

Full Length Research Paper

Selected soil properties and small-holder dairy farmers' perceptions on improved forage varieties in the Southern highlands of Tanzania

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The current study was aimed at assessing selected soil properties of forage gardens and perceptions of small-holder dairy farmers to newly introduced improved forage in Southern highlands, Tanzania. A total of 101 respondents were randomly sampled and interviewed on the issues relating to management, preferences, and adoption challenges of different pasture varieties. Some surveyed households (38) were purposefully chosen for soil sampling and analysis, since they had pasture plots >256 m² (~0.1 acres) and established *Brachiaria* hybrid, cv Cayman and cv Cobra, as well as *Pennisetum purpureum* cv Ouma and cv ILRI 16835 in their plots at the time of this survey. Results showed that total soil nitrogen was sufficient, exchangeable potassium was on the borderline between medium and low, and available phosphorus was below the required amount for optimum pasture production. The soil in some farms was acidic (pH<5.5) which could inhibit phosphorus uptake and other cations availability. Little land was allocated for pasture cultivation and household income from dairy production was moderate. It was concluded that improving access to planting materials and dairy marketing could encourage farmers to intensify pasture and dairy production, hence, improving pasture farms' soil condition and their livelihoods.

Key words: Sustainable dairy production, pasture perception, pasture production challenges, pasture pests, soil fertility, soil pH.

INTRODUCTION

Dairy farming involves the keeping of livestock such as goat, cattle and water buffalo for milk production. It provides income, food, employment and supports livelihoods of over 150 million small-holder dairy farmers

worldwide (FAO, 2010; Hawkins et al., 2021). Small-holder dairy farmers in the tropics and sub-tropics are faced with a shortage of high-quality feedstuffs needed to meet the nutritional requirements of high-producing dairy

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cattle. The shortage is attributed to low herbage yields of predominantly native forage species contributed by low genetic potential, seasonal rainfall patterns, and poor soil properties (Ruvuga et al., 2021; Boote et al., 2022).

Farmers have been using nutrient dense agricultural by-products such as maize bran and oilseed cakes as dairy cattle feed in a time of amplified feed shortage. These feeds are expensive and limited because of competition from other animals following changes in their eating habits, e.g. consuming whole grain or hulled maize (Asimwe et al., 2015; Ekpa et al., 2019). Other potential feed sources are crop residues e.g. rice straws, maize stovers and wheat straws, which have poor nutritional quality despite their abundance (Nazli et al., 2018; Wei et al., 2018). Introducing improved, high-yielding pasture varieties and addressing soil fertility issues could alleviate feed shortage thus improve dairy productivity and ultimately livelihoods of dairy farmers (Hawkins et al., 2021; Kavana et al., 2021).

Climate-Smart Dairy Project (CSDP) was inceptioned in 2018 by International Centre for Tropical Agriculture (CIAT) aiming to improve pasture production and feeding strategies among small-holder dairy farmers in Southern highlands where most small-holder dairy farmers are located in Tanzania (Michael et al., 2018). The project provided site-specific pasture solutions to participating farmers, which could lead to sustainable intensification of dairy cattle production (CIAT, 2017). Farmers were supplied with different varieties of *Brachiaria* hybrid (Cayman and Cobra) and *Pennisetum purpureum* (Ouma and ILRI 16835) which have records of high biomass yields and good nutritional values compared to native forage species (Maass et al., 2015; Negawo et al., 2017; Ohmstedt and Mwendia, 2018). These pasture species were expected to alleviate feed shortage, increase dairy production, improve livelihoods and reduce greenhouse gas emissions per unit of land and milk produced (Hawkins et al., 2021).

Mutimura and Everson (2012) and Apolinário et al. (2017) mentioned that forage growth, biomass yield, and their nutritional value are positively influenced by soil physical and chemical properties. Optimum forage metabolism and growth are determined by the soil's ability to supply essential nutrients such as nitrogen, phosphorous, potassium, and other trace mineral elements. Also, soil physical properties such as aeration and water retention determine suitability of soil for plant growth. These soil properties are affected by routine pasture harvesting or grazing with inappropriate fertilizer application, hence causing exhaustion of available soil nutrients for pasture growth or nutrient loss through leaching.

