Received: 23 July 2025 | Accepted: 18 August 2025 | Published online: 21 November 2025

DOI: 10.53550/ijsc.v53.i2.197

ORIGINAL ARTICLE

Indian Journal of Soil Conservation

Biomass and Nutrient Accumulation of Green Manure Species in Humid Tropical Subsistence Cropping Systems of Papua New Guinea

Paula Kaupa[1] | Rajashekhar Rao Bangady Killur[1]*

[1]School of Agriculture, Faculty of Natural Resources, The Papua New Guinea University of Technology, PMB, Lae, 411, Papua New Guinea
ORCID ID: 0000-0003-2925-797X

***Corresponding Author:**
E-mail: rsraobk@rediffmail.com

Handling Editor:
Dr Raman Jeet Singh

Key words:
Nitrogen fixation
Subsistence farming
Sustainable agriculture
Weed suppression

ABSTRACT

This study aimed to identify leguminous green manure species with strong adaptability, high nutrient accumulation, and effective weed suppression for subsistence farming in Papua New Guinea. It also examined the optimal termination age of 45 and 65 days after planting (DAP) for lablab, velvet bean, calapo, centro, and puero. The agronomic performance was compared to natural vegetation in a field experiment laid out in a Randomized Complete Block Design. Velvet bean produced the highest aerial dry matter (11.2 t ha^{-1}), leading to significantly greater accumulation of the primary nutrients nitrogen (374 kg ha^{-1}), phosphorus (61 kg ha^{-1}), and potassium (119 kg ha^{-1}) within 65 days. The green manure crops evaluated derived 21.8%–87.7% of their N from atmospheric fixation. Within 28 DAP, velvet bean and lablab suppressed weed growth by 87% and 53%, respectively. Termination age significantly affected the nutrient accumulation in velvet bean, suggesting 65 DAP could be ideal for soil incorporation, whereas lablab can be terminated at 45 DAP. Our findings suggest that integrating velvet bean and lablab in improved fallow systems could enhance soil fertility and weed management in humid tropical regions.

1 | INTRODUCTION

In Papua New Guinea (PNG), food production primarily relies on subsistence farming, which includes practices such as food garden fallows, slashing, and burning of fallow vegetation (Hartemink, 2003). However, these methods are becoming increasingly environmentally unsustainable and threaten long-term soil fertility and crop yields (Walter *et al.,* 2010). Continuous cropping and crop intensification without sufficient fallow periods further damage soil health and reduce agricultural productivity. About 75% of soils under food crop cultivation in PNG have low to moderate nitrogen levels and are at risk of erosion (Hartemink, 2003), which worsens soil degradation. This decline in natural resources endangers food and nutritional security (Meena *et al.,* 2018). However, limited availability of organic manure, high costs, and inaccessibility of inorganic fertilizers, and the insufficient contribution of primary nutrients from fallow vegetation under humid tropical conditions pose major challenges to maintaining soil fertility (Hartemink, 2003; Kaupa & Rajashekhar Rao, 2014); Ramakrushna *et al.,* 2022

Maintaining tropical soil fertility involves increasing soil organic carbon (Mosier *et al*., 2021). Organic matter boosts soil processes, nutrient dynamics, water relations, and soil health, impacting productivity (Kaupa & Rajashekhar Rao, 2014; Mosier *et al*., 2021). Continuous application of organic matter via crop residues, manure, legumes in rotations or as intercrops, green manure, and fallow species, combined with fertilizers, is vital (Kumar *et al*., 2020; Sunil Kumar *et al*., 2024). In subsistence farming, integrating legume green manures into crop rotations or fallows can improve yields (Anand, 2018). Legumes or cover crops enhance soil fertility by accumulating nutrients for subsequent crops. Although they mainly fix N_2 via legumes, integrating green manures is climate-friendly, boosts organic carbon, biological fertility, and nutrient availability, and reduces erosion (Kumar *et al.*, 2020). Limited information exists on the best green manure species for subsistence agroecosystems. These vary in growth habits, flowering, biomass, chemistry, climate adaptation, optimal incorporation age, and nitrogen fixation, especially in legumes (Hauser & Nolte, 2002; Hirpa *et al.*, 2009; Singh *et al*., 2013). In PNG's humid tropics, ideal legume green manures should produce high biomass, fix nitrogen, and suppress weeds quickly. This study aimed to identify legume green manure species suitable for subsistence farming in humid tropical regions, specifically in PNG. It evaluated green manures based on biomass, nutrient uptake, nitrogen fixation, and weed suppression across five species—lablab, velvet bean, Calopo, Centro, and Puero—grown in various PNG zones. Lablab and velvet bean are popular in the highlands for their edible seeds and pods (Bourke and Harwood, 2009). Centro is used as a cover crop to reduce weeds in rubber and coconut plantations. Velvet bean, Puero, and Calopo improve soil fertility and control weeds in oil palm farms (Pipai, 2014).

