manures. The farmer besides using on-farm manure also purchases manure off-farm and imports it into the farm. This was included as IN 2a and IN 2b. Besides, a part of crop residue was also directly recycled into the farm by incorporation / burning. Outflows in the farm included crop uptake (OUT 1), removal in crop residue (OUT 2), leaching (OUT 3), gaseous loss (OUT 4) and erosion losses (OUT 5).

NUTMON-Toolbox generated nutrient flows: NUTMON-Toolbox generated flow diagram representing the flows between various units within the irrigated Nathegoundenpudur village farm are given in Fig. 2. The flow of nutrients to the farm from external sources was mainly through mineral fertilizers (IN 1) and on-farm and off-farm manures (IN 2) to banana (PPU 2), onion + chillies (PPU 3) and turmeric (PPU 5). The volume of flow to these PPUs was large as compared to the flows to other PPUs *viz*., pulses (PPU 6), maize (PPU 4) and sorghum (PPU 1). Similarly the nutrients exported out of the farm (EXT) from PPUs that occurred through the STOCK were large with maize (PPU 4), turmeric (PPU 5), onion + chillies intercropping (PPU 3) and blackgram (PPU 6). In the case of banana (PPU 5) and sorghum (PPU 1) nutrients were directly exported out of the farm (EXT) without going into the STOCK. The volume of flow of nutrients exported out of the farm (EXT) from the STOCK was the largest and occurred through human consumption and sale of produce. Some quantity of nutrients has come into the STOCK as seed materials and stored in the farm.

The secondary production units in the farm are tropical lactating cow (SPU 1, SPU 2) from which, nutrient flow occurred mainly to turmeric (PPU 5) and banana (PPU 2) through the compost heap (RU 1). Also, through a portion of the residue from onion + chillies intercropping (PPU 3) and from external source as mineral fertilizers (viz., urea and SSP) nutrient flow occurred to compost heap (RU 1). The flow diagrams helps to identify the shortcomings in nutrient distribution pattern of the farm.

Nutrient balance at crop activity (PPU) level: The quantified nutrient balance at the crop activity level (PPUs) using NUTMON-Toolbox is presented in Table 1. The full balance was highly positive with onion + chillies intercropping (PPU 3) for N and P (71.2 and 68.2 kg ha^{-1}). The lowest positive N balance of 25.8 kg ha^{-1} was observed with sorghum (PPU 1). However, the N balance was negative with banana (PPU 6) and turmeric (PPU 5). Similar to N, the highest negative P balance (-23.2 kg ha^{-1}) was recorded with banana (PPU 2). Among the three nutrients, full K balance was negative and high (-233.3 kg ha^{-1}) in onions + chillies intercropping (PPU 3). All the crops showed signs of negative balance with K. Similar trend of results was also observed with partial NPK balances.

