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Monitoring Soil Nutrient Balance in Different Agroclimatic Zones of Tamil Nadu Using Nutmon Tool

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An investigation was carried out to monitor the nutrient flows and stocks and to calculate the nutrient balance both at crop activity level and at farm level in different Agro-Climatic Zones of Tamil Nadu. A total number of 139 farms covering Cauvery Delta Zone, North Western Zone, Western Zone, North Eastern Zone and Southern Zone representing irrigated as well as rainfed farming systems were selected. Farm inventory and periodical monitoring along with soil and plant sampling were done to generate data required for the calculation of nutrient balance using NUTMON-tool. The results indicated that nitrogen and potassium were negative in majority of the farms and in all the zones and phosphorus was negative in few farms. The outcome from this study will be useful to agricultural policy makers and also to the farmers to design policy interventions to mitigate the negative nutrient balance.

Key words: Nutrient balance, Nutmon, Agroclimatic zones

Decline in soil fertility seldom gets the same public attention as floods and droughts, since it is a gradual process and not associated with catastrophes and mass starvation. Monitoring the changes in soil nutrient stocks over time in a given farm or a region would help to quantify the extent of nutrient mining and to provide an early warning on adverse trends in nutrient inflows and outflows on a farm. Hence, a quantitative knowledge on the depletion of plant nutrients from soil is essential to understand the status of soil degradation and to devise optimum nutrient management strategies. The success of production agriculture depends on the exploitation of the world's capital held in the form of soil organic matter and nutrients. The unintended outcome of production oriented agriculture is recent global degradation of soil and water resources and the consequent loss of biodiversity (Srivastava *et al*., 1996). Nutrient monitoring (NUTMON) is a method that quantifies systems' nutrient inflows and outflows, resulting in nutrient balances (Vlaming *et al*., 2001). A nutrient balance when determined at the level of individual activity (crop, livestock, *etc*.) within a farm is a very useful and variable tool providing insight into causes and magnitudes of losses of nutrients from the agricultural production system. Monitoring of nutrient stocks and flows is a tool for assessing the degree of "nutrient mining" in an agroecosystem. Nutrient monitoring has been a valuable tool for scientists to summarize and facilitate the policy makers to understand the nutrient cycling in agroecosystems and used as regulatory policy instruments (De Walle and Sevenstar, 1998).

Papers on quantification and management of on-farm nutrient flows in tropical land use systems have been published in the past years (Van der Heide, 1989; Jagadeeswaran, 2003; Surendran *et al* 2005; Surendran and Murugappan, 2007 and Abebayehu Aticho *et al*., 2011). The NUTMON-Toolbox (Nutrient Monitoring) is a very useful Decision Support System (DSS), which helps to monitor and evaluate the impact of technologies applied by providing scientific and quantitative information (Vlaming *et al*., 1997 and De Jager *et al*., 1998). With this background knowledge, the present study was carried out to monitor the nutrient stocks and flows and to quantify nutrient balance in major crops and cropping systems using Nutrient Monitoring (NUTMON) Tool in five Agro-Climatic Zones of Tamil Nadu.

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Materials and Methods

Study area

The study was carried out in five major agro-climatic zones of Tamil Nadu *viz*., North-Eastern, North-Western, Western, Cauvery-Delta and Southern zones during 2011-2012 in one year complete crop period. The selection of farms was done considering various cropping pattern/system, farm size and management variations. Totally 139 farms (47 in Cauvery-Delta zone; 29 in North-Western zone; 21 in Western zone; 20 in North Eastern zone and 22 in Southern zone) were selected in the 5 agro-climatic zones involving the major cropping systems and varying input levels.

Major Crops / cropping systems studied

Under high Input System (Irrigated) Rice – rice – pulses; Rice – sugarcane; Turmeric –

sugarcane;Turmeric – banana; Sugarcane – oilseeds; Cotton-oilseeds; Sugarcane; Maize; Gingelly; Tapioca and Banana as single crop and under low Input System (Rainfed) Groundnut + redgram; Sorghum + pulses; Sorghum alone; Groundnut alone; Cotton alone; Tapioca alone and Maize alone.