2 | MATERIALS AND METHODS

2.1 | Experimental Site

The study was initiated in August 2022 at the experimental farm of the PNG University of Technology (6°41′S, 146°98′E, altitude 65 m a.s.l.) located in Morobe Province, Papua New Guinea. The location of the study site is presented in Fig. 1. The site's climate is classified as "tropical and rainy" under the Köppen system (classification code Af), with a unimodal distribution and over 60 mm of rain in the driest month based on 10-year average conditions. In the 2022 meteorological year, total precipitation was 2,158 mm, with each month receiving at least 100 mm of rainfall. Monthly rainfall totals were 201 mm, 116 mm, 168 mm, and 215 mm for August, September, October, and November, respectively. Minimum and maximum temperatures ranged from 19.3-21.7°C and 28.5-30.6°C, respectively.

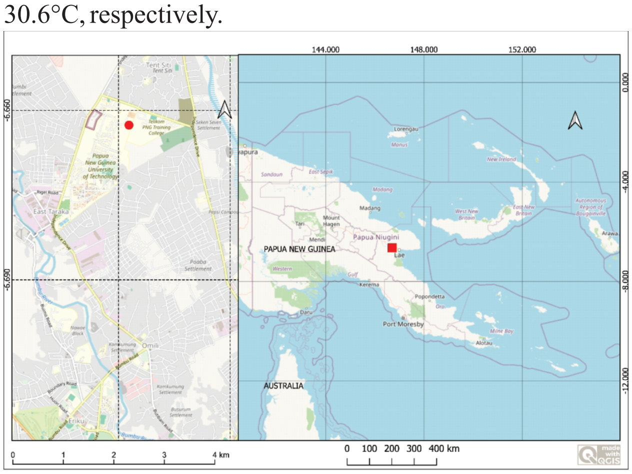

FIGURE 1 The study location is shown on the map with a red marker.

A composite soil sample (0–15 cm) was collected from 10–12 random points across the experimental site before starting the study. The sample was air-dried in the shade for five days, gently crushed, and sieved through a 2 mm mesh. Soil samples in triplicate were analyzed for soil pH using the potentiometric method (1:2.5 soil: water v/w), organic carbon by the Walkley-Black method, available phosphorus by $NaHCO_3$ extraction (Olsen's method), and measured with a UV-Vis spectrophotometer (Shimadzu UV-1800, Shimadzu Corporation, Brisbane, Australia at 882 nm. Soil texture was determined by the Bouyoucos hydrometer method. Total nitrogen was estimated using the semi-micro Kjeldahl steam distillation method (Rayment & Lyons, 2011). The topsoil (0–15 cm) was slightly acidic (pH 6.36), with a total nitrogen content of 1.94 g kg^{-1} and an organic carbon content of 1.67%. Extractable Ca, Mg, and K concentrations of the soil were 13.4, 4.81, and 0.13 c mol kg^{-1}, respectively. The soil was classified as a mixed, isohyperthermic, Typic Tropofluvents (USDA Soil Taxonomy), well-drained, slightly gravelly, with a sandy loam texture (83.2% sand, 6.40% silt, and 10.4% clay).

HIGHLIGHTS

- Velvet bean and lablab were the top green manure species, yielding high biomass, nutrients, and weed suppression in humid tropical farming.
- Early harvest at 45 days lowered yields, showing growth duration's importance.
- Using selected green manures sustainably boosts soil health, nutrient cycling, and weed control in humid tropics.

2.2 | Green Manures

Five legume green manure crops were chosen for the experiment based on the local availability of seeds. The species selected for the screening trial were lablab [*Lablab purpureus* (L.) Sweet], late-maturing white-seeded velvet bean [*Mucuna pruriens* var. utilis (L.) D.C.], Calopo [*Calopogonium mucunoides* (Desv.)], Centro [*Centrosema pubescens* (Benth.)], and Puero [*Pueraria phaseoloides* (Roxb.) Benth.]. Fig. 2 presents pictures of the seeds and the green manure plants evaluated. Lablab seeds were sourced from the Lae Main Market in Morobe Province, while seeds of Calopo, Puero, and Centro were obtained from farmers in peri-urban settlements and along the Bumbu River in Lae, as well as the Markham area of Morobe Province. Velvet bean seeds were obtained from NARI-Kerevat in Rabaul, East New Britain Province, PNG. Seed germination rates exceeded 90%. To break dormancy, Centro, Calopo, and Puero seeds were soaked in hot water for three minutes before sowing.

2.3 | Experimental design and green manure crop cultivation

Before planting the green manure seeds, the natural vegetation was cut back, and the land was plowed twice using a tractor-mounted cultivator. Raised plots measuring 2m x 4m were manually built with shovels. Treatments included five green manure crops arranged in a randomized complete block design (RCBD) with three replications. Plots without green manure crops served as controls. Seeds were manually drilled in rows spaced 0.4 m apart, and four weeks after planting, plants were thinned to two per hill at 0.4 m spacing within the rows, so the plant population per plot was 160. No mineral fertilizer or irrigation was applied during the study. Planting occurred in August, and harvest took place in November. A preventive insecticide spray (Orthene®, Acephate 75SP) was applied once to control leaf defoliators and aphids. To prevent green manure plants from encroaching on neighboring plots, weekly monitoring was conducted, and any vines crossing plot borders were manually redirected.

