Madras Agric.J.,2026; https://doi.org/10.29321/MAJ.10.26M001

RESEARCH ARTICLE

Nutrient Budgeting using NUTMON - Toolbox for Sustainable Agriculture - A 51-Year-Old Long-Term Fertilizer Experiment in Tamil Nadu

G. Sridevi[1], Priya E. E[1], Priyadharshini.B[1], D.Jayanthi[1] and U.Surendran[2]

[1]Department of Soil Science and Agricultural Chemistry, Agricultural College & Research Institute (AC & RI), Tamil Nadu Agricultural University, Coimbatore- 641 003, India.

[2]Land and Water Management (Agriculture) Division, KSCSTE- Centre for Water Resources Development and Management, Kozhikode -673 571

ABSTRACT

NUTrient MONitoring (NUTMON) is interactive computer software that helps decision-makers use data and models to solve unstructured problems. An attempt was made to carry out nutrient audits, which include the calculation of nutrient balance at the field (farm) level and the evaluation of trends in nutrient mining/enrichment using the NUTMON-Toolbox. Nutrient Monitoring (NUTMON) is a multiscale approach that assesses the stocks and flows of N, P, and K in a well-defined geographical unit based on the inputs viz., mineral fertilizers, manures, meteorological data, atmospheric deposition, sedimentation, and outputs of harvested crop products, residues, leaching, denitrification, and erosion losses. The nutrient budgeting study was carried out using the NUTMON model for the Long-term fertilizer experiment trial, adopting the standard procedures and calculations (viz., Chemical fertilizers and Integrated nutrient management). The calculated nutrient balances at crop activity level indicated a Positive balance for nitrogen and phosphorus in 100 % NPK + FYM @10 t ha^{-1}, and a negative balance was observed for potassium in all maize treatments. The results revealed that the nutrient management practices are not appropriate and sustainable. Management options to mitigate this mining by judiciously manipulating all inputs and outputs through an integrated system approach are suggested, and one way to redefining the nutrient recommendation based on site-specific requirements was worked out. A strategy was worked out to derive the nutrient prescription rate using site-specific soil test results for the individual crops of the selected farms. By assuming prescribed nutrients are applied to the individual PPUs, nutrient balances were simulated with NUTMON-Toolbox, and the results indicate positive balances for N and P and negative balances for K.

Received: 13 Oct 2025

Revised: 13 Dec 2025

Accepted: 16 Mar 2026

Keywords: *Nutrient balance, Inputs, Outputs, Fertilizers, Nutrient mining, NUTMON, Yield*

INTRODUCTION:

Nutrient budgeting is a systematic approach used in agriculture to assess the balance of nutrients, particularly nitrogen (N), phosphorus (P), and

*Corresponding author mail: sridevi@tnau.ac.in

potassium (K), in cropland. This method helps identify whether there is an excess or deficiency of nutrient inputs, which is crucial for optimizing fertilizer use and enhancing agricultural sustainability. NUTMON (NUTrient MONitoring), initiated by Stoorvogel and Smaling, is a nutrient-monitoring concept in Sub-Saharan Africa that employs input-output analysis to assess nutrient balances, focusing on inputs such as fertilizers and outputs such as harvested crops, leaching, and erosion (Færge & Magid, 2004). The NUTMON model is a comprehensive tool for nutrient budgeting in agricultural systems, focusing on assessing nutrient flows and balances. It evaluates the inputs and outputs of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) within defined geographical units. This model has been applied in various contexts, demonstrating its utility in addressing soil fertility issues and enhancing agricultural productivity. NUTMON facilitates the calculation of nutrient balances by accounting for inputs (e.g., fertilizers, manures) and outputs (e.g., harvested crops, leaching) (Surendran *et al*., 2016) (Surendran et al., 2005). It has been effectively utilized in regions such as Nigeria and India to assess nutrient management practices and recommend improvements (Abdulrahman et al., 2019) (Surendran et al., 2005). In Nigeria, NUTMON revealed positive nutrient balances in irrigated rice farms, indicating effective fertilizer use despite low soil fertility (Abdulrahman et al., 2019). In Tamil Nadu, India, the model highlighted negative balances of N and K, prompting the need for integrated management strategies to mitigate nutrient mining (Surendran et al., 2016) (Surendran et al., 2005). NUTMON supports sustainable agricultural practices by providing data-driven insights for fertilizer recommendations, ultimately enhancing soil fertility and crop yields (Kathuku et al., 2007). NUTMON is a methodology for analyzing nutrient flows and balances in farming systems. It integrates economic performance with nutrient management, utilizing the NUTShell tool to facilitate the assessment of nutrient and economic flows, particularly in peri-urban agricultural contexts (Bostch et al., 2001). The model's adaptability across various agro-ecological zones underscores its significance in global food security efforts. Conversely, while NUTMON offers valuable insights into nutrient management, its effectiveness depends on accurate data collection and farmer engagement, which can be challenging in resource-limited settings.