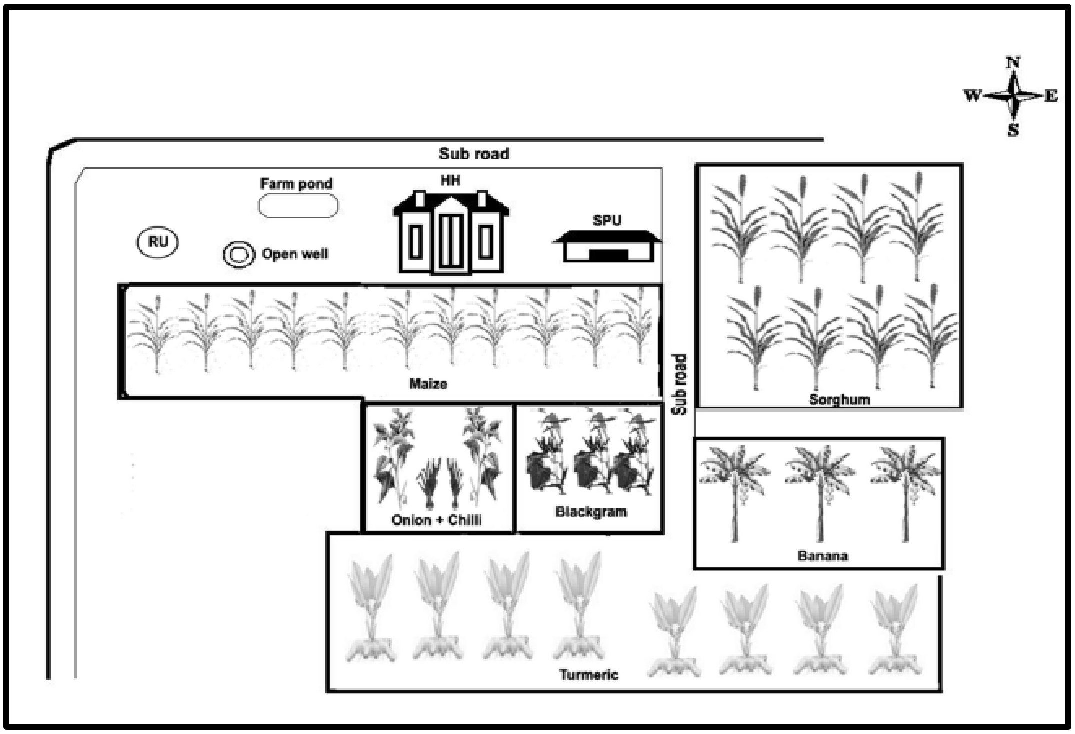

Fig. 1: Farm sketch indicating crop activities in Nathegoundenpudur

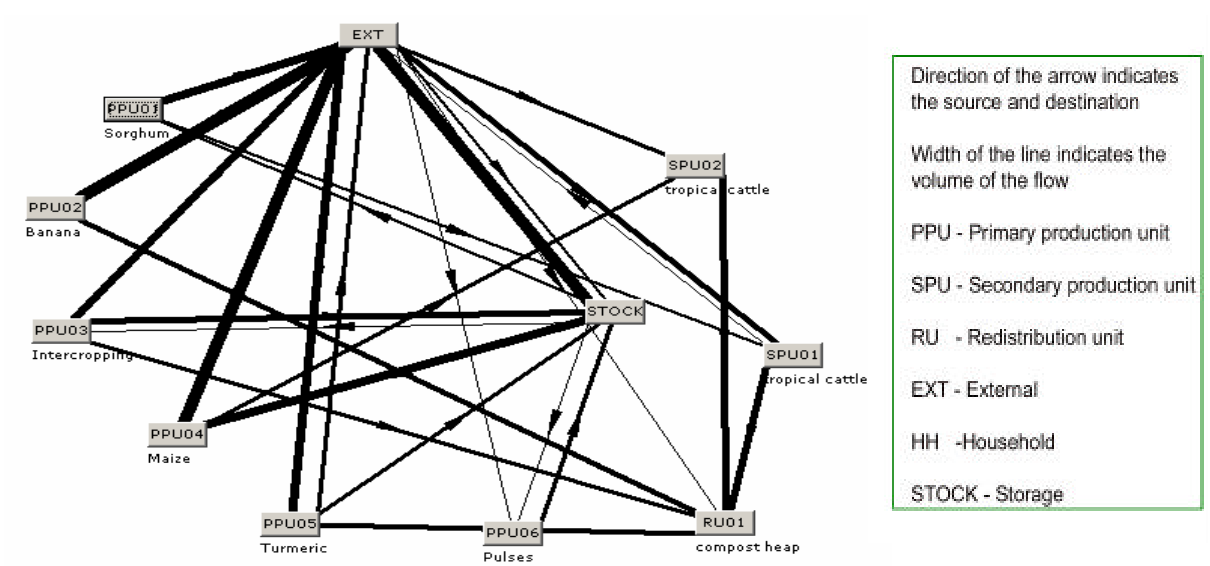

Fig. 2: NUTMON-Toolbox generated nutrient flows between various units of the farm at Nathegoundenpudur

Table 1: NUTMON-Toolbox generated nutrient balance for the irrigated farm in Nathegoundenpudur