2.4 | Sampling of green manures, weeds, and chemical analysis

Green manure samples were collected and weighed from 0.5 m × 0.5 m independent quadrats in each plot at 14, 35, 45, 55, and 65 days after planting (DAP) to estimate biomass at each time point. Approximately 500 g of fresh green manure biomass was carefully rinsed with tap water, followed by distilled water, air-dried to remove excess moisture, and then oven-dried at 70°C in a forced- air oven until it reached a constant weight. Oven-dried plant samples collected at 45 days and 65 DAP, ground to 0.5 mm with a stainless-steel grinder, were analyzed in triplicate for total N concentration using the Micro Kjeldahl method (BÜCHI Speed Digester K-436 and BÜCHI Distillation Unit K-350, Avantor, Australia). A powdered sub-sample was digested with an HNO_3-$HClO_4$ mixture and analyzed for P and K concentrations using ICP-OES at the Analytical Services Laboratory of the PNG University of Technology. Nitrogen, P, and K accumulation were calculated by multiplying their respective concentrations by the dry biomass weight per plot.

The potential of green manure crops to suppress weeds was evaluated by measuring the fresh and dry weights of weed biomass at 14, 28, and 42 DAP. Weeding was carried out in each plot using 0.5 m × 0.5 m independent quadrats that remained undisturbed from previous sampling. Weed plants were manually uprooted, soil particles were gently shaken off the roots, and the fresh weight was recorded with an electronic balance. The weed samples were then washed with tap water, oven-dried at 70°C in a forced-air oven until their weight was constant, and then recorded.

The amount of biologically fixed N2 was estimated using the N difference method, which compares N accumulation in legume green manure crops with that in non-N_2-fixing natural weeds from the control plots. The natural weed flora was dominated by *Cyperus esculentus*, *Cynodon dactylon,* and *Panicum maximum*. The difference in total shoot nitrogen accumulation per plot between the legume crops and natural weeds was attributed to symbiotic N2 fixation by the legumes. This method assumes that both legumes and non-legumes absorb the same amount of soil nitrogen.

Diazotrophic N_2 fixation was calculated using Equation (1) from Unkovich *et al.* (2008):

Diazotrophically fixed N_2(kg ha^{-1})=

Total N yield $_{(fixing system)}$ – Total N yield $_{(non\text{-}fixing system)}$ -------- (1)

2.5 | Statistical Analysis

The fresh and dry matter yields of green manure samples and weeds, along with major nutrient concentrations in green manures, nutrient accumulation, and biological N2 fixation estimates at different DAP, were analyzed using factorial analysis of variance (ANOVA) in Statistix 8.0 software for MS Windows®. Green manure crop species and termination age were treated as two factors. Termination age refers to the time interval (days) between planting and the point when a green manure crop is terminated—usually by slashing or weedicide application—and subsequently incorporated into the soil. To identify significant differences among treatments, the Least Significant Difference (LSD) test was conducted at $p \leq 0.05$.

3 | RESULTS AND DISCUSSION

3.1 | Adaptability of green manures, biomass production, and weed suppression potential

The green manures tested varied significantly ($p < 0.001$) regarding biomass yield (*Fig. 3*). Biomass yield increased significantly ($p < 0.05$) as time progressed from 14 to 55t ha^{-1} and 10–48 t ha^{-1}, respectively (*Fig. 3a*), over the 65 days, compared to the natural vegetation or control (7–10 t ha^{-1}). The dry matter followed a similar pattern, with velvet bean and lablab producing dry biomass ranging from 2–11 t ha^{-1} and 1–9 t ha^{-1},respectively, over the 65 days, compared to the natural vegetation (1–1.9 t ha^{-1}) (*Fig. 3b*). Velvet bean and lablab produced nearly 6× and 5× more dry matter than natural vegetation, respectively. Apart from velvet bean and lablab, all other green manure crops produced dry biomass of less than 3.0 t ha^{-1}.

FIGURE 2 Green manure plant seeds with corresponding plants (45 DAP)

Biomass accumulation potential is a key criterion in the selection and success of green manure crops in cropping sequences. Velvet bean plants established quickly and grow vigorously, producing substantial amounts of above-ground fresh biomass (up to 22 t ha^{-1}) within the first month, and nearly 50 t ha^{-1} of fresh biomass after 60 days, which was within the range (11.4-60 t ha^{-1}) reported by Philipp and Gamboa (2003) from Nicaragua. The fresh (48 t ha^{-1}) and dry biomass (9 t ha^{-1}) accumulation in lablab, at 65 days after planting in this study, were comparable to the 47 t/ha fresh biomass and 9 t/ha dry matter observed by Bhardwaj and Hamama (2019) at around 90 days after planting. The biomass weights of velvet bean obtained in this study closely align with the values reported by Kaizzi *et al.* (2006) and Hauser and Nolte (2002), who found dry matter yields ranging from 2.6–7.9 t ha^{-1} during 22 weeks of growth in the tropics.