Nutrient budgeting using the NUTMON (Nutrient Monitoring) toolbox is a critical approach for sustainable agriculture, enabling the assessment of nutrient flows and balances in farming systems. This methodology aids in identifying nutrient surpluses or deficits, thereby enhancing nutrient use efficiency and promoting sustainable practices. The following sections outline the key aspects of nutrient budgeting through NUTMON. Nutrient budgets calculate the balances of nitrogen (N), phosphorus (P), and potassium (K) in agricultural systems, providing insights into nutrient-use efficiency (Ludemann, 2023). For instance, in 2020, average N surpluses varied significantly, with Africa at approximately 10 kg N/ha/year and Asia exceeding 90 kg N/ha/year (Ludemann, 2023). Nutrient budgeting can mitigate soil-water-air (SWA) contamination by monitoring nutrient surpluses linked to excessive fertilizer use (Bhattacharyya et al., 2021). Effective nutrient management practices, such as crop rotation and organic amendments, can enhance nutrient balance and reduce environmental impacts (Willoughby et al., 2022).

MATERIALS AND METHOD

Experimental site and climate

The field experiment was carried out in the research farm of Tamil Nadu Agricultural University, Coimbatore district of Tamil Nadu, India Long Term Fertilizer Experiment (LTFE) was started in 1972 at Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore and being maintained till date 11° N latitude, 77° E longitude with an elevation of 426.7 m above MSL with finger millet-maize cropping sequence under irrigated condition, soil classified as *Inceptisol* having black calcareous sandy clay loam soil (*Vertic Ustropept*) belongs to Periyanaickenpalayam series.

The climate of Coimbatore is tropical, characterized by hot and humid summers and cold winters. The maximum and minimum temperatures at the experimental site are about 33.9 and 22.1 °C, respectively. The average annual rainfall recorded from January 2023 to June 2023 is 1.34 cm.

Initial soil analysis during 1972 revealed that the organic carbon (0.30%) and available N status (178 kg ha^{-1}) were low, available P was medium (12.3 kg ha^{-1}), and available K was high (907 kg ha^{-1}). In the LTFE trial, until 2020-2021, 110 crops were raised, and data on crop yield, nutrient uptake, changes in soil fertility status, and nutrient balance were reported.

Experimental details

Long Term Fertilizer Experiment consists of ten different treatments *viz.,* 50% NPK (T_1), 100% NPK (T_2), 150% NPK (T_3), 100% NPK + Hand Weeding (T_4), 100% NPK + Zinc (T_5), 100% NP (T_6), 100% N (T_7), 100% NPK + FYM (T_8), 100% NPK (Sulphur free source) (T_9) along with control (T_{10}) replicated thrice by laid in a Randomized Block Design.

Fertilizer levels were 250:75:75 kg ha^{-1} for Maize and 60:30:30 kg NPK ha^{-1} for Finger Millet (N in 3 splits), which were supplied through Urea, Single Superphosphate (SSP), and Muriate of Potash (MOP). At the time of sowing, 50% of RDF N was applied in the form of urea, and 100% of RDF of P and K were applied as Single Super Phosphate (SSP) and Muriate of Potash (MOP), respectively, for all the treatments except for T_9 (100% NPK – S). DAP can be used as a source. Another 50% of N was applied in two equal splits during the knee-high and pre-tasselling stages of crop growth. For INM (100% NPK + FYM) treatment, plots were applied with 10 t ha^{-1} of FYM for every crop.

Structure of NUTMON -Toolbox

NUTMON-Toolbox is a user-friendly computerized software for monitoring nutrient flows and stock, especially in tropical soils (Vlaming *et al.* 2001). This product consists of a structured questionnaire, a database, and two simple static models (Fig 1). The tool calculates flows and balances of the macronutrients (N, P, and K) and the farm's economic performance through an independent assessment of major inputs and outputs using the following equation.

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

There is a set of five inputs (IN 1-5 mineral fertilizer, organic inputs, atmospheric deposition, biological nitrogen fixation and sedimentation), five outputs (OUT 1-5 farm products, other organic outputs, leaching, gaseous losses, erosion), and six internal flows (consumption of external feeds, household waste and human excreta, crop residues, grazing, animal manure, and home consumption of farm products). Nutrient flows are quantified in three ways in NUTMON, viz., using primary data, estimates, and assumptions. A detailed description of NUTMON-Toolbox is provided in Surendran *et al* (2015). Farm inventory and farm monitoring of nutrient flows into and out of the farm were conducted using available questionnaires through farmer participatory analysis.