	Flows (kg)											
	Inputs				Outputs				Partial balance	Full balance	Partial balance	Full balance
Units	IN 1	IN 2	IN 3	IN 4	OUT 1	OUT 2	OUT 3	OUT 4	(kg)	(kg)	(kg haG^1)	(kg haG^1)
Nitrogen												
PPU 1 Sorghum (8094 m^2)	42.0	0.6	2.8	0.0	15.3	3.2	6.0	0.0	24.1	20.9	29.8	25.8
PPU 2 Banana (4047 m^2)	59.0	22.5	1.4	0.0	60.3	33.3	8.4	0.0	-11.8	-18.8	-29.2	-46.5
PPU 3 Onion+Chillies (2023 m^2)	60.0	0.2	0.2	0.0	30.1	10.2	5.7	0.0	19.9	14.4	98.4	71.2
PPU 4 Maize (6070 m^2)	31.5	0.0	1.1	0.0	32.9	5.4	3.2	0.0	-6.8	-8.9	-11.2	-14.7
PPU 5 Turmeric (8094 m^2)	30.5	44.9	2.2	0.0	71.5	17.7	7.2	0.0	-13.8	-18.8	-17.0	-23.2
PPU 6 Blackgram (2023 m^2)	0.0	0.0	0.1	2.3	15.3	3.2	6.0	0.0	-4.6	-2.3	-22.7	-11.4
Phosphorus												
PPU 1 Sorghum (8094 m^2)	0.0	0.2	0.5	0.0	5.8	1.4	0.0	0.0	-7.0	-6.5	-8.6	-8.0
PPU 2 Banana (4047 m^2)	7.4	2.5	0.2	0.0	13.4	6.1	0.0	0.0	-9.6	-9.4	-23.7	-23.2
PPU 3 Onion + Chillies (2023 m^2)	21.0	0.0	0.0	0.0	5.1	2.1	0.0	0.0	13.8	13.8	68.2	68.2
PPU 4 Maize (6070 m^2)	9.0	0.0	0.2	0.0	8.0	0.9	0.0	0.0	0.1	0.3	0.2	0.5
PPU 5 Turmeric (8094 m^2)	22.5	10.6	0.4	0.0	9.8	2.4	0.0	0.0	20.9	21.3	25.8	26.3
PPU 6 Blackgram (2023 m^2)	4.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	3.2	3.2	15.8	15.8
Potassium												
PPU 1 Sorghum (8094 m^2)	0.0	0.2	1.8	0.0	3.9	10.1	0.1	0.0	-13.8	-12.1	-17.0	-14.9
PPU 2 Banana (4047 m^2)	60.1	3.0	0.9	0.0	41.6	21.1	0.5	0.0	-4.6	-4.2	-11.4	-10.4
PPU 3 Onion+Chillies (2023 m^2)	0.0	0.0	0.1	0.0	34.9	12.4	0.0	0.0	-47.3	-47.2	-233.8	-233.3
PPU 4 Maize (6070 m^2)	17.3	0.0	0.7	0.0	15.9	2.9	0.4	0.0	-1.5	-1.2	-2.5	-2.0
PPU 5 Turmeric (8094 m^2)	14.8	28.0	1.4	0.0	55.7	13.7	0.3	0.0	-26.6	-25.5	-32.9	-31.5
PPU 6 Blackgram (2023 m^2)	0.0	0.0	0.1	0.0	2.5	0.0	0.0	0.0	-2.5	-2.4	-12.4	-11.9

Table 2: NUTMON-Toolbox generated nutrient balance for the irrigated farm in Nathegoundenpudur

	Flows (kg)											
	Inputs				Outputs				Partial balance	Full balance	Partial balance	Full balance
Nutrients	IN 1	IN 2	IN 3	IN 4	OUT 1	OUT 2	OUT 3	OUT 4	(kg)	(kg)	(kg haG^1)	(kg haG^1)
Nitrogen	256.3	2.6	7.8	2.3	164.8	83.3	30.7	2.0	10.8	-11.8	4.7	-5.1
Phosphorus	83.0	0.5	1.3	0.0	29.3	19.8	0.0	0.0	34.4	35.7	15.0	15.5
Potassium	103.3	1.8	5.2	0.0	123.4	57.3	1.4	0.0	-75.6	-75.7	-32.9	-31.3

Nutrient balance at farm level: For the farm as a whole the nutrient balance was expressed as the sum of inputs minus the sum of outputs covering all FSUs, SPUs and RUs. There has been a slight variation in the nutrient balance of the farm than the individual PPUs. NUTMON-Toolbox generated nutrient balance for the experimental farm as a whole in Nathegoundenpudur showed that the full balances were positive for P and negative for N and K, while the partial balance was positive for N and P and negative for K (Table 2).