The differences in biomass yield of green manures observed in this study compared to other research likely result from various factors. These include the timing of green manure termination, management practices influencing weed competition, genetic differences among species and accessions, N uptake and fixation capabilities, and favorable environmental conditions such as soil quality and rainfall at the site (Hauser & Nolte, 2002; Bhardwaj & Hamama, 2019). Additionally, other green manure crops like Calopo, Centro, and Pueraria took longer to establish and were similar in growth to natural vegetation.

Significant differences were observed in weed growth, as shown by the weed biomass recorded among different green manures (*Fig. 3c*). The fresh weed biomass under velvet bean and lablab decreased by 80% and 17%, respectively, from 14 to 28 days after planting due to the vigorous growth of these green manures. In contrast, weed biomass under calopo, centro, and puero plots increased by 40-60%. Mucuna and lablab plots had the lowest mean dry weed biomass, at 26 kg ha^{-1} and 36 kg ha^{-1}, respectively, compared to calopo (87 kg ha^{-1}), centro (93 kg ha^{-1}), and puero (94.6 kg ha^{-1}) (*Fig. 1d*). A highly significant ($p<0.01$) interactive effect was observed between the growth of green manures and weed biomass.

3.2 | Nutrient accumulation and N_2 derived from atmosphere

Green manure plants and natural vegetation significantly differed in their accumulation potential of primary nutrients (N, P, and K) (*Fig. 4*). N accumulation in the above-ground biomass of velvet bean at 45 and 65 days after planting was significantly higher at 218.5 kg ha^{-1} and 374.2 kg ha^{-1}, respectively, followed closely by lablab with 193.2 kg ha^{-1} and 226.9 kg ha^{-1}. Velvet bean and lablab also showed significantly higher P and K accumulation potentials (*Fig. 4b and 4c*). The accumulation of P and K by lablab declined slightly with increasing plant age, which is indicative of the need to incorporate this green manure into the soil early (45 days). The C:N ratio in the above-ground tissue of the legume green manure crops ranged from 11.2 to 15.8. The mean C:P and C:K ratios of the above-ground tissue of the green manure crops ranged from 59-101 and 29-51, respectively, over 65 days.

The termination age of green manure influences its chemical makeup, including nutrients and biochemical constituents such as cellulose, carbohydrates, proteins, polyphenols, and lignin (Sunil Kumar *et al*., 2024). Previous studies have shown N accumulation in velvet bean ranging from 147-222 kg ha^{-1} at 40 DAP (Hauser & Nolte, 2002), 80-200 kg ha^{-1} at 154 DAP (Kaizzi et al., 2006), and 80-100 kg ha^{-1} over 45-60 days (Meena *et al*., 2018). Therefore, velvet bean varieties differed in their growing periods, total biomass production, and N uptake. Green manures such as Calopo, Centro, and Pueraria did not acquire significant amounts of P and K compared to natural soil vegetation. Wendling *et al*. (2015) suggested that the ability of certain green manure species to accumulate nutrients may depend on root architecture, such as root length and large surface area, to extract nutrients from deeper soil layers.

Green manures and their termination age significantly influenced N_2 fixed by manure species (Table 1). On the 45th day after planting, all species except for velvet bean and lablab showed negative values for biologically fixed N_2. This was due to lower N accumulation in legumes than in non-N-fixing weeds, likely because the legumes relied primarily on soil N during their early growth stages. Poor growth as reflected by biomass and delayed onset of N_2 fixation may have further contributed to this pattern (Unkovich *et al.,* 2008). The contribution of N derived from the atmosphere after 65 days was highest in velvet bean (87.7%), followed by lablab (79.7%), Pueraria (45.8%), Centro (36.7%), and the lowest in Calopo (21.9%). Velvet bean and lablab were superior in terms of early biological N fixation. By 65 days after planting, velvet bean had significantly higher N_2 fixed (328.1 kg ha^{-1}) compared to all other legume green manures. The N difference method assumes that the difference in total shoot nitrogen accumulation between legume crops and natural weeds is attributed to symbiotic N_2 fixation by the legumes, based on the assumption that both absorb equal amounts of soil nitrogen. The negative values indicate that N uptake by legumes was lower than that of the natural weeds, possibly due to the legumes relying solely on soil N, delayed N_2 fixation, and exhibiting poor growth. The N_2 fixation appeared to be directly related to the ability of the crop to produce biomass. This trend aligns with the expectation that increased legume cover generally results in more N_2 fixation, as suggested by Silva *et al.* (2011). Their study reported that around 70% of the N in the shoots of *Mucuna pruriens* var. utilis is derived from atmospheric N (Silva *et al*., 2011).