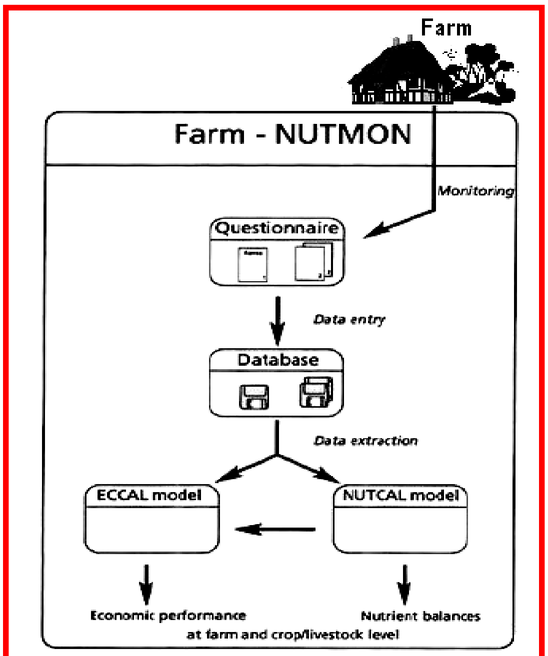

Fig.1. NUTMON – Toolbox structure

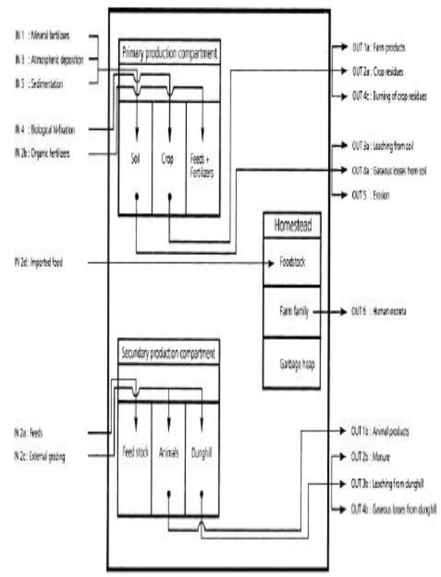

Fig. 2. Inflows and outflows in NUTMON tool box

Fig.1. On-farm monitoring of nutrient balance using NUTMON-Toolbox

Calculating nutrient flows and nutrient balance

The data were analysed using the data processing module, and the nutrient flows and nutrient balances for individual farms were calculated by combining information from the farm inventory, farm monitoring, and the background database. Soil sampling and analysis provided information on the current nutrient status of soils.

Data analysis and interpretation

The data processing module produced farm reports with biophysical results for individual activities and for the farm as a whole. The resultant NPK balances at the PPU level, FSU level, and also at the whole farm level were expressed as full (Σ *IN* -Σ*OUT*) and partial [Σ *IN* -(*OUT 1* + *OUT 2*)] nutrient balance.

RESULTS AND DISCUSSION

Soil Carbon (SOC)

The mean SOC in the post-harvest soil of finger millet ranged from 4.93 g kg-1 (control) to 7.50 g kg^{-1} (100 % NPK + FYM) and was significantly higher than in all other treatments. The increase in NPK dose from 50% to 150% increased SOC. However, omission of K or PK resulted in a significant decrease in SOC. Mean SOC values showed that HW and Zn applications significantly increased SOC over 100% NPK (Fig. 2).

A 149% increase in SOC was observed in the 50-year experimental results for 100% NPK+ FYM (T8), followed by 150% NPK, and the increase in the control was 65.3%. Direct addition of organic matter from farmyard manure, which contains 30% carbon, might be a reason for the increase in organic carbon content in the case of 100% NPK + FYM treatment, and it also contains carbonaceous material for decomposition by microorganisms and subsequent conversion of mineralized organic colloids, besides adding them to the soil reserves. The application of organic matter stimulates the activity of microorganisms, leading to higher biomass production and higher humification rate of added organic manures. The microorganisms flourish and later perish, thereby increasing the organic carbon pool and the organic carbon content reported by Bhattacharyya *et al.* (2011).

Soil Nutrient Status

In the crops, the available N, P, and K status was highest under 100% NPK + FYM@ 10 t ha^{-1}, followed by 150% NPK. Increasing the NPK levels (50-150%) significantly improved the soil's available N, P, and K status. Continuous addition of N alone reduced the soil's available N, P, and K status compared to the NPK treatments. Skipping K or PK resulted in decreased available K status in both crops compared to 100% NPK, indicating the importance of balanced fertilization. The measured increase in potentially available N status of soil was most likely due to the addition of FYM along with NPK, and was probably related to increases in soil

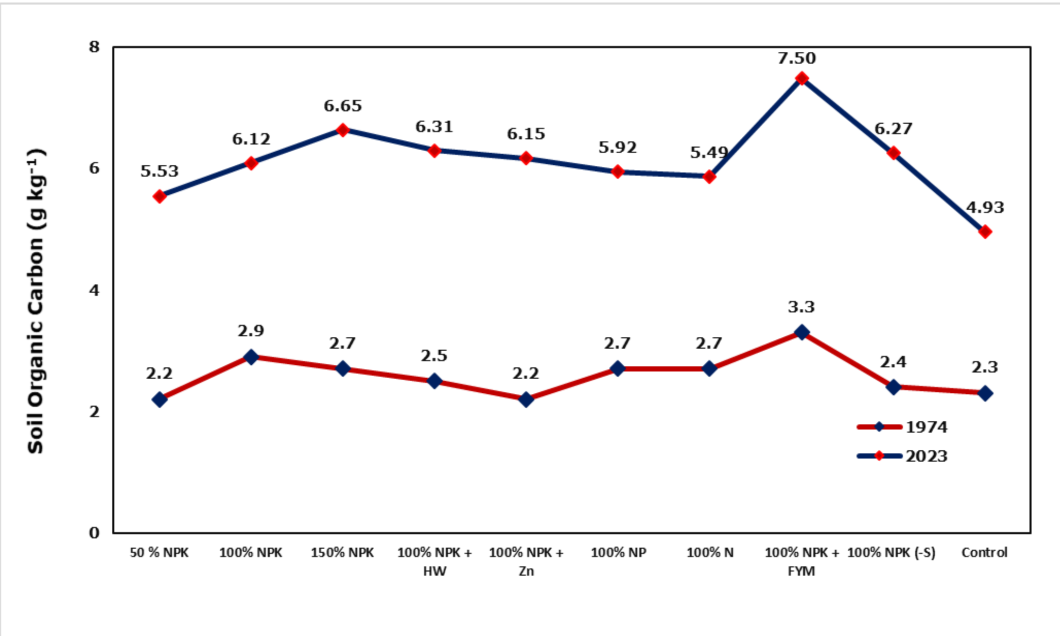

Fig.2. Effect of long-term fertilization on the soil organic carbon status of the maize crop