Calculation of nutrient balance

The nutrient flow taking place in a crop / cropping system covers all possible inputs and outputs. The possible inputs (mineral fertilizers, organic manures, atmospheric deposition, biological nitrogen fixation and sedimentation) and possible outputs (nutrient uptake by economic produce, uptake by crop residue, leaching, ammonia volatilization and erosion loss) were quantified from farm database and laboratory analysis. Mathematical functions were also used to calculate nutrient balance at different levels *viz*., crop or cropping system and farm, as a whole.

A decision support system for nutrient monitoring under agricultural land use *viz.*, NUTMON-Tool (Vlaming *et al*., 2001) was employed to monitor the nutrient flow and balance. The tool calculates flows and balances of the macronutrients (N, P and K) of the farm through independent assessment of major inputs and outputs as follows.

Net soil nutrient balance $= \Sigma$ (Nutrient INPUTS)

$- \Sigma$ (Nutrient OUTPUTS)

NUTRIENT BALANCE

Mineral fertilizer (IN *1*)		**Crop uptake (*OUT 1*)**
Organic manure (IN *2*)		**Crop residue (*OUT 2*)**
Atmospheric deposition (IN *3*)	—	**Leaching (*OUT 3*)**
Biological N fixation (*IN 4*)		**NH_3 volatilization (*OUT 4*)**
Sedimentation (*IN 5*)		**Erosion (*OUT 5*)**

Σ IN (1-5) - Σ OUT (1-5)

The study was carried out on a farmers' participatory approach. The resource inventory was carried out to generate basic information and the periodical monitoring was done to quantify the nutrient flows in the farm. The collected and analyzed data were entered in Nutmon-tool to quantify the balance.

Results and Discussion

Agro-climatic zone wise findings

In Cauvery Detla zone (Thanjavur and Tiruvarur district), the major crops grown are rice-pulses or rice-rice-pulses; gingelly, maize; cash crops like banana-sugarcane and coconut. In Pudukottai district the crops like sugarcane, groundnut and maize are grown. The soils are clay, clay loam, sandy loam in texture with good water holding capacity. The farmers go for application of farm yard manure (FYM), inorganic fertilizers like DAP, urea, potash, complex and mixers even for rice and cash crops whereas, coconut receives only FYM. In some areas the sheep penning is also practiced to add organic manure. The nitrogen balance in soil vary from -115 kg ha^{-1} to 187 kg ha^{-1} with a mean of 77 kg ha^{-1}, which is very low in status; phosphorus balance vary from -8 kg ha^{-1} to 50 kg/ha with a mean of 25 kg ha^{-1}, which is high status; potassium balance vary from 49 kg ha^{-1} to 371 kg ha^{-1} with a mean of 209 kg ha^{-1}, which is medium status (Table 1).

In North Eastern zone (Villupuram and Cuddalore district), the major crops grown in this region are sugarcane, rice, groundnut and pulses. As far as nutrient management is concerned, farmers go for application of sufficient quantity of FYM, biocompost, biofertilizers, inorganic fertilizers like DAP, urea, potash, complex fertilizers, since the district is dominated by sugarcane. The nitrogen balance in soil vary from -155 kg ha^{-1} to 248 kg ha^{-1} with a mean of 51 kg ha^{-1}, which is very low in status; phosphorus balance vary from -11 kg ha^{-1} to 33 kg ha^{-1} with a mean of 15 kg ha^{-1}, which is medium status; the potassium balance vary from 26 kg ha^{-1} to 255 kg ha^{-1} with a mean of 137 kg ha^{-1}, which is medium status (Table 1).

In North Western zone (Dharmapuri and Krishnagiri district), the major crops grown are rice, sugarcane, turmeric, banana, vegetables, flowers, tapioca under assured irrigated area and in rainfed areas tapioca, groundnut, sorghum, Bengal gram and mango plantation. The soils are loamy to sandy loam in texture with good production potential. As far as the nutrient management is concerned, farmers go for application of sufficient quantity of FYM, inorganic fertilizers like DAP, urea, potash, complex and mixers both by direct application and by drip fertigation. The nitrogen balance in soil vary from -41 kg ha^{-1} to 152 kg ha^{-1} with a mean of 48 kg ha^{-1}, which is very low in status; phosphorus balance vary from 12 kg ha^{-1} to 45.0 kg ha^{-1} with a mean of 23 kg ha^{-1}, which is high status; the potassium balance vary from -42 kg ha^{-1} to 268 kg ha^{-1} with a mean of 124 kg ha^{-1}, which is medium (Table 1).

