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Effect of Domesticated Trees Stand Density on Avian Droppings and Growth of *Zea mays* (L) in Re-fragmented Attachi II Forest Reserve, Nigeria

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ABSTRACT

Stand forest patches present interface with arboreal life forms for the unique fertility index associated with tropical soils. This study investigated two categories of farm landscapes that were primed at 3 forest trees stand densities- High (10-13), Medium (6-9), Low (3-5); and then None (zero) trees stand per acre as potential habitat traps for avian droppings in a randomized complete block experiment. Soil samples from 0-20cm were analyzed for pH, TN, AP, CEC, OC, OM, MC, C-N and Ca-Mg ratios and amended with harvested avian droppings for cropping Zea mays. Germination, average plant height and leaf areas at 1 and 4 WAP were taken and data collected subjected to analysis of variance while significant means separated with Duncan Multiple Range Test at 5%. Results revealed that the H-farm landscape had highest mean avian dropping weight (94.42 ± 0.54gm) > Medium (M) > Low (L) > none (N) trees stand farm landscapes. There was no significant difference ($p < 0.05$) between mean pH (H2O) of H and M-farm landscapes while C-N ratio was highest (1:14) in N-farm landscape compared to H-farm landscapes. Soil organic matter was highest (2.25%) and least (0.45%) in the H and N-farm landscapes. Ca-Mg ratio of H and L farm landscapes were highest and significantly different for M and N farm landscapes to depict better nutrient retention qualities and use efficiencies for germination (100%), leaf area (55.43 ± 0.51mm^2) and plant height (45.5 ± 0.12cm).

INTRODUCTION

The demand for fertile soil by agriculture has been the bane of forest conservation in the tropics and sub-Saharan Africa as uncontrolled population surge continue to undermine traditional practice of subsistence farming amidst growing economic recession (FAOSTAT, 2021; Girard, 2021; Ihemezie *et al.*, 2020; Iwejingi, 2011). Pressure on available lands for arable crops increases farmland expansion with virgin and relatively intact remnant high forests as target for sustained soil nutrient supply. Unfortunately, with the larger proportion of tropical forest nutrient resident in the forest vegetative matters, the marginal nutrients in forest soils become exhausted after intensified 4-6 cropping periods to spell poor yield and shifting cultivation at the perceived depletion of soil nutrients (Akinyemi, 2021; Gupta, 2019; Ureigho *et al.*, 2020).

However, prevalent practice of seeking new farmlands with standing forest reached an all-time climax (Vitteck *et al.*, 2014; Gibbs, 2010) and became unattractive due to the decline in available forest area and the use of inorganic fertilizers to augment available depleted forest soil nutrients (Okunomo *et al.*, 2006) But the increasing cost and in-availability of inorganic fertilizer coupled with its purported soil pollution capabilities on prolonged use have critically led to the pursuit of environmentally friendly agroecological systems to induce increased yield (Kulik *et al.*, 2017; Wei, 2020; Wesenbeeck *et al.*, 2021). Agroecological practices in the tropics have therefore advanced to rely on standing forest and its component allies of floor litter matrix, micro and macro-fauna to churn out composite nutrient materials beneficial as organic fertilizer for arable crops. The forest ecosystem is well endowed with environmental and edaphic re-engineering service potential due to the capacity to offset carbon and restore soil structure, providing habitat for an array of arboreal species that contribute significantly to soil fertility and fertilization by cross-pollination of the understory plant community (UNESCO, 2006; Adio *et al.*, 2010).

The crown structure of standing indigenous tropical trees constitute habitat for wide class of birds species that colonize various layers for different activities. The gradual deposit of dungs matters with varying decomposition pattern from different bird species on unique interaction with other ecosystem engineers and plant components initiate soil fertility restoration to enrich upper horizon. Although time of decomposition vary with different forest types and matter pattern of soil restoration and fertility within the ecosystem remains the source of nutrient for agriculture due to carbon-nitrogen interaction (Eka, 2022; Oroka & Ureigho, 2019). Nested portions of tree branches promote faster leaf and twig falls and thereby contribute to soil structure, even though the amount of leaves have been estimated to be higher in soil restoration compared to twigs. Yet twigs are known for sustainably higher moisture storage capacity and therefore act more as strong moisture retention materials in the forest floor. Richer fibrous contents in twigs wick up available moisture to assist floor in regulating basic

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activities essential for micro-fauna operations particularly in reaction with available wildlife dungs (Adeola & Ogunwale, 1992). Notably, standing forest tree species within farmlands have the potential to regularly supply underlying agricultural crops with moisture via these organs and the root suction process, particularly in the growing season, for enhanced development.