Organic carbon status. In the post-harvest sample of the maize crop, where the minimum available nitrogen concentration was recorded in the absolute control (152 kg ha-1), followed by the 50% NPK and 100% N alone treatments. However, the addition of suboptimal, optimal, and superoptimal fertilizer dosages of N leads to increased N content and enrichment of N pools (Bairwa *et al*. 2021) in soil. The graded level of NPK fertilizers (50% NPK to 150% NPK) has been observed to increase the available phosphorus level in soil. The omission of P fertilizer resulted in a detrimental decrease in available P status (13.9 kg ha^{-1}). FYM treatment might be due to the direct addition of K from FYM,, and FYM also limits K fixation in soil and enhances the release of fixed K by contact of organic matter with clay (Manimaran et al., 2022) (Table 1).

The NUTMON tool generated the nutrient balance of the maize crop.

The farm selected for the study is located in the eastern block of Tamil Nadu Agricultural University, Coimbatore. The area of the farm is 1 ha, and the farmer uses inorganic and INM practices. The OF farm comprises three farm section units (FSUs) and is divided based on homogeneous soil properties, slope, and crops grown in the farm. These FSUs consist of two Crop activities/Primary Production Units (PPUs), viz., PPU 1 (Finger millet) and PPU 2 (Maize). Nutrients for the farm were mainly provided through chemical fertilizers and organic manures, met from external sources, rather than on-farm-generated manures. The farmer, in addition to using on-farm manure, also purchases manure off-farm and imports it onto the farm.

Nutrient balance at crop activity (PPU) level in OF and INMF

The NUTMON tool generated the nutrient balance of the maize crop.

The farm selected for the study is located in the eastern block of Tamil Nadu Agricultural University, Coimbatore. The area of the farm is 1 ha, and the farmer uses inorganic and INM practices. The OF farm comprises three farm section units (FSUs) and is divided based on homogeneous soil properties, slope, and crops grown in the farm. These FSUs consist of two Crop activities/Primary Production Units (PPUs), viz., PPU 1 (Finger millet) and PPU 2 (Maize). Nutrients for the farm were mainly provided through chemical fertilizers and organic manures, met from external sources, rather than on-farm-generated manures. The farmer, in addition to using on-farm manure, also purchases manure off-farm and imports it onto the farm.

Table 1. Long-term fertilization and manuring on the soil fertility status of the post-harvest soil of the maize crop in an Inceptisol

Treatments	Initial soil Status (kg ha^{-1})			Post-harvest Soil (kg ha^{-1})		
	Available Nitrogen	Available Phosphorus	Available Potassium	Available Nitrogen	Available Phosphorus	Available Potassium
T_1-50 % NPK	170	20.2	561	170	21.2	557
T_2-100 % NPK	192	23.1	624	191	24.1	626
T_3- 150 % NPK	226	25.2	721	229	26.2	719
T_4- 100 % NPK+HW	199	22.2	626	202	23.2	622
T_5- 100 % NPK + Zn	212	23.0	621	214	24.0	624
T_6- 100 % NP	188	21.8	584	191	22.8	584
T_7- 100 % N	182	12.9	562	183	13.9	563
T_8- 100 % NPK +FYM	242	29.4	765	245	30.3	766
T_9 - 100 % NPK (-S)	191	21.5	613	193	22.4	617
T_{10}- Control	149	8.6	526	152	9.58	523
SEd	4.6	0.84	10.1	6.1	0.85	10.0
CD (p=0.05)	9.4	1.72	20.7	13	1.74	21.0

Table 2. NUTMON -Toolbox generated N balance for Maize

Treatments	Inputs (kg /ha)					Outputs (kg/ha)					Partial balance (kg ha^{-1})	Full balance (kg ha^{-1})
	IN 1	IN 2	IN 3	IN 4	IN 5	OUT 1	OUT 2	OUT 3	OUT 4	OUT 5		
50% NPK	90.0	10.6	0.7	0	0	59.2	65.4	21.4	8.6	0.2	-53.5	-24.0
100% NPK	135.0	10.8	0.7	0	0	65.4	71.2	37.4	11.0	0.2	-38.7	9.2
150% NPK	202.5	10.2	0.7	0	0	65.8	74.5	53.4	14.6	0.2	70.7	72.4
100% NP	135.0	10.6	0.7	0	0	64.2	73.2	37.4	11.0	0.2	-39.7	8.2
100% N	135.0	10.6	0.7	0	0	44.8	52.6	37.4	11.0	0.2	0.3	48.2
100% NPK + FYM	135.0	78.6	0.7	0	0	76.2	81.6	29.6	10.4	0.2	16.3	55.8
Control	0.0	9.2	0.7	0	0	31.5	36.4	2.4	0.8	0.1	-61.3	-58.7