DISCUSSION

Nutrient balance at crop activity (PPU) level: In the case of millets, N, P and K balances were negative due to mismatch between nutrient input and output / export. Economic constraints of the farmer would necessitate adoption of technology at sub-optimal level which leads to less concern with the farmer about sustainability issues like appropriate nutrient management to sustain agricultural production systems [12, 13].

But in the case of black gram, N and K balances were negative and P balance was positive. Black gram usually receives P through foliar nutrition and therefore depletion of soil P reserve by it may not be exhaustive. Negative balances for N and K, suggest for updating the existing fertilizer recommendation since K is omitted in the presently followed state recommendation [14].

Negative balances for all the three nutrients were seen with banana, implying that the amount of fertilizer applied to banana was sub-optimal and other managements like manure addition, recycling of wastes, use of bio-fertilizers etc., were insufficient to match the gap between nutrient export out of the farm and input into the farm.

Nutrient balance research results also revealed that adequate attention was given by the farmer in nutrient management in crops where the prices for the produce are remunerative. This was evident from the results obtained with turmeric, where N and K balances were marginally negative and P balance was marginally positive. However, even in this case, the negative trend in nutrient balance has to be arrested by properly fine tuning the fertilizer recommendation or making adjustments with other nutrient inputs like on-farm manuring / vermicomposting / green manuring, crop residue recycling etc. [15].

Among the crop activities, there was only one inter-cropping component *viz*., onion + chillies in which case the N and P balances were positive and this indicate that inter-cropping systems receive adequate attention on N and P management but not in K management. Adequate attention on K management in such inter-cropping system is essential because both the companion crops remove large quantities of K from the soil. If this trend of negative K balance is left unchecked, the continuing K mining would deplete soil K to a level below the critical level at which yield will be limited.

Nutrient balance at farm level: This negative N balance at farm level was due to the high outflow of N through harvested produces, crop residues, losses from manures, leaching and gaseous losses. Leaching and gaseous losses of N in the irrigated farms were high (10.8 to 46.8 kg), which is in agreement with the findings of Kroeze *et al*. [16]. A review and upward revision of existing fertilizer application rates to crops, use of slow release N fertilizers or use of urease / nitrification inhibitors to improve N use efficiency and growing and insitu incorporation of green manure crop during fallow period to contain leaching losses that occur in considerable amounts in the selected farm and production and application of on-farm organic manures to recycle nutrients in crop produces / residues to improve soil fertility are the possible options to mitigate the negative N balance [17]. The difference in full and partial balance of N might be due to the contribution of N from Nitrogen fixation.

Full and partial balances of P were positive. This positive balance was mainly due to the optimal use of P fertilizers and absence of pathways of losses of P other than crop uptake (OUT 1) and loss in crop residues (OUT 2). Kumaraswamy [18] was of the view that in soils with such buildup of P, fresh P inputs through fertilizers can be omitted or a maintenance dose of P can be applied to effect saving on cost of P fertilizer. Use of P solubilizing (Phosphobacteria) and mobilizing (VAM) microorganisms as biofertilizers will improve the utilization of native soil P in such situations of P fertility buildup in soil [19].

This negative K balances was due to major outflow of nutrients from the farm through removal in harvested produce (OUT 1) and crop residues (OUT 2). K removal in crop produce and crop residues far exceeded the K fertilizer addition. Crop uptake of K is usually as much as N uptake and sometimes, as in the case of tubers, vegetables etc., higher than N uptake. But the amount of K replenished through fertilizer K recommendation by the crops is always very low in magnitude as compared to that of N [14]. Besides the soil fertility sustainability issue, the sub-optimal K application to crops reduces the potential profitability from them and the likelihood of recouping farmers' investment on crop production. With total dependency in India on imports for K fertilizer, such concern on economics will permit to stretch K imports to fulfill the crop requirements.