The current study was conducted to describe the dairy cattle production and evaluate smallholder dairy farmers' management of improved pasture species and the challenges they faced in Southern Highlands, Tanzania. It also aimed to assess the soil properties of established

pasture plots in the highlands. It is expected that results from the current study could provide crucial information needed when planning to upscale improved pasture species elsewhere. Also, it could provide policy and decision makers with insights when planning strategies aiming to improve dairy production in African highlands.

METHODOLOGY

Description of the study areas

The study was conducted in Mufindi (8°S, 30°E), Njombe (8°S - 9°S, 33°E - 35°E) and Rungwe (8°30' - 9°30'S, 33° - 34°E) districts in Southern highlands, Tanzania. The districts have an altitude of 1700 to 2200 m above sea level (a.s.l) for Mufindi, 1600 to 1800 m a.s.l for Njombe and 1700 to 2400 m a.s.l for Rungwe. The highlands climate is humid with rainfall ranging from 1000 to 1600 mm, 1200 to 1600 mm and 2500 to 3500 mm while the mean annual temperature is 18, 15 and 18°C for Mufindi, Njombe and Rungwe districts, respectively. The vegetation is characterised by forests both natural and planted, scattered bushes and temperate grasslands with well drained acrisols and volcanic soil (pumice), and mountainous topography (National Bureau of Statistics, NBS and Njombe District Council, NDC, 2016, 2017; United Republic of Tanzania, URT, 2018). The main economic activity in the districts is agriculture which includes both crop cultivation and animal husbandry. The districts were selected for the current study due to their long dairy farming history and presence of Climate-Smart Dairy Project (CSDP) activities since 2018. Two wards were selected per district during data collection, namely Igwole and Mtwango (Mufindi), Ikuna and Kichiwa (Njombe), and Kiwira and Lufingo (Rungwe) (Figure 1).

Study design and data collection

Stratified random sampling was used to select responding households and only farmers who were part of the project were involved. A total of 101 respondents (31% female and 69% males) were sampled randomly out of 345 individuals who fitted the sampling criteria. Sixteen farmers were sampled on average from each ward and an open-ended questionnaire was used to collect data whereby respondents were asked questions on land allocation, dairy production, pasture management, pasture preferences and challenges limiting pastures adoption. Head of selected household was interviewed most of the time but in their absence during household visit another household member i.e spouse was interviewed. Sampled households gave verbal consent and agreed to participate in the study.

Out of the 101 households surveyed, 38 were deliberately chosen for soil sampling and analysis with the presumption that they were dedicated pasture farmers. Since, they had >256 m² (~0.1 acres) pasture plot and established *Brachiaria* hybrid cv Cayman and cv Cobra, as well as *P. purpureum* cv Ouma and cv ILRI 16835 at the time of the survey. These improved forage species were initiated by Climate Smart Dairy Project (Korir et al., 2021). Soil sampled households were 12 in Mufindi, 15 in Njombe and 11 in Rungwe. Fertilizer usage and agronomic practices of 38 households were obtained from CSDP extension officers in order to describe farm management practices. The soil was sampled from the respective pasture plot using 0.25 m x 0.25 m quadrat and a soil auger. The quadrat was thrown randomly six times on sampled plot to identify the sampling spot and a soil auger was used to collect soil samples at 0 to 20 cm (top-soil) and 21 to 50 cm (sub-soil) depths. The two depths were selected because top-soil covers