Partial balance = (ΣIN1-2) — (Σ OUT1-2) **Full balance = (Σ *IN* 1-5) – (Σ *OUT1-5*)

Nutrient balance at crop activity (PPU) level in OF and INMF

NUTMON -Toolbox generated N balance for Maize

Nutrient balances at the PPU level, covering all the FSUs in the farm, generated using NUTMON –Toolbox, are presented in Table 2. All the treatments showed a positive N balance, except control and 50% NPK (24 and 58.7 kg ha^{-1}), respectively. With respect to K, all the treatments showed a negative balance.

NUTMON -Toolbox generated P balance for Maize

Nutrient balances at the PPU level, covering all the FSUs in the farm, generated using NUTMON –Toolbox, are presented in Table 3. All the treatments showed positive balance of phosphorus except control and 50 % N (-28.6 kg ha^{-1}), and control (-17.4 kg ha^{-1}) was negative, respectively.

NUTMON -Toolbox generated K balance for Maize

With respect to K, all the treatments showed a negative balance (Table 4)

In nutshell, integrated nutrient management practices (100% NPK + FYM) exhibited a positive nitrogen and phosphorus balance, which was clearly observed. The K balance was negative due to very limited use of external inputs, such as mineral fertilizers and off-farm manures.

Crop Yield

Conjoint application of inorganic and organic (T8 :100 % NPK+FYM) practices in the long run has

Table 3.NUTMON -Toolbox generated P balance for Maize

Treatments	Inputs (kg /ha)					Outputs (kg/ha)					Partial balance (kg ha^{-1})	Full balance (kg ha^{-1})
	IN 1	IN 2	IN 3	IN 4	IN 5	OUT 1	OUT 2	OUT 3	OUT 4	OUT 5		
50% NPK	31.3	2.21	0.2	0	0	15.4	16.8	0	0	0.2	1.3	1.3
100% NPK	62.5	2.21	0.2	0	0	19.8	17.2	0	0	0.2	27.7	27.7
150% NPK	93.8	2.21	0.2	0	0	24.0	27.4	0	0	0.2	44.6	44.6
100% NP	62.5	2.21	0.2	0	0	20.3	20.8	0	0	0.2	23.6	23.6
100% N	0.0	2.21	0.2	0	0	14.6	16.2	0	0	0.2	-28.6	-28.6
100% NPK + FYM	62.5	21.21	0.2	0	0	28.1	29.4	0	0	0.2	26.2	26.2
Control	0.0	2.21	0.2	0	0	9.1	10.6	0	0	0.1	-17.5	-17.4

Partial balance = (Σ IN1-2) — (Σ OUT1-2) **Full balance = (Σ *IN* 1-5) – (Σ *OUT1-5*)

Table 4. NUTMON -Toolbox generated K balance for Maize

Treatments	Inputs (kg /ha)					Outputs (kg/ha)					Partial balance (kg ha^{-1})	Full balance (kg ha^{-1})
	IN 1	IN 2	IN 3	IN 4	IN 5	OUT 1	OUT 2	OUT 3	OUT 4	OUT 5		
50% NPK	25.0	9.04	0.2	0	0	55.4	61.2	9.8	0.0	0.2	-82.6	-92.4
100% NPK	50.0	9.04	0.2	0	0	65.4	75.2	19.4	0.0	0.2	-81.6	-101.0
150% NPK	75.0	9.04	0.2	0	0	70.4	78.6	26.5	0.0	0.2	-65.0	-91.5
100% NP	0.0	9.04	0.2	0	0	58.6	68.4	19.4	0.0	0.2	-118.0	-137.4
100% N	0.0	9.04	0.2	0	0	42.6	51.3	19.4	0.0	0.2	-84.9	-104.3
100% NPK + FYM	50.0	72.4	0.2	0	0	72.4	79.6	19.4	0.0	0.2	-29.6	-49.0
Control	0.0	9.04	0.2	0	0	32.4	38.6	2.4	0.0	0.1	-62.0	-64.3

Partial balance = (Σ IN1-2) — (Σ OUT1-2) **Full balance = (Σ *IN* 1-5) – (Σ *OUT1*-5)

produced a significant positive influence on the grain yield of maize in all the years (2019-2023) with a mean grain yield of 6319 kg ha^{-1} (Table 5). This was followed by the treatments: 150 % NPK and 100 % NPK in all years, which were comparable. The increase in yield in T_8 ranged from 847 kg ha^{-1} in 2019 to 974 kg ha^{-1} in 2023, representing a 100% increase in NPK.