In Western zone (Coimbatore and Erode district), the major crops grown are rice, sugarcane, maize, cotton, sunflower, banana, vegetables in irrigated farms and sorghum in rainfed areas. As far as the nutrient management is concerned, farmers go for application of sufficient quantity of FYM, inorganic fertilizers like DAP, urea, potash, complex fertilizers. Balanced application of NPK is lacking among small and marginal farmers, as it is restricted by fertilizer availability and purchasing power. The nitrogen balance in soil vary from -242 kg ha^{-1} to 264 kg ha^{-1} with a mean of 76 kg ha^{-1}, which is very low in status; phosphorus balance vary from -6 kg ha^{-1} to 30 kg ha^{-1} with a mean of 9 kg ha^{-1}, which is low status; the potassium balance vary from -374 kg ha^{-1} to 278 kg

Table 1. An overview of soil nutrient balance in different agroclimatic zones of Tamil Nadu

Agro-climatic zone (No. of farms studied)	N balance (kg/ha)	P balance (kg/ha)	K balance (kg/ha)
Cauvery Delta (47)			
Minimum	-115	-8	49
Maximum	187	50	371
Mean	77	25	209
Standard Deviation	85	18	101
North Western (29)			
Minimum	-41	12	-42
Maximum	152	45	268
Mean	48	23	124
Standard Deviation	63	9	89
Western Zone (21)			
Minimum	-242	-6	-374
Maximum	264	30	278
Mean	76	17	84
Standard Deviation	162	9	181
North Eastern (20)			
Minimum	-155	-11	26
Maximum	248	33	255
Mean	51	15	138
Standard Deviation	126	12	75
Southern Zone (22)			
Minimum	-105	-11	-56
Maximum	167	14	204
Mean	21	4	116
Standard Deviation	76	9	75

ha^{-1} with a mean of 84 kg ha^{-1}, which is low in status (Table 1).

In Southern Zone (Ramanathapuram, Toothukudi and Tirunelveli district) the major crops grown are sugarcane, rice, groundnut and pulses. As far as the nutrient management is concerned, farmers go for application of sufficient quantity of FYM, DAP, urea and potash. The nitrogen balance in soil vary from -105 kg ha^{-1} to 167 kg ha^{-1} with a mean of 21 kg ha^{-1} which is very low in status; phosphorus balance vary from -11 kg ha^{-1} to 14 kg ha^{-1} with a mean of 4 kg ha^{-1}, which is low in status; the potassium balance vary from -56 kg ha^{-1} to 204 kg ha^{-1} with a mean of 116 kg ha^{-1}, which is in low status (Table 1).

In all the zones nitrogen and potassium balance were negative in majority of farms and phosphorus was also negative to some extent. This variation might be due to, the amounts of N, P and K withdrawn from soil by harvest; quantity of N, P and K added to soil (through fertilizer, wet deposition, biological fixation and other inputs) and their susceptibility for the removal through leaching and erosion (Abebayehu Aticho *et al*., 2011). The standard deviation of N balance is high in Western Zone (161.5 kg ha^{-1}) and low in North Western zone (62.7 kg ha^{-1}). The standard deviation of P is high in Cauvery delta zone (17.8 kg ha^{-1}) and low in Southern zone (8.8 kg ha^{-1}), whereas the standard deviation in K balance is high in Western zone (180.5 kg ha^{-1}) and low in Southern zone (74.6 kg ha^{-1}).

The soil nutrient balance calculated for different cropping systems *viz*., rice, sugarcane, banana, vegetables and other crops cultivated both under irrigated and rainfed conditions followed in different agroclimatic zones of Tamil Nadu are presented in Table 2. In rice based cropping system, the nitrogen balance varied from -115 kg ha^{-1} to 187 kg ha^{-1} with a mean and standard deviation of 63 and 83, respectively. The phosphorus balance varied from -10 to 50 kg ha^{-1} with a mean of 29 kg ha^{-1} and the potassium availability varied from -56 to 371 kg ha^{-1} with a mean of 182 kg ha^{-1}. The N and P balance under sugarcane based system recorded negative value -115 and -11 kg ha^{-1}, respectively. Whereas, the K balance under this system was positive and varied from 26 to 345 with a mean of 165 kg ha^{-1}. The N and K balance were highly negative in banana based cropping system with a minimum value of -173 kg ha^{-1} and -206 kg ha^{-1}, respectively. Rainfed system recorded very low mean values of 3 kg ha^{-1} for N, 6 kg ha^{-1} for P and 113 kg ha^{-1} for K, which reflect the low input application for rainfed crops.