3.3 | Implications for managing subsistence food systems

The study results showed a strong potential for producing nitrogen-rich biomass using green manures such as velvet bean and lablab. Incorporating these effective green manure species into subsistence farming systems as alternatives to natural fallow practices might also pose environmental risks. In tropical areas with high rainfall, residue

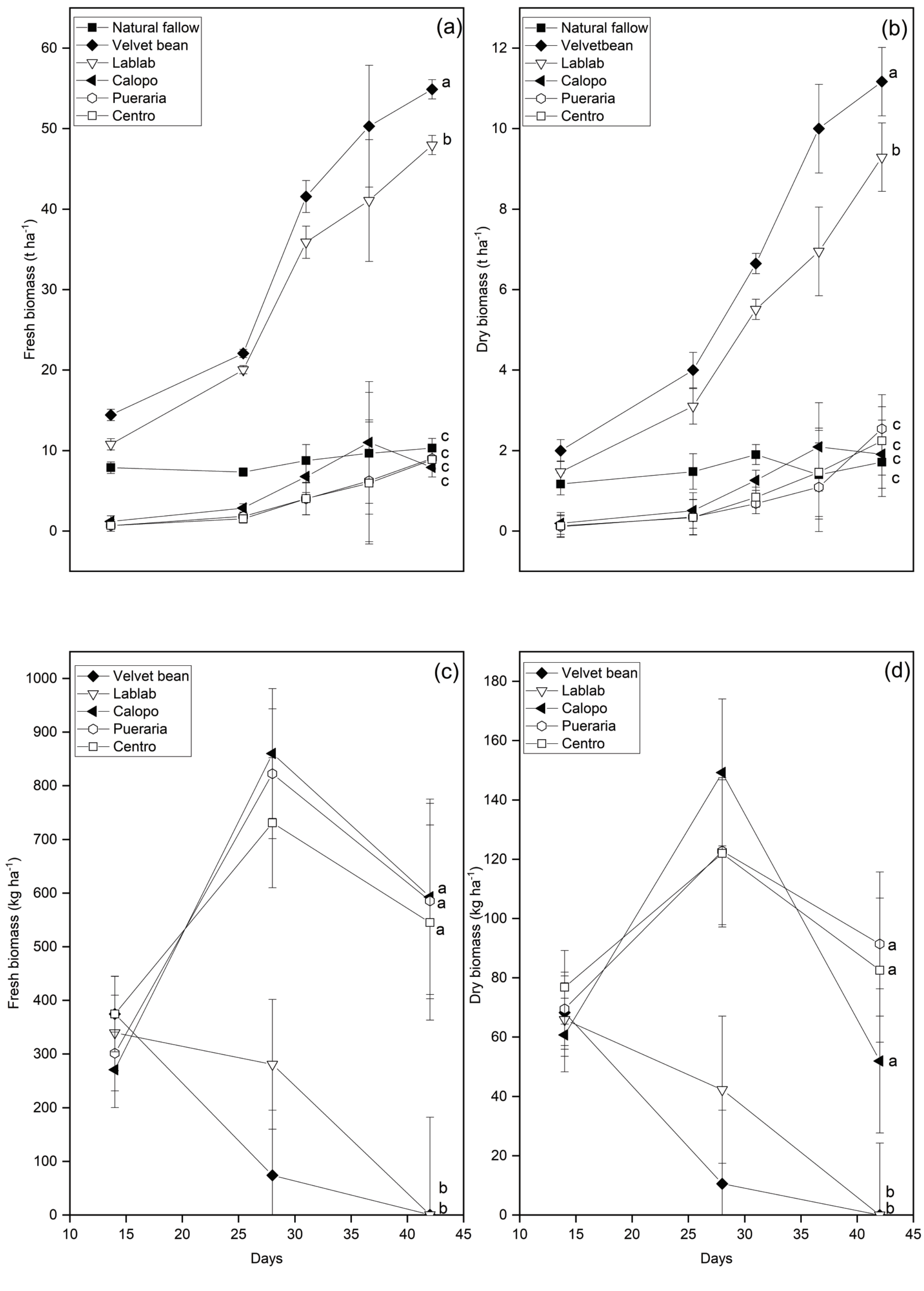

FIGURE 3 Green manure (a & b) and weed growth (c & d) over time. Error bars indicate LSD $_{(p\ 0.05)}$