Application of zinc failed to produce a significant effect on the grain yield of maize compared with the 100 % NPK treatment. A remarkable decline in grain yield was noted under the S omission (T9) treatment in all 5 years (2019-2023). Hand weeding (T_4) also resulted in a lower yield than 100% NPK (T_2). When P and K were not applied, the reduction in grain yield relative to 100 % NPK + FYM was remarkable, ranging from 36.2 to 38.4 %, with a mean reduction of 38.2 %. The decline in grain yield over 100 % NPK +FYM was 16.09 -18.86 % when 100 % NP was applied. This could be attributed to the exponential growth of the microbial population and the activity of hydrolytic enzymes may also contribute to the positive outcomes of FYM treatment by Bairwa *et al.* (2021) and another reason might be due to ready supply of nitrogen having a positive response on overall improvement in crop growth, enabling the plant absorb more nutrients which empowered the

Table 5. Grain Yield of Maize as influenced by Long-Term Fertilisation Practices

Treatments	Grain yield (kg ha^{-1})					
	2019	2020	2021	2022	2023	Mean
T_1-50 % NPK	5055	4911	4983	4972	4927	4969
T_2-100 % NPK	5399	5437	5453	5461	5399	5430
T_3-150 % NPK	5421	5447	5476	5482	5494	5464
T_4-100 % NPK + HW	5330	5140	5137	5142	5101	5170
T_5-100 % NPK + Zn	5382	5363	5374	5373	5424	5383
T_6-100 % NP	5240	5155	5157	5151	5397	5220
T_7-100 % N	3986	3918	3913	3910	3814	3908
T_8-100 % NPK + FYM	6245	6301	6329	6348	6373	6319
T_9-100 % NPK (-S)	5151	5080	5087	5189	5256	5153
T_{10}-control	2721	2643	2629	2723	2804	2704
SEd	125	79	61	78	83	40
CD (P = 0.05)	214	162	125	159	170	80

plant to synthesis more quantity of photosynthates accumulating them in reproductive parts. It reflects in terms of yield and better source-sink relationship, translocation of metabolites to reproductive organs, leading to improved grain yield. The essential functions of soil microorganisms and enzymatic processes in altering and making nutrient elements accessible within the soil are well documented, and the constant application of FYM improved the physical conditions of the soil and created an ideal environment for plant development and nutrient uptake, as reported by Sridevi *et al*. (2024).

Nutrient uptake

a) Nitrogen Uptake

Application of NPK under INM practice (100% NPK+ FYM (T_8)) influenced N uptake (Fig 3) significantly, which ranged from 144.3 to 148.7 kg ha^{-1}. Addition of FYM with 100% NPK was found to increase N uptake by 33.0 to 40.0 kg ha^{-1} over 100% NPK (T_2). A significant increase in N uptake was observed as the NPK dose increased from 50% to 150% NPK. Omission of K in 100% NP treatment (T_6) and omission of PK in 100% N treatment (T_7) significantly reduced N uptake in all the 5 years of the study.

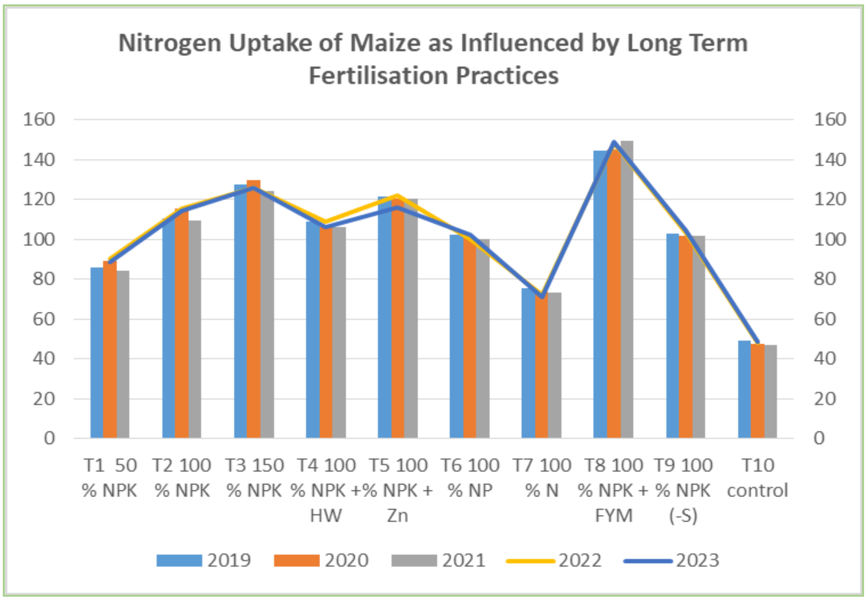

Fig 3. Nitrogen Uptake (kg ha^{-1}) of Maize as Influenced by Long-Term Fertilisation Practices