Typical agro-ecological practice as agroforestry therefore has been crafted as a multiple land use forest-restoration combatant technique for degraded landscapes under public conservation and community land hold system (Majarua, 2024). However, the annual nutrient budget for sustained yield of farmlands under agroforestry has been shown to increase with time (Asubonteng, 2018) but become truncated due to tenure of the forest trees components at maturity to detriment of agricultural yield (Kindu, *et al*., 2015; Pardon, 2018; Pardon, 2020). It is this loop-sidedness in the crafting management objective skewed to conservation that creates the key bottleneck in the sharing of benefits from the agroforestry, especially the Taungya system. Consequently, the widely propagated varieties of the agroforestry system its ultimate abrogation of agriculture from the system with time has limited its adoption as sine qua non to conservation for smart agricultural practice in the sub-Saharan Africa.

Therefore, the challenge of developing a sympathetic attitude towards agroforestry system that could meet the needs of agriculture in farm landscapes to supply nutrients from forest ecosystem components (Musurmanov, 2021; Verharen *et al*., 2021) is beginning to appeal to original participants of Taungya farmers in the lowland rainforest in upland Niger Delta region. The increasing introduction of agricultural crops underneath with significant yield on annual basis (Edwards *et al*., 2021) confers on modeled prototype agroforestry system as possible solution to the imbalance often created by conservation over agriculture. In addition, the growing menace of insecurity as a result of farmers herdsmen clash in the region does not allow for distant farming practice in the core rich high forest zones.

Hence, this study examined the growing development and application of farmers' traditional agro ecological knowledge of Taungya system under different forest trees stand densities on farm landscapes and influence of avian droppings for sustainable soil fertility, prolong stay on particular farmlands and thereby, curbing deforestation and forest degradation amidst the growing threat of de-reservation phobia of remnant Gazetted Government Forest Reserves that have over the years provided notable soil nutrient for sustained yield.

MATERIALS AND METHODS

Description of study area

The study was carried out in degraded and re-fragmented portions of Attachi 11 Forest Reserve in Aniocha South LGA of Delta State on lat. 6^o 7'42"N and long 6^o29'E. The forest reserve has a total area of 637ha which was constituted in 1965 on the lowland rainforest ecological zone of Delta State with annual rainfall and temperature of 23-30^{o}C and 2762mm/annum respectively (Egwunatum & Ureigho, 2022). It was re-fragmented by the Ministry of Environment in 2006 as a pilot project with a view to accommodating more land-use technique for reducing anthropogenic pressure by land hunger in degraded forest reserves across the State. Approximately 45ha of the forest reserve was re-fragmented and re-assigned to donor community for sole agricultural uses while the 592ha was regenerated for conservation by Taungya.

Two (2) categories of farmlands in three (3) replicates were selected from the re-fragmented farm centers. Category 1 farm landscape was with different species of forest trees species in Nsukwa community, Aniocha South Local Government Area of Delta State. The trees species were mostly domesticated indigenous with biometric enumeration in Table 1. Category 2 comprised of farmlands without any trees (none) species within the same fragmented portion in the community.

Seventy (70) percent of the trees species were well set out by the farmers within the respective farmlands at almost rectangular blocks. The 10-13 and 6-9 trees species had three (3) and 2 rectangular frameworks respectively while the 3-6 were just randomly planted within the farmlands. Agricultural crops under cultivation included Manihot esculenta (cassava), Dioscora (yam), pepper, okra, plantain (Musa spp) in both categories.

Each farmland was delineated with the GPS and ranged between 1.00 – 1.10 acres in size. The average ages of standing trees species in farm landscapes was 7, 9 and 10 years for the 3-6, 6-9 and 10-13 forest trees density respectively. However, older trees species are pruned and decapitated on attaining individual farmer choice height while the roots are solely maintained for tap rooted structure to avoid branching at the upper 40cm forest floor region.