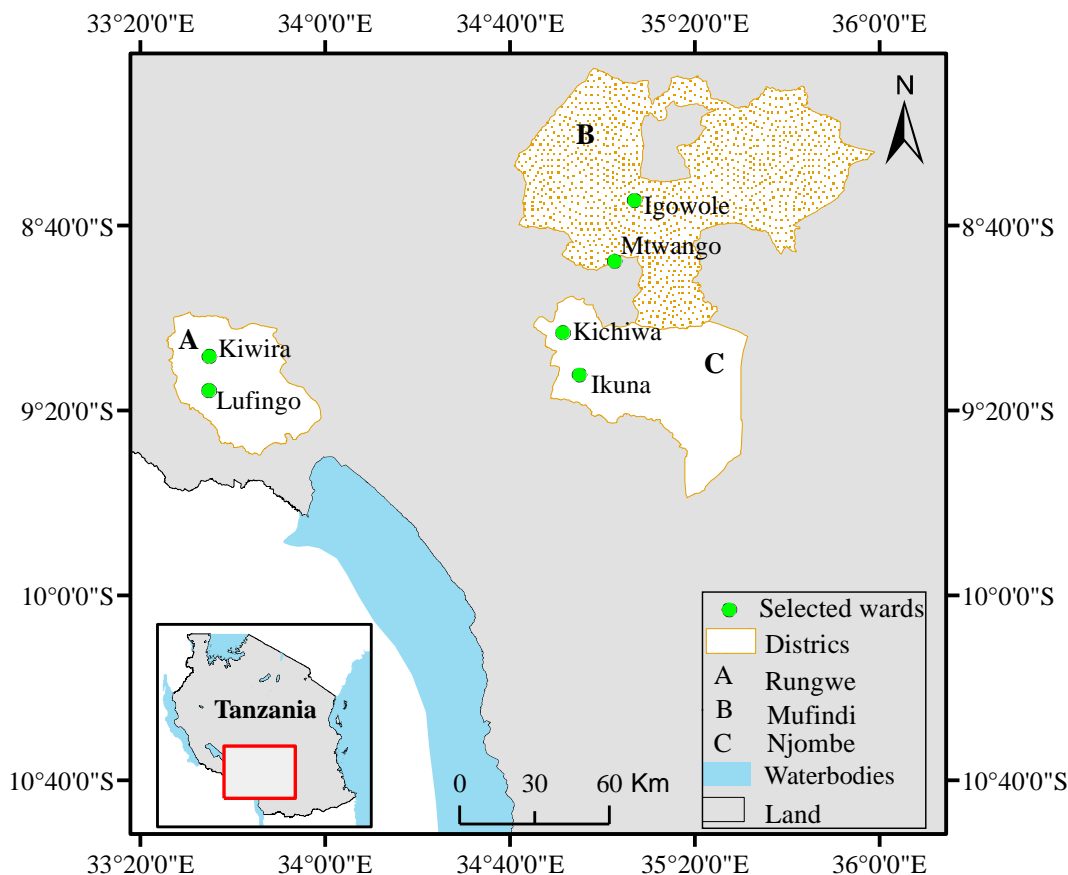


Figure 1. Map showing selected wards for households' interview in Southern highlands, Tanzania. Source: NBS (2012)

the rooting zone of most pasture species, while sub-soil shows potential soil nutrients which are not available to cultivated pasture. The sample soil collected from each soil depth was mixed thoroughly with its counterpart from other sampling spots within the same pasture plot to obtain a composite sample. About 500 g of soil was taken from the respective soil depth composite sample, labelled and sent to the laboratory for analysis.

Upon arrival at the laboratory, respective soil samples were air-dried at room temperature for one week and were sieved using a 2 mm screen. Soil particle sizes in the respective soil samples were analysed using hydrometer as per Beretta et al. (2014) procedures. Soil pH was taken by pH meter in a mixture of soil-water suspension (1:2.5) and 1 N KCl at ratios 1:2.5. Total nitrogen (TN) was analysed using the Kjeldahl method as described by Nelson and Sommer (1982) and available phosphorus (P) was analysed using Bray methods as described by Okalebo et al. (2002) since sampled soil was acidic. Atomic Absorption Spectrophotometer was used to measure exchangeable calcium (Ca^{2+}) and magnesium (Mg^{2+}) while a flame photometer was used to determine exchangeable sodium (Na^+) and potassium (K^+) concentrations (Hendershot et al., 1993).