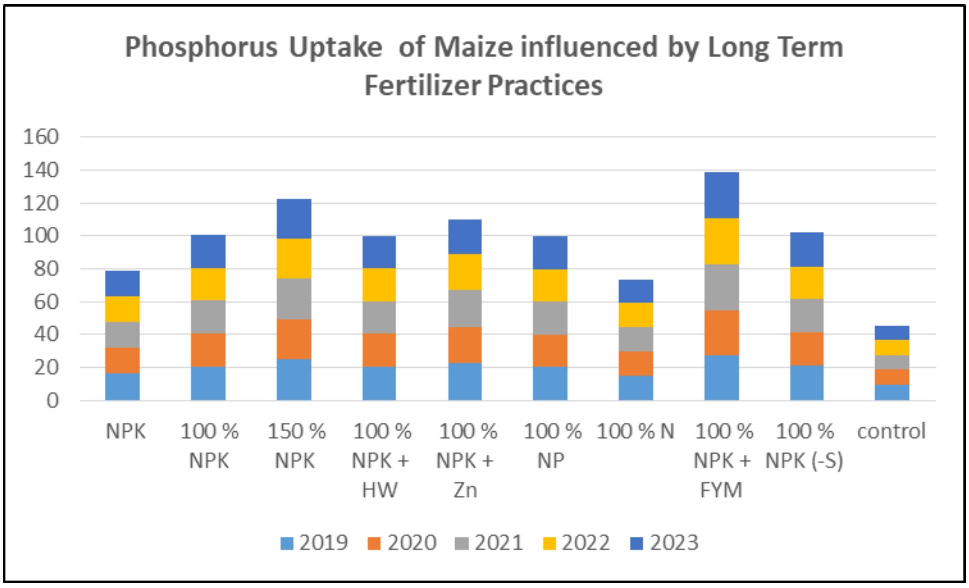

Fig 4. Phosphorus Uptake (kg ha^{-1}) of Maize as Influenced by Long Term Fertilisation Practices

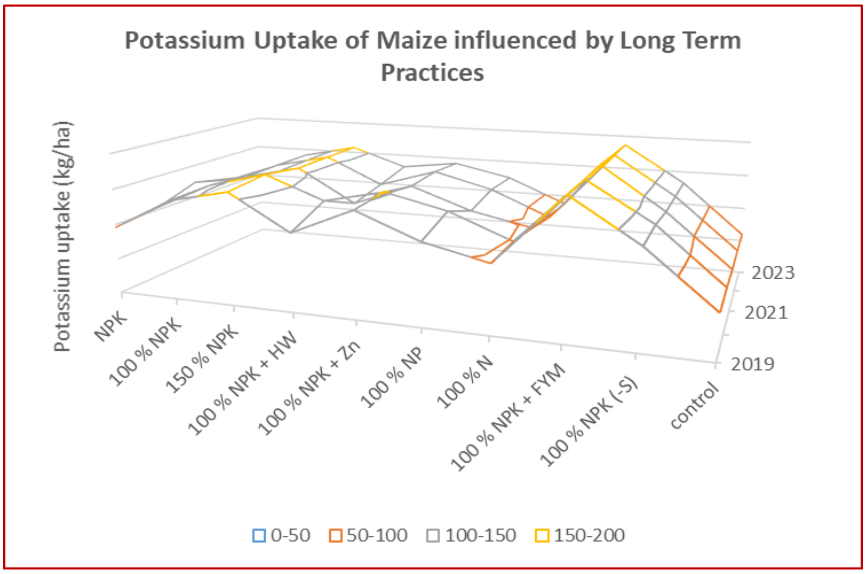

Fig 5. Potassium Uptake of Maize as Influenced by Long-Term Fertilisation Practices

b) Phosphorus Uptake

P uptake differed significantly across nutrient treatments. The highest P uptake by maize (Fig 4) was observed under 100% NPK + FYM (T_8), and it ranged from 27.4 to 28.2 kg ha^{-1}, wherein a significant increase of P uptake to the tune of 6.9 to 8.4 kg ha^{-1} was observed due to FYM application over 100% NPK (T_2). Phosphorus uptake increased from 15.8 to 24.4 kg ha^{-1} with an increase in NPK dose from 50 (T_1) to 150% (T_3).

c) Potassium Uptake

The pooled mean data for five years and the individual-year data showed that K uptake was significantly influenced by the different treatments (Fig 5). Integration of FYM @ 10 t ha^{-1} with 100% NPK recorded the highest K uptake, ranging from 187.1 (2019) to 189.1 (2021). The mean K uptake by different treatments followed the order: $T_8 > T_3 > T_5 \geq T_2 > T_9 > T_6 \geq T_4 > T_1 > T_{10}$.

CONCLUSION

Thus, in the present investigation, nutrient monitoring with NUTMON-Toolbox at different spatial scales (viz., micro (plot) and meso (farm) levels) showed a trend of depletion of N and K from soil reserves, whereas P was positive, indicating the need for carefully redefining N and K management strategies. But the simulated nutrient recommendation with soil and water conservation strategies prescription turns the negative N and K balances into positive ones. Decision Support Systems (DSS).

Hence, it is concluded that judicious use of inorganic and organic fertilizers in an integrated manner is essential to maintain better crop yield and the sustenance of soil health.

Funding and Acknowledgment

The authors acknowledge the Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, for providing lab facilities and library facilities for the writing the research article

Ethics Statement:

Field experiments were carried out with the cultivated plants and as authors we confirm that all methods were carried out in accordance with relevant Indian national guidelines, standards and legislation set for the same

Originality and Plagiarism:

The research article is outcome of the UG project studies. The article is originally prepared by the authors Consent for Publication:

All authors must agree to the content of the article and its publication in the journal.

Competing Interests:

No potential conflict of interest was reported by the author(s).