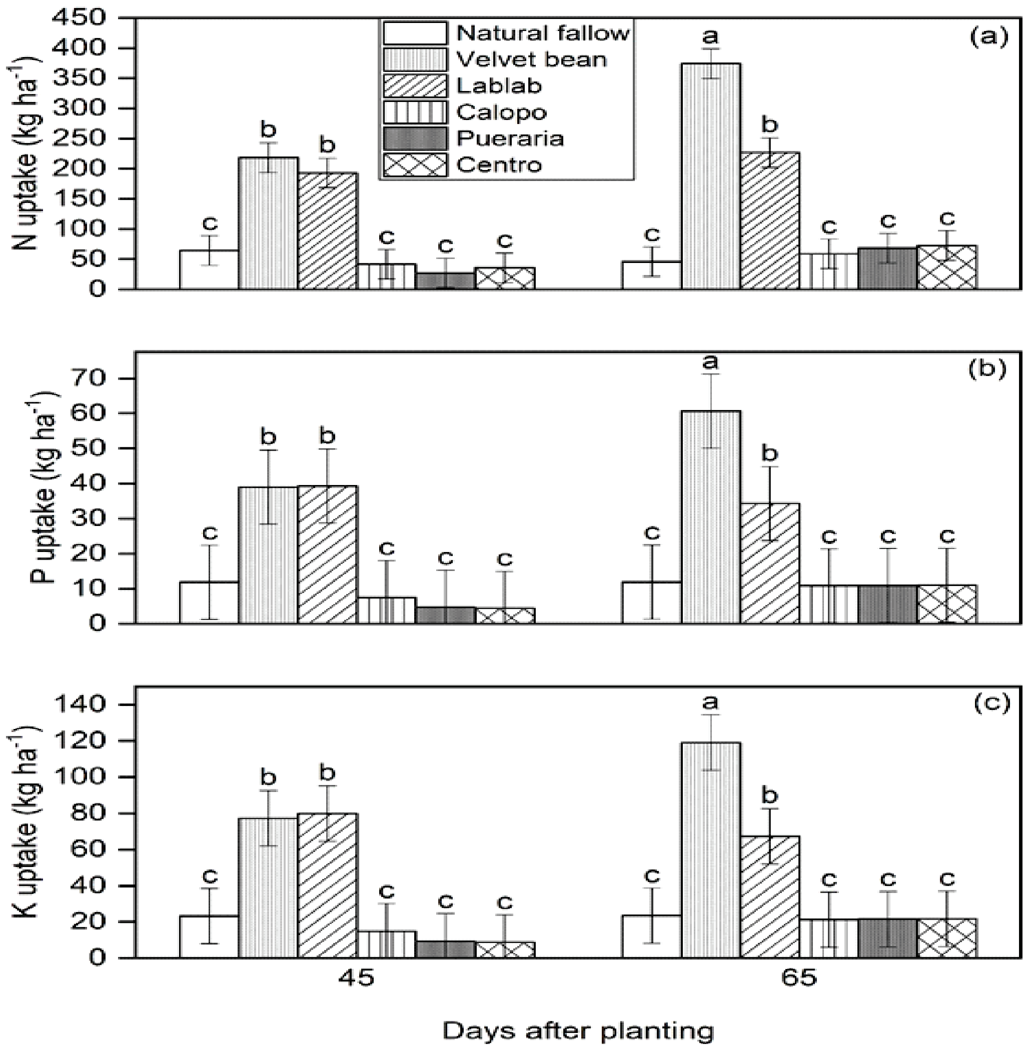

FIGURE 4 Nutrient accumulation in green manures over time. Error bars show $LSD_{(0.001)}$.

TABLE 1 The N uptake, N fixed by N-difference technique and % of N_2 derived from atmosphere (%Ndfa)

Green manures	Absolute N uptake (kg ha^{-1})		N_2fixed (kg ha^{-1})		%Ndfa	
			Termination age			
	45 days	65 days	45 days	65 days	45 days	65 days
Natural vegetation	64.60c	46.20c	-	-	-	-
Velvet bean	218.49b	374.20a	153.89b	328.15a	70.43	87.67
Lablab	193.16b	226.88b	128.56b	180.68b	66.56	79.66
Calopo	41.97c	59.08c	-22.63cde	12.88cde	0.00	21.88
Pueraria	27.45c	77.56c	-37.15e	31.36c	0.00	45.77
Centro	36.02c	72.94c	-28.58de	26.74c	0.00	36.68
F test significance						
Green manures		***		***		
Termination age		***		***		
Green manures x Termination age		**		*		

Values with different superscripts in columns are significantly different; ***, $p < 0.001$ and *, $p < 0.05$.

decomposition speeds up due to warm, moist conditions that boost microbial activity and nutrient mineralization. The heavy rain can also cause excessive leaching of mineralized nutrients, especially nitrogen in nitrate form, which reduces nutrient availability for crops and raises the risk of groundwater contamination (Kaupa & Rajashekhar Rao, 2014). Proper management is essential to align nutrient release with crop needs and minimize environmental losses. Green manures harvested 45 days after planting tend to have a lower C:N ratio, indicating they decompose more quickly because of higher nitrogen content and lower lignin levels (Toleikiene *et al.*, 2024). This leads to rapid nutrient release when incorporated, benefiting subsequent crops if timing is correct, but potentially causing nutrient loss in areas with very high rainfall, such as humid tropics. On the other hand, green manures harvested at 65 days usually have a higher C:N ratio and more lignified biomass, resulting in slower decomposition and longer nutrient release, which helps build soil organic matter over time—though it may delay nutrient availability for crops. The age at which green manure is terminated influences the residue quality and helps determine the best timing for incorporation to optimize nutrient availability and reduce environmental risks.

Within Papua New Guinea's subsistence farming systems, the use of green manure crops faces many adoption challenges. Most smallholder farmers have limited land, and dedicating space to non-food crops like velvet bean or lablab is often seen as impractical because it could threaten food production. Labor availability and small-scale machinery for soil incorporation are also important constraints, as growing and applying green manure requires extra time and effort that busy families may lack due to existing farm workloads (Meena *et al*., 2018; Kaupa & Rajashekhar Rao, 2023). Additionally, a lack of knowledge and training on the benefits and management of green manure discourages farmers from adopting it. The unavailability of green manure seeds, especially in remote rural areas, is another barrier. For farmers focusing on short-term income and food security as subsistence farmers, perceived risks and limited immediate benefits further decrease the likelihood of adopting green manure as an improved fallow system (Kaupa & Rajashekhar Rao, 2023)

3.4 | Limitations of the study

Caution is advised when interpreting the results of N_2 fixation measurements. The N difference method tends to underestimate N_2 fixation at 45 and 65 days after planting because legumes generally use less soil nitrogen than non-legume weed fallow. Furthermore, since roots and nodules were not examined for nitrogen content and accumulation in this study, they may also contain some fixed N_2 (Unkovich *et al*., 2008).