Data analysis

Household interviews and soil data were analysed using the Statistical Package for Social Sciences (SPSS, version 20 for Windows) and Statistical Program R (version 4.0.1), respectively. Household data were coded and categorised into their respective

districts and were analysed for the frequency and mean. Household's means and frequencies among the districts were compared using an independent sample t-test and Pearson Chi-square test at a 95% confidence interval. Soil pH, TN, available P, exchangeable cations (K^+ , Ca^{2+} , Mg^{2+} and Na^+) and particle sizes (clay, silt and sand) were analysed using ANOVA type III mixed effect model: $Y = \text{Soil depth}_{(\text{Fixed})} + \text{District}_{(\text{Fixed})} + \text{Soil depth} \times \text{District}_{(\text{Fixed})} + \text{Ward}_{(\text{Random})} + \text{Residual error}$. Tukey's method was used for mean soil parameters comparison between soil depths and among districts. The differences were declared significant at $p < 0.05$ and the results were presented as mean \pm standard error (SE). The mean soil pH was categorised according to Booker Tropical Soil Manual (Landon, 1991). Top-soil fertility was categorised using the same manual and TN, available P and exchangeable K were used so as to assess soil suitability for pasture cultivation.

RESULTS

Socio-economic characteristics

Most respondents had formal education (95%) and many households in Rungwe (74%) compared to Mufindi (37%) relied on crop cultivation as the primary source of income while mixed farming was the main source of income in Njombe (40%). Dairy production was very important for

Table 1. Household and herd structures (mean) among interviewed households (n=101) in Southern Highlands, Tanzania.

District	Njombe (n=35)	Rungwe (n=35)	Mufindi (n=31)
Household structure (mean number)			
Female (0-17 years)	1.3	1.6	1.0
Male (0-17 years)	1.2	1.2	1.1
Female (18-45 years)	0.9	1.5	0.9
Male (18-45 years)	0.7	1.2	0.7
Female (46-60 years)	0.3	0.5	0.5
Male (46-60 years)	0.3	0.4	0.5
Female (>60 years)	0.1	0.1	0.2
Male (>60 years)	0.1	0.1	0.2
Household size	5.0 ^a	6.5 ^b	5.2 ^a
Herd structure (mean number)			
Bulls	0.3	0.4	0.4
Cow	1.4 ^a	2.5 ^b	1.5 ^a
Heifer	0.7	1.0	0.8
Steers	0.4	0.3	0.2
Female calves	0.5 ^{a,b}	0.4 ^a	0.9 ^b
Male calves	0.2 ^a	0.3 ^{a,b}	0.6 ^b
Herd size	3.5	4.8	4.4

Mean in the same row with different letters were statistically different.
Source: Study

household income in Njombe (66%) and Mufindi (51%) while most households in Rungwe (74%) thought it was of moderate importance. There were statistical differences ($p < 0.05$) in household size among districts whereby it was larger in Rungwe (6.5 people) compared to the other two districts. The household structure did not vary among the districts as shown in Table 1.

Dairy cattle and pasture management

Interviewed households kept improved cattle dairy breeds (*Bos taurus*) such as Friesian and Jersey and these cattle were mostly zero grazed. The number of cows and calves (both female and male) differed statistically among districts ($p < 0.05$, Table 1). Rungwe had the highest cow number (2.5) while it had the lowest number of female calves (0.4) and the intermediate number of male calves (0.3) per household compared to the other two districts. There were statistical differences ($p < 0.05$) in land size allocated for forage cultivation among districts. Land allocated for pasture cultivation was bigger in Njombe (0.45 ha) compared to Rungwe (0.12 ha) and Mufindi (0.12 ha). Crop cultivated and timber areas also differed among districts as shown in Figure 2.