Further, the farmer in the research area do not regularly and effectively recycle the residues from crops like sugarcane, turmeric, coconut etc., which contain appreciable amounts of K. This was a major cause for the observed negative balance in farm level K budget [20]. Increasing the rate of K fertilizer addition at an economically optimal level, import of off-farm manure sources (IN 2) into the farm and effective recycling of farm wastes are the possible management options to maintain a positive K balance at farm level.

The nutrient stocks and flows diagram (Fig. 2) for the irrigated farm in Coimbatore district gave a clear picture about the stocks of nutrients in the farm at different sources and the flows that occurred between different units. A careful analysis of the diagram helps to formulate policy interventions for effecting optimal flow of nutrients between different units within the farm. For example, the flow of nutrients from on-farm manure to various crop activities was not uniform. In this farm most flow occurred to turmeric and banana. Nutrient flow to manure heap occurred *via* the secondary production units *viz*., cattle and / or goat. But the nutrient flow to manure heap via crop residues was also minimal. Therefore, there is a need to re-look into the nutrient management programme to ensure that recycling of the farm wastes is done with high accuracy to avoid nutrient losses via residues that are not used for feeding the cattle or in the manure preparation activity in the farm. Also, burning of residues should also be avoided and thereby these residues can be profitably used in manure making.

Strategy: Nutrient depletion is the result of a net imbalance, between incoming and outgoing nutrients in farm inputs and outputs. Because many aspects of farm

Table 3: NUTMON-Toolbox generated nutrient balance when fertilizer programme is from DSSIFER for the experimental farms in Narasimhanaickenpalayam

	Flows (kg)											
	Inputs				Outputs				Partial balance	Full balance	Partial balance	Full balance
Nutrients	IN 1	IN 2	IN 3	IN 4	OUT 1	OUT 2	OUT 3	OUT 4	(kg)	(kg)	(kg ha^{-1})	(kg ha^{-1})
Nitrogen	188.3	7.0	2.8	0.0	106.0	26.0	20.7	2.9	63.3	42.5	78.2	52.5
Phosphorus	60.8	2.2	0.5	0.0	55.3	7.5	0.0	0.0	0.2	0.7	0.2	0.9
Potassium	129.3	7.8	1.8	0.0	115.5	12.5	5.3	0.0	9.1	5.6	11.2	6.9

management, influence these processes, there is a need for a `basket of technology options', addressing the various causes of depletion. However, fertilizer being the major input, a strategy was worked out for each PPU of individual farm under research using the DSSIFER software tool (Decision Support System for Integrated Fertilizer Recommendation).

DSSIFER is a computer software, which gives crop, site and season specific fertilizer prescriptions for a specified yield target / percentage yield sufficiency based on the equations generated through Soil Test Crop Correlation research (STCR) conducted earlier in Tamil Nadu State [9]. Strategies were worked out for achieving a neutral nutrient balance in the farm using DSSIFER based fertilizer prescription rate (both organic and inorganic) for the soil fertility status of the individual PPU, by taking into account the season and specific yield target. The fertilizer recommendation derived from DSSIFER tool for the crops grown at Nathegoundenpudur irrigated farm were 407.2, 117.7 and 264.1 kg of N, P and K, respectively (Table 3). NUTMON-Toolbox generated nutrient balance was positive for all the three nutrients, when the fertilizer programme is DSSIFER based. Among the N, P and K balances, P balances were highly positive at both full and partial balance modes (20.2 and 19.7 kg ha^{-1}, respectively).

CONCLUSIONS

Nutrient budgeting with NUTMON-Toolbox at different spatial scales (*viz.*, micro (plot) and meso (farm levels) exhibited a trend of depletion of N and K from soil reserve, whereas P was positive indicating the need for carefully redefining N and K management strategies. But the DSSIFER based fertilizer prescription turns the negative balance of N and K in to a positive one. So this research proves that system's approach via NUTMON and DSSIFER serves as a tool to identify the depletion of nutrients and helps to suggest the management options for sustainable farming.

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