4 | CONCLUSIONS

The results of the study clearly highlight the substantial potential of green manures, particularly velvet bean and lablab, in generating above-ground biomass, effectively suppressing and smothering weeds, and accumulating significant quantities of primary nutrients. These findings suggest that velvet bean and lablab are superior to natural vegetation, making them highly beneficial for integrating into improved fallow systems. Both velvet bean and lablab demonstrated an early onset of nitrogen fixation within the first 45 days of growth, marking them as suitable green manure crops for humid tropical conditions. The high biomass yield, along with the accumulation of primary nutrients alongside their weed suppression capabilities, makes these legumes highly effective for possible soil improvement. Delaying the termination of legume green manure beyond 45 days may not offer additional benefits in terms of N, P, and K availability from the phytomass, except for velvet bean. This research supports the incorporation of velvet bean and lablab as early maturing, highly effective green manure crops for improved fallows in humid tropical regions. However, future research should focus on multi-season and multi-location trials to capture variability across soil types, rainfall regimes, and management practices. Such studies are essential to confirm the long-term benefits of green manure legumes for soil fertility restoration, crop productivity, and resilience of subsistence farming systems in the humid tropics.

ACKNOWLEDGEMENTS

This research received financial support from the Postgraduate Studies, Research & Innovations Committee of the PNG University of Technology and the PNG Science and Technology Secretariat to the first author. The assistance of Mr. Sovera Guti, Bakiki Nesio, and Ms Elizabeth Matrus of Analytical Services Laboratory is kindly acknowledged.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

All data generated or analysed during this study are included in this published article.

AUTHOR’S CONTRIBUTION

PK: Conceptualization, methodology, investigation, writing – original draft; RR: Data curation, formal analysis, writing – review & editing, supervision.

REFERENCES

Anand, S. 2018. Evaluation of nutrient uptake of selected cover crops and biochar on the yield advantage of two taro (*Colocasia esculenta*) cultivars in Samoa. *The South Pacific Journal of Natural and Applied Sciences* 36(1): 9-17. https:// doi.org/ 10.1071/ Sp18002.

Bhardwaj, H.L. and Hamama, A. A. 2019. A preliminary evaluation of Lablab biomass productivity in Virginia. *Journal of Agriculture Science* 11(13): 42-47.https://doi.org/10.5539/jas.v11n13p42.

Bourke, R.M. and Harwood, T. 2009. *Food and Agriculture in Papua New Guinea.,* Published by ANUE press. The Australian National University Canberra ACT0200, Australia.

Hartemink, A.E. 2003. Sweet potato yield and nutrient dynamics after short

-term fallows in the humid lowlands of Papua New Guinea. *Netherlands Journal of Agricultural Science* 50: 297-319. https://doi.org/10.1016/s1573-5214(03)80014-3

Hauser, S. and Nolte, C. 2002. Biomass production and N fixation of five *Mucuna pruriens* varieties and their effect on maize yields in the forest zone of Cameroon. *Journal of Plant* Nutrition and Soil Science 165: 101-109.https:// doi.org/ 10.1002/1522-2624(200202)165:1<101::AID-JPLN101>3.0.CO;2-F

Hirpa, T., Gebrekidan, H., Tesfaye, K. and Hailemariam, A. 2009. Biomass and nutrient accumulation of green manuring legumes terminated at different growth stages. *East African Journal of Sciences* **3**(1):18-28. http://dx.doi.org/10.20372/eajs.v3i1.67

Kaizzi, C.K., Ssali, H. and Vlek, P. L.G. 2006. Differential use and benefits of Velvet bean (*Mucuna pruriens* var. utilis) and N fertilizers in maize production in contrasting agro-ecological zones of E. Uganda. *Agricultural Systems* 88(1): 44-60. http://dx.doi.org/10.1016/j.agsy.2005.06.003

Kaupa, P. and Rajashekhar Rao, B.K. 2014. Nitrogen mineralization and efficiency from co-applied animal manures and mineral fertilizer in weet potato under humid tropical conditions. *Field Crops Research* 168: 48-56. https://doi.org/10.1016/j.fcr. 2014.08.011

Kaupa, P. and Rajashekhar Rao, B.K. 2023. The role of green manures in sustaining soil health and crop productivity in PNG: A review. Presented at PNG Update 2023, Day 2, Panel 4E, University of Papua New Guinea, Port Moresby, 17–18 August 2023. https://devpolicy.org/2023-PNG-Update/Day_ 2/ Panel_ 4E_1_ Kaupa.pdf