The main cultivated improved pasture species were *Brachiaria* hybrid cv. Cayman, *Brachiaria* hybrid cv. Cobra, *P. purpureum* cv. Ouma and *P. purpureum* cv. ILRI 16835 and *Chloris gayana* (Rhodes). However, *Brachiaria* hybrid varieties were cultivated by most

farmers (75%) in the area and 41% of surveyed farmer cultivated the combination of *Brachiaria* (Cayman and Cobra), ILRI 16835, Ouma and Rhodes. These forage species were grown as pure stand except for a few farmers (19%) who intercropped grass with legumes (*Desmodium intortum*) or cultivated them with timber or fruit trees e.g. avocado. According to key informants, farmers were weeding using hand hoes, used fertilisers in their pasture plots and harvested forage after about 40 days' regrowth period.

Respondents preferred improved pasture species because they resulted in high milk production (31%), had a high regrowth rate after harvesting (20%) and were highly palatable, that is, easily eaten by cattle (18%). Other preferred pasture qualities are presented in Figure 3. Respondents mentioned lack of awareness (62.5%), planting materials (20.8%) and poor establishment rate (16.7%) as major challenges that limited wider adoption of improved pasture species.

It was also observed during household's interview that some unfenced pasture plots were grazed and there were banana weevil (*Cosmopolites sordidus*) look-alike beetles (Figure 4) which attacked the roots of *Brachiaria* hybrids varieties in Kichiwa ward, Njombe district.

Soil management and condition

There were differences in soil physical and chemical properties between soil depth and among districts (Table

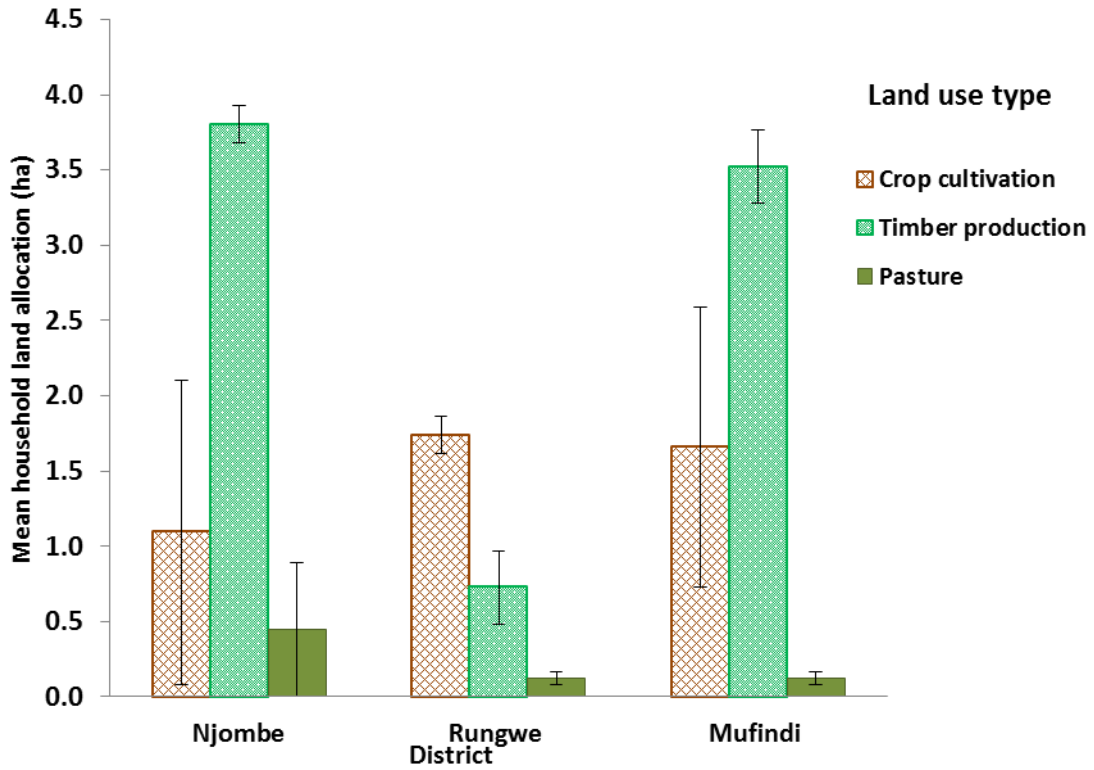


Figure 2. Mean land size allocated for pasture, crop and timber production per household in study area in Southern Highlands, Tanzania. Source: Study