Dobermann *et al.*(1996a) reported that the average partial net K balance studied under different cropping systems in Asia was highly negative in all NPK combinations tested (-34 to –63 kg ha^{-1}) per crop cycle. Velu and Ramanathan (1996) reported that the N balances in the wet land soil of Tamil Nadu under rice was found to be 55 kg N ha^{-1} yr^{-1} during warmer season (summer and kuruvai), while it was negative (-31 kg N ha^{-1}) during the cold (thaladi) season. The negative K balance observed in many farms of Western and Southern Zones is in accordance with the findings of the Coimbatore centre of Long Term Fertilizer Experiment (LTFE), which proved beyond doubt that K depletion still proceed even in plots receiving fertilizer K at 150 % of recommended level (Murugappan *et al*., 1999). Chandrasekharan and Sankaran (1996) recorded a negative K balance (-441.8 kg ha^{-1}) in maize-rice-cotton system.

Nutrient monitoring studies using NUTMON–Tool in a farm at Coimbatore district reported a positive N balance (15.3 kg ha^{-1}) and negative P (-9.6 kg ha^{-1}) and K (-157.8 kg ha^{-1}) balance (Jagadeeswaran, 2002). Similar studies in irrigated farms of Coimbatore and Erode districts by Surendran and Murugappan (2007) indicated that the N, P and K balances were negative with sugarcane, turmeric, banana, tapioca, paddy and cotton. However, in certain horticultural and oilseed crops (*viz*., bhendi, brinjal, cucumber, sunflower and coconut) the N, P and K balances were mostly positive.

Thus, to summarize, nutrient application for rainfed and low value crops was sub-optimal and

Table 2. Soil nutrient balance under different cropping systems studied at different Agroclimatic zones of Tamil Nadu

Major cropping systems studied	N balance (kg/ha)	P balance (kg/ha)	K balance (kg/ha)
Rice based system			
Minimum	-115	-10	-56
Maximum	187	50	371
Mean	63	20	182
Standard deviation	83	17	100
Sugarcane based system			
Minimum	-155	-11	26
Maximum	248	46	345
Mean	63	20	165
Standard deviation	114	14	87
Banana based system			
Minimum	-173	-6	-206
Maximum	264	28	278
Mean	83	15	113
Standard deviation	135	9	140
Vegetables and other crops			
Minimum	-242	-11	-374
Maximum	218	35	234
Mean	19	12	74
Standard deviation	105	13	138
Irrigated system			
Minimum	-173	-11	-206
Maximum	264	50	371
Mean	69	21	161
Standard deviation	107	15	116
Rainfed system			
Minimum	-105	-10	-15
Maximum	109	14	186
Mean	3	6	113
Standard deviation	77	9	70

rarely met from external sources. On-farm nutrient recycling was rarely practiced irrespective of zone and farm sizes. The causes for negative nutrient balances identified in different zones were, i) soil erosion ii) nitrogen leaching and ammonia volatilization (due to broadcasting and failure to irrigate immediately after application, failure to apply nitrogen inhibitors) iii) continues cultivation in the same land without adding sufficient manures/ fertilizers, iv) Failure to recycle the crop residues generated on-farm and v) non-inclusion of leguminous crops in the cropping system.

Conclusion

The present study enumerates the situation of sub-optimal application of major nutrients, which is not in accordance with the requirement of crops/ cropping systems followed in many areas. Restoration of soil fertility can no longer be regarded as an issue connected with the use of organic and inorganic nutrient sources only. It requires a long-term perspective and a holistic approach. The holistic approach should take care of the nutrient stocks within a farm and their flow between various activities within the farm. In the present study, the nutrient balance at farm level is arrived by matching nutrient inflows into the farm and nutrient exports out of the farm. Such a knowledge intensive management plan requires participatory research and development focus rather than a purely technical focus. The outcome from this will be useful to agricultural policy makers and also to the farmers to design policy interventions to mitigate undesirable trends, if any in nutrient management.

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