Table 1: Biometrics of silvical composition in study farm landscapes

Tree Density/acre	Trees species	Tree Height (m)	Mean DBH (cm)	Rooting %
3-5	*Irvingia gabonenisis, Vitex dodoyana, Coula edulis, Anacardium occidentale*	4.20 - 6.15	0.43 - 0.51	50.00
6-9	*Dacryodes edulis, Tectona grandis,*	3.11- 6.52	0.48 - 0.91	< 50.00
10-13	*Irvingia gabonenesis, Vitex, Garcina kola,Tectona grandis, Parkia filicoides, Gmelina arborea*	4.53 - 7.68	0.56 - 0.95	> 50.00

Collection of droppings and vegetative matters

Five (5) quadrats of 1.50 x 1.50 m were established at equidistant between standing trees canopies in category I farms. Each quadrat was then fenced with four (4) wooden pegs of 1m high before protection roundabout with nets of mesh sizes 2mm to protect the expected droppings from interferences by creeping fauna. The same number was established in category II farm landscapes without tree species.

Established quadrats were then assessed for avian droppings at two days intervals for a period of 24 days by collecting and weighing on sensitive scale balance before storage in refrigerator with black plastic bags. Total weight deposited per farm landscape was computed at the end of every six (6) days. The same established quadrat was engaged for the trapping of various vegetative matters including leaves, twigs, barks, etc from the forest trees species. These were recorded as carried out for the folivores droppings.

Soil sampling and agronomic evaluation

Soil samples were collected from 0-20cm depth in each quadrat from the two category farm landscapes. These were bulked for each farm landscape type and then characterized for selected physical and chemical soil properties while the various parameters were determined as follows: Hydrogen ion concentration (pH) was with the Gallenkamp pH meter (IITA, 1982), Organic carbon using the wet oxidation method (Nelson & Summer, 1982), organic matter by multiplying organic carbon with factor of 1.72, Total Nitrogen (Juo, 1979), Available phosphorus Bray 1 method (IITA, 1982), and Exchangeable cations by atomic absorption spectrophotometer for Ca and Mg while Na and K by Flame photometry method (IITA, 1982).

Bulked soil samples were further mineralized with collected avian droppings on treatment basis before use for the germination trials of Zea mays under screen house condition. Three (3) maize seeds were planted in black Polypots for each avian dropping mineralized forest type-soil at three replicates to examine the respective influence on Zea mays germination for two weeks.

Percentage germination was computed as the ratio of germinated to planted seeds multiplied by 100 percent. Plant height was taken at 4weeks after planting from the soil level to the tip. Average leaf widths of three (3) representative leaves per plant was taken from the top, middle and base while the length from basal point the leaf to the tip of leaflet and widest part of the leaf were measured with a transparent rule. Leaf area was derived from the length and breadth of the longest leaf per plant, and a correction factor of 0.75 was used to multiply the value of the length and breadth following the procedure of Curnard (1971). The leaf area per plant was obtained by multiplying the leaflet area by the number of leaves.

Experimental design and statistical analysis

The experiment was conducted in a randomized complete block design comprised of 2 types of farm landscapes and 4 treatments of farms without forest trees species (none), then with 3-5, 6-9 and 10-13 forest trees stand density per acre respectively in 3 replicates. Data collected were subjected to analysis of variance and significant means separated with the Duncan Multiple Range Test (DMRT) at 5% level of significance.

RESULTS AND DISCUSSION

Effects of tree stand density on avian droppings

The influence of tree stand density on the average deposit of avian droppings on farm landscapes is shown in Table 2. There were significant differences ($p < 0.05$) between the mean droppings throughout the period in the two categories of farm landscape. In the first week, mean weight of dung ranged between 12.20 ± 1.02 to 94.42 ± 0.54gm with significant differences ($p < 0.05$) among the farm landscapes. The farm landscapes with highest stand density of trees recorded the highest mean weight of 94.42 ± 0.54gm while the least was shown by the category I farm landscapes that had no single trees species.

The same trend of significant differences was shown across the period of data collection with the order of deposit as 10-13 > 6-9 > 3-5 trees > none. This may not be unconnected with the various trees stand density per acre which served probably as habitat (or nesting) grounds and perching/roosting points during movement. This finding agrees with Schaefer *et al.*, (2014) that reported higher potential in restoration of degraded forest ecosystem with colored-fruit trees species that attracted avian folivores and mammalian frugivores at different times to significantly assist in the dropping and transport to other areas within the restoration landscape. Furthermore, the elevation differences between the two categories (primed farm landscapes and those without trees species) favors the primed since it provided choice access to birds at higher plane. Then within the primed forest trees stand farm landscape, the density also influenced the traffic of birds' species as revealed by the mean quantity of dungs per week. This may be as a result of the differences in species and height (age) since the farmers manage the height. This finding is in consonance with Boake (2000) that regular flight at lower altitudes expends higher energy to descend and re-alight upwards with birds becoming depleted in fat reserve and susceptible to diseases. This assertion comparatively presupposes that the category I with no single trees species but has solely arable crops may not experience the regular visit of birds perhaps except where critical necessary.

Table 2: Influence of trees stand density on average avian droppings

Category	Farm landscapes (No of Trees species/acre)	Mean wt. of dung (gramweek^{-1})			
		I	II	III	IV
I	None	12.20 ± 1.02^{d}	12.71 ± 0.96^{d}	10.78 ± 1.02^{d}	13.10 ± 0.98^{d}
II	3 – 5	38.55 ± 0.51^{c}	39.10 ± 0.44^{c}	46.42 ± 0.87^{c}	41.20 ± 0.54^{c}
	6 - 9	60.75 ± 0.73^{b}	64.11 ± 0.61^{b}	68.80 ± 0.65^{b}	67.50 ± 0.11^{b}
	10 -13	94.42 ± 0.54^{a}	88.56 ± 0.29^{a}	94.77 ± 0.12^{a}	96.20 ± 0.33^{a}

Mean ± standard error with the same superscript in the same column is not significantly different (p > 0.05)

Effect of avian droppings on soil properties

The physico-chemical properties of soils in the farm landscapes are shown (Table 3). There was no significant difference in the mean pH (H_2O) of farm landscapes with 6-9 and 10-13 trees stands (Table 3). There was significant difference ($p < 0.05$) between the available phosphorus of the 3-5 and farm landscape without trees species (none). The soil organic matter was highest (2.25%) and least (0.45%) in the H and N-farm landscapes respectively. The highest organic carbon of 10-13 the nutrient dilution status varies among the class II category farm landscapes probably due to the acidity (pH) that invariably moderate its availability.

The higher number of trees may have accounted for not only the large proportion of avian droppings but equally the twigs and midribs of leaves which hold significantly more moisture may have assisted in the shift on acidity to enable increase fertility. The fertility index of alkalinizing high acid soils through the interaction and microbial action of avian droppings with rich forest floor may have contributed to the better yield of category II farm landscape type. Catalytic activity of avian droppings produces rich ammonium compounds that supply soil nutrient-enriching components, particularly nitrogen that assist in the balance of nutrient-use efficiency.

Table 3: Effect of Avian droppings on soil chemical properties of farm landscapes

Farm landscape (No of Trees species/acr)	pH (1:1)		Organic Carbon (%)	Organic Matter (%)	Av. Phosphorus (ppm)	Total Nitrogen (%)	C-N ratio
	H_2O	KCl					
None (N)	6.10±0.78d	4.47±0.66d	0.26±0.34c	0.45±0.11d	0.13±0.87c	3.87±0.31c	1:14a
3-5 (L)	6.48±0.81b	5.64±0.69c	0.72±0.66b	1.23±0.14c	0.18±0.79b	6.56±0.47b	1:9b
6-9 (M)	6.73±0.86a	5.96±0.54b	0.83±0.46b	1.45±0.25b	0.17±0.86b	8.21±0.34a	1:10b
10-13 (H)	6.78±0.93a	6.30±0.60a	1.31±0.48a	2.25±0.13a	0.28±0.87a	8.08±0.44a	1:6c

Means ± standard errors with the same superscript in the same column are not significantly different (p > 0.05)

There were significant differences ($p < 0.05$) in the C-N ratio with the highest (1:14) for the N farm landscape and least (1:6) for the H-farm landscape (Table 3). There was no significant difference ($p > 0.05$) between C-N ratios of the L and M-trees stand density farm landscapes. These results may not be unconnected with the introduced levels of disturbances by the strategic use of more deciduous trees species that are quick in shedding foliar and accompanying twigs components as shown in Figure 1. This finding agrees with Kerfahi *et al.* (2023) that reported increased natural availability and fertility soil nutrients by release of base cations into soil due to disturbances from the habitual foliar falls to produce a rich forest floor mosaic for the facilitation of ion uptake.

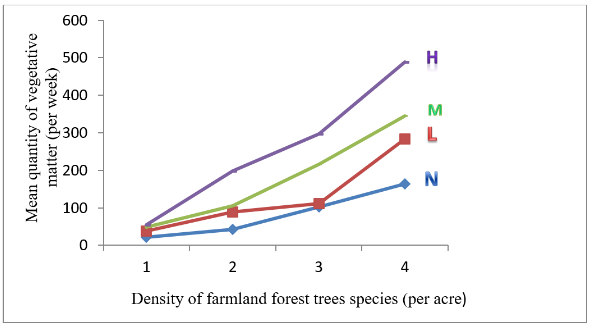

Figure 1: Quantity of mean vegetative matter yield per week/acre

Effects on exchangeable soil complex

There were significant differences ($p < 0.05$) in the mean Ca^{2+} content among farmlands with the highest and least values recorded by the H and N respectively (Table 4). There was no significant difference ($p > 0.05$) between the N and L tree stand density farm landscapes.

There were significant differences in the mean Mg^{2+} content with the H-tree stand density farm landscapes showing the highest value of 3.14meq100g soil^{-1}. The M tree stand density farm landscape recorded a value of 2.88meq100g soil^{-1}. There was no significant difference between the Mg^{2+} content of N and L-tree stand density farm landscapes. This result concurs with Mariama *et al* (2019) that reported an all soil nutrient increased content except for Mg under increasing forest crown cover density compared to treeless control plot. The K$^+$ showed the same trend with the H trees stand density farm landscape recording the highest mean value (1.65meq100g soil^{-1}) that was significantly different from others. There was no significant difference between N and L trees stand density farm landscapes. The mean Na$^+$ content of farm landscape also differed significantly but with the N-tree density farm landscape recording the highest mean value (0.88meq100g soil^{-1}) while the H-tree stand density farm landscape had the least value of 0.33meq100g soil^{-1}. There was no significant difference between the mean Na$^+$ contents of L and M tree density farm landscapes.

The Ca-Mg ratio of H and L trees stand density farm landscapes were highest and significantly different ($p < 0.05$) from the M and N farm landscapes. There were no significant differences the Ca-Mg ratios of H and L as well as M and N ($p > 0.05$). The high Ca-Mg ratio of L farm landscape may not be unconnected with the species of trees which even though low in stand density, were particularly aromatic in flavor. This may have attracted more bird species as nesting and perching resources to account for more droppings and produce the high soil quality with inherent ability to retain nutrient for efficient usage.

The Ca-Mg ratio showed two classifications of 3 and 4 to reveal the proximity in soil characteristics of the various farm landscapes as modified by the trees and avian droppings. While the L and H farm landscapes showed higher soil nutrient retention potential, the N and M had lower retention capacity. However, the resemblance of M (6-9 trees stand density) may not be unconnected with species type even though with higher trees stand density compared to the farm without trees. This is in line with Isaac and Borden (2019) that observed reduced nutrient losses by leaching to facilitate similar nutrient uptake that would have been beyond reach of arable crop roots outside the agroforestry system.

The reverse variation in C-N and Ca-Mg ratios of the N and H farm landscapes may not be unconnected with the quicker transformation of organic matter as a result of absence of sufficient organic matter. This finding agrees with Wezel *et al.* (2014) that organic matters are relatively lost at higher rate under less vegetative cover due to the competition for resource utilization by soil fauna. However, the resource quality determines Ca-Mg ratio due to the varieties of vegetative transformation that is chemically attained to provide nutrient retention by altering soil structure.

Growth characteristics of Zea mays

Germination percentage at 1WAP was highest for the M and H-farm landscapes and least for N-farm landscape (Table 5). The L farm landscape showed higher germination percentage compared to farm landscape without forest trees species.

There were significant differences in average height at 4WAP with the H-farm landscape and N-farm landscape recording the highest and least values of 45.5cm and 12.8cm respectively. Mean leaf area followed similar statistical trend as H (55.43 ± 0.51) > M (41.20 ± 0.11) > L (30.54 ± 0.14) > N (20.35 ± 0.01). The higher leaf area of H- trees stand density farm landscape could be related with higher photosynthetic potential that may have led to yielding higher produce of maize compared to the N-farm landscape. Even the low (L) density farm landscape performed better than the N and was significantly different from M and H. Therefore the presence of the respective stand densities of trees species per acre may have significantly contributed to these observations which are related to both activities of avian dropping and different parts of the trees.