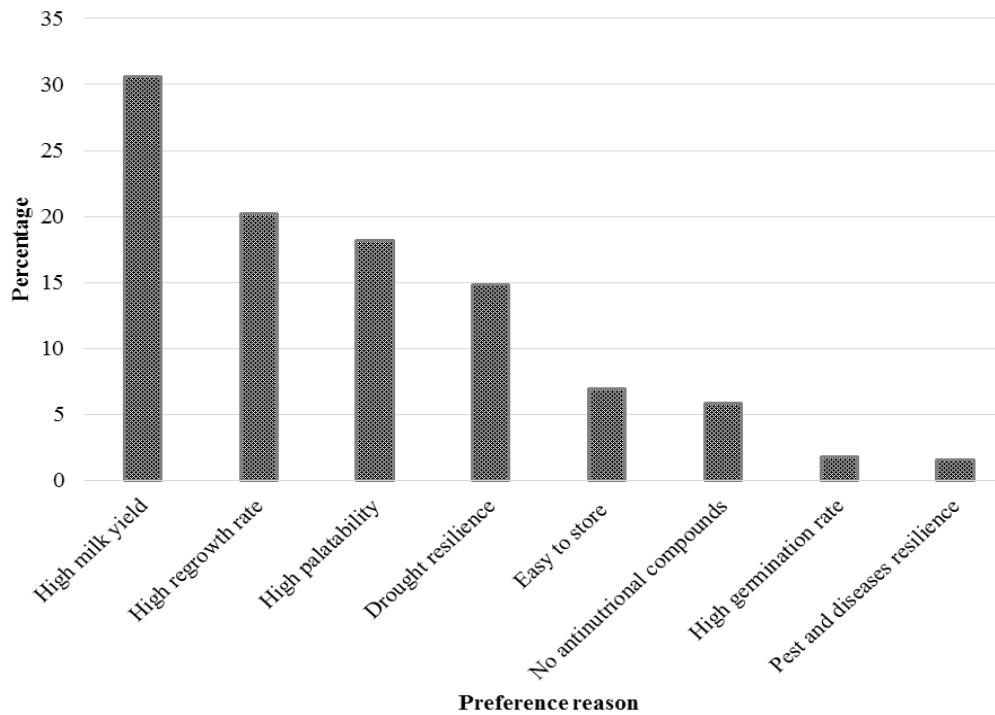


Figure 3. Dairy farmers (% responses, n=445) perception and preference of the improved pasture species in Southern highlands, Tanzania. Source: Study



Figure 4. Banana weevil (*Cosmopolites sordidus*) look alike beetles (A) found in soil with affected dead roots of *Brachiaria* hybrid varieties (B) in Kichiwa ward, Njombe district.
Source: Study

2). Soil particle size, pH, TN, available P and exchangeable Na varied with depth whereby sand, TN, available P and exchangeable Na were higher in top-soil than sub-soil for Mufindi and Rungwe districts except for clay and pH which was higher in sub-soil than top soil in the same districts. Furthermore, the Rungwe district had lower clay but higher exchangeable K, silt and sand in the two soil depths compared to Mufindi and Njombe districts. Soil pH in two soil depths was acidic (soil pH<5.5) in all districts except for Rungwe which was medium (5.6 and 5.9 for top and sub-soil, respectively). Secondary data obtained from the agricultural extension officer showed that farmers were using a combination of inorganic (urea) and organic (manure) fertilisers on their pasture plots.

Soil fertility varied among districts' top-soil, exchangeable K was on borderline (0.2 Cmol+/kg) of medium and low values in Mufindi and Njombe while it was medium for Rungwe (0.6 Cmol+/kg). Available P was categorised as adequate for pasture cultivation in Mufindi (8.7 mg/kg) but it was deficient in Njombe (2.9 mg/kg) and Rungwe (0.03 mg/kg) while TN was medium (0.2-0.3%) in all district.

DISCUSSION

Dairy and pasture management

Results showed that farmers in the study area