Data Availability:

All the data generated or analyzed during this study are included in this article. Data can be provided under reasonable request

Author Contributions

G. Sridevi[*1], Priya E. E[*2], Priyadharshini.B[*3], - Prepared the original manuscript

D.Jayanthi[*4] - Helped in editing the article

U.Surendran[*5] - helped in processing the data in NUTMON modelling software

REFERENCE

Abdulrahman, B. L., Jibrin, J. M., & Bashir, M. 2019. Estimating partial nutrient balance using nutmon model in irrigated rice-based farms of the Nigerian dry savanna. *Nigerian J Soil Sci*, *28*(2), 131-8. DOI:10.36265/njss.2019.280215

Bairwa, J., Dwivedi, B., Rawat, A., Thakur, R. and Mahawar, N. 2021. Long-term effect of nutrient management on soil microbial properties and nitrogen fixation in a vertisol under soybean-wheat cropping sequence. Journal of the Indian Society of Soil Science 69, 171-178.DOI: 10.5958/0974-0228.2021.00032.3

Bhattacharyya, Ranjan, Samaresh Kundu, Anil Kumar Srivastva, Hari Shankar Gupta, Ved Prakash, and Jagdish Chandra Bhatt. 2011. "Long term fertilization effects on soil organic carbon pools in a sandy loam soil of the Indian sub-Himalayas." *Plant and soil* 341:109-124. DOI:10.1007/s11104-010-0627-

Bhattacharyya, S. S., Adeyemi, M. A., Onyeneke, R. U., Bhattacharyya, S., Faborode, H. F. B., Melchor-Martínez, E. M & Parra-Saldívar, R. 2021. Nutrient budgeting—a robust indicator of soil–water–air contamination monitoring and prevention. *Environmental Technology & Innovation*, *24*, 101944. DOI:10.1016/j.eti.2021.101944

Bosch, H. V. D., Eaton, D., Wijk, M. V., Vlaming, J., & Jager, A. D. 2001. Monitoring nutrient flows and economic performance in African farming systems: the NUTMON approach and its applicability to peri-urban agriculture. In *Waste composting for urban and peri-urban agriculture: closing the rural-urban nutrient cycle in Sub-Saharan Africa* (pp. 176-192). Wallingford UK: CABI Publishing. **https://doi.org/10.1079/9780851995489.0176**

Færge, J., & Magid, J. 2004. Evaluating NUTMON nutrient balancing in sub-Saharan Africa. *Nutrient Cycling in Agroecosystems*, *69*, 10 DOI https :// doi.org/ 10.1023 / B:FRES .0000029680.97610.51

Kathuku, AN., Kimani, S. K., Okalebo, J. R., Othieno, C. O., & Vanlauwe, B. 2007. Integrated soil fertility management: Use of NUTMON to quantify nutrient flows in farming systems in central Kenya. In *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities* (pp. 283-288). Springer Netherlands. DOIhttps://doi.org/10.1007/978-1-4020-5760-1_25

Ludemann, C. I., Wanner, N., Chivenge, P., Dobermann, A., Einarsson, R., Grassini, P., ... & Tubiello, F. 2023. A global reference database in FAOSTAT of cropland nutrient budgets and nutrient use efficiency: nitrogen, phosphorus and potassium, 1961–2020. *Earth System Science Data Discussions*, *2023*, 1-24. https://doi.org/10.5194/essd-16-525-2024, 2024

Manimaran, G., Jayanthi, D., Janaki, P., Amirtham, D. and Gokila, B. 2022|. Long Term Impact of Fertilization and Intensive Cropping on Maize Yield and Soil Nutrient Availability under Sandy Clay Loam Soil (Inceptisol). *International Journal of Plant & Soil Science* 34 : 795-801. 10.9734/ijpss/2022/v34i2031223

Surendran, U., Murugappan, V., Bhaskaran, A., & Jagadeeswaran, R. 2005. Nutrient budgeting using NUTMON-Toolbox in an irrigated farm of semi arid tropical region in India-A micro and meso level modeling study. *World Journal of Agricultural Sciences*, *1*(1), 89-97. ISSN 1817-3047

Surendran, U., Rama Subramoniam, S., Raja, P., Kumar, V., & Murugappan, V. 2016. Budgeting of major nutrients and the mitigation options for nutrient mining in semi-arid tropical agro-ecosystem of Tamil Nadu, India using NUTMON model. *Environmental monitoring and assessment*, *188*, 1-17 https://doi.org/10.1007/s10661-016-5202-x

Sridevi, G., Santhoshkumar, P., S.Thiyageshwari. 2024. Long Term Effect of Integrated Nutrient Management on Soil Organic Carbon Status and Yield of Sunflower in Alfisols. *Environment and Ecology* 42 (1):181—184 (January—March) Article DOI: https://doi.org/10.60151/envec/UKHX4362

Vlaming, J., Van den Bosch, H., Van Wijk, M. S., De Jager, A., Bannink, A., & Van Keulen, H. 2001. *Monitoring nutrient flows and economic performance in tropical farming systems (NUTMON); part 1: manual for the NUTMON-toolbox*. Alterra (report)

Willoughby, C., Topp, C. F., Hallett, P. D., Stockdale, E. A., Stoddard, F. L., Walker, R. L., .& Watson, C. A. 2022. New approach combining food value with nutrient budgeting provides insights into the value of alternative farming systems. *Food and energy security*, *11*(4), e427. https://doi.org/10.1002/fes3.427