The higher number of trees could have influenced more decomposing part considering the better micro-climatic moisture and temperature which may have created typical environmental gradient to initiate faster germination process due to reduced internal water stress compared to the none-density trees species farmlands. This finding concurs with the result of Zhang *et al.* (2018) and Menyailo *et al.* (2022) that the interplay of temperature, moisture content and pH gradients accounted for higher activities of decomposers in the relatively intact forests compared to degraded areas with agricultural practices. In other words, the varying degrees of priming with forest trees species accounted for different levels of carbon deposit unlike the bare farmland without trees species. And with the preference for available carbon-rich matters by micro-organisms during essential decomposition activities, this may have resulted in the wider carbon-nitrogen ratio in farmland category without trees species.

Unfortunately, the accumulated nitrogen in the C-N ratio could not translate to increase in height and leaf

Table 4: Effect of Avian dung on exchangeable soil complex properties of farm landscapes

Farmland types (No of Trees species/acre)	**Tree Density index**	**Exchangeable cations (meq100gSoil^{-1})**				**Ca-Mg atio**
		Ca	**Mg**	**K**	**Na**	
None	N	6.89 ± 0.32cd	2.03 ± 0.43c	0.64 ± 0.55c	0.88 ± 0.21a	3.00b
3-5	L	7.43 ± 0.22c	2.15 ± 0.75c	0.85 ± 0.65c	0.52 ± 0.34b	4.00a
6-9	M	9.85 ± 0.36b	2.88 ± 0.43b	1.24 ± 0.58b	0.48 ± 0.27bc	3.00b
10-13	H	11.78 ± 0.12a	3.14 ± 0.22a	1.65 ± 0.53a	0.33 ± 0.45d	4.00a

Means ± standard errors with the same superscript in the same column are not significantly different ($p > 0.05$)

area of Zea mays probably as a result of poor nitrogen mineralization potential during the early growth period at 4weeks after planting. But the three forest trees species-primed farm landscape category may have supplied sufficient carbon matter from the various parts in addition to the avian dungs to facilitate resultant balance between C-N for efficient microbial activity. This assertion supports the study of Awoonor *et al.* (2023) that reported insufficient carbon and phosphorus above nitrogen as critical transition challenge of forest to cropland to limit productivity in the tropical soil. Significantly, the height of maize crops as supported by the nutrient in the respective forest floor soils revealed that the N-density farm landscape had the least probably due to the absence of trees that could have created the interdependent relationship for strong plastic response and enhanced P uptake as reported by Kumar and Jose (2018).

Table 5: Agronomic evaluation of cropped Zea mays on farmland type soils

Growth Characteristics	**Farm landscape types (No of trees species/acre)**			
	N	**L**	**M**	**H**
Germination at 1WAP (%)	50.00	75.00	100	100
Avg. Height at 4WAP (cm)	12.8 ± 0.11^{d}	22.7 ± 0.23^{c}	38.3 ± 0.28^{b}	45.5 ± 0.12^{a}
Leaf area at 4WAP (mm²)	20.35 ± 0.01^{d}	30.54 ± 0.14^{c}	41.20 ± 0.11^{b}	55.43 ± 0.51^{a}

Means ± standard errors with the same superscript in the same row are not significantly different (p > 0.05)

CONCLUSION

The study showed that loss of soil nutrients due to deforestation can be reinvented with agro ecological system at deliberate landscapes with varying forest trees stand densities to maximize the abundance of avian and arboreal folivores. Hence, subsistent farming using relatively medium to high domesticated trees stand density with aromatic flavor provided essential leverage for the supply of droppings from arboreal birds to fertilize underlying soils as H > M > L trees stand densities offered significant variation to the existing nutrient conditions compared to the N-farm landscapes without trees. This enhanced deposits of avian droppings and created effective carbon-nitrogen as well as calcium-magnesium ratio in the low-high trees stand density farm landscape for appropriate nitrogen utilization with minimized nitrogen-leaching; thus retained and managed nutrient use efficiency to support early growth indices of Zea mays for sustained yield in the re-fragmented portion of Attachi II Forest Reserve.

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