Kumar, S., Saluja, S. and Sukul, P. 2020. Green manuring and its role in soil health management. In: *Soil Health: Soil Biology, vol 59*. (Giri, B. and Varma, A. Eds.). pp. 219-241, Springer Nature, Switzerland. https://doi.org/10.1007/978-3-030-44364-1_13

Meena, B.L., Fagodiya, R.K., Prajapat, K., Dotaniya, M.L., Kaledhonkar, M.J., Sharma, P.C., & Kumar, S. (2018), Legume green manuring: an option for soil sustainability. In: *Legumes for Soil Health and Sustainable Management.* (Meena, R., Das, A., Yadav, G. and Lal, R. Eds.). pp.387-408. Springer, Singapore. https://doi.org/ 10.1007/978-981-13-0253-4_12

Mosier, S., Córdova, S.C. and Robertson, G.P. 2021. Restoring soil fertility on degraded lands to meet food, fuel, and climate security needs via perennialization. *Frontiers in Sustainable Food Systems* 5: 706142. https://doi.org/10.3389/fsufs.2021.706142

Philipp, D. and Gamboa, W. 2003. Observations about the mucuna - corn system in the slopes of Waslala, Atlantic Region of Nicaragua. *Agronomía Mesoamericana* 14(2): 215–221. https://doi.org/10.15517/am.v14i2.11951

Pipai, R. 2014. *Biological nitrogen fixation by cover legumes under oil palm plantations in Papua New Guinea* (Master's thesis). University of Adelaide, Australia.

Ramakrushna. G.I., Das, Anup., Layek, Jayenta., Verma, B.C., Babu, Subhash., Mohapatra, K.P., and Sahane, A.A., 2022. Assessing maize based cropping systems for higher productivity and income under shifting cultivation in eastern Indian Himalayas. Indian J. Soil Cons 50(2) 101-106. https://doi.org/10.59797/ijsc. v 50.i2.164

Rayment, G. E. and Lyons, D.J. 2011. *Soil Chemical Methods-Australasia*: *Australian Soil and Land Survey Handbook and Soil Science Series, Vol. 3*, 495 pp. CSIRO, Collingwood, Australia.

Silva, A., de Brito, G., Guerra, J.G.M., Junior, M. G., Costa, J.R., Espíndola, J.A.A. and da Silva, A.E. 2011. Agronomic performance of velvet bean at different spatial arrangement. *Pesquisa Agropecuária Brasileira* 46(6): 603-608. http://dx.doi.org/10.1590/S0100-204X 20 11 00 0 6 00005

Singh, S., Singh, R.J., Kumar, K., Singh, B., and Shukla, L. 2013. Biofertilizers and green manuring for sustainable agriculture. In: *Modern Technologies for Sustainable* Agriculture. (Kumar, S. and Prasad, B. Eds.). pp. 129–150. New India Publishing Agency, New Delhi. https:doi.org /1 0 . 1 3140/2.1.5014.0160

Singh , Y.P., Tomar, S.S., Tiwari, S., Yadav, R.S. and Dubey, S.K. 2024. Relay sowing of berseem (*Trifolium alexandrinum*) in mustard (*Brassica juncea*) improves system productivity, economics and soil fertility. *Indian J. Soil Cons.,* 52(3): 261-266. DOI: 0.59797/ijsc.v52.i3.180

Sunil Kumar, T., Virdia, H.M., Patel, K.G., Ragi, S., Chowdhury, M., Kumar, P., Elbagory, M., Omara, A.E.D., Salem, A., Elbeltagi, A. and El-Shinawy, D.M. 2024. Effect of summer legume residue incorporation and fertilizer regimes on rice growth, yield, and nutrient uptake. *Frontiers in Sustainable Food Systems* 8: 1467201. http://dx.doi.org/10.3389/fsufs.2024.1467201

Toleikiene, M., Arlauskiene, A., Suproniene, S., Sarunaite, L., Capaite, G. And Kadziuliene, Z. 2024. Processing of legume green manures slowdowns C release, reduces N losses and increases N synchronization index for two years. *Sustainability* 16: 2152. https://doi.org/10.3390/su16052152

Unkovich, M., Herridge, D., Peoples, M., Cadisch, G., Boddey, R., Giller, K., Alves, B. and Chalk, P., 2008. *Measuring plant-associated nitrogen fixation in agricultural systems*. ACIAR Monograph No.136, 258 pp. ACIAR, Australia.

Walter, R., W., Rajashekhara Rao, B.K. and Bailey, J.S. 2010. Distribution of potassium fractions in sweet potato (*Ipomoea batatas*) garden soils in the Central Highlands of Papua New Guinea and management implications. *Soil Use and Management* 27(1): 77-83. https://doi.org/10.1111/j.1475-2743.2010.00313.x

Wendling, M., Büchi, l., Amosse, C., Sinaj, S., Walter, A. and Charles, R. 2015. Nutrient accumulation by cover crops with different root systems. *Aspects of Applied Biology* 129: 91-96.

How to cite this article: Paula Kaupa and Rajashekhar Rao Bangady Killur 2025. Biomass and Nutrient Accumulation of Green Manure Species in Humid Tropical Subsistence Cropping Systems of Papua New Guinea. *Indian J. Soil Cons*., **53(2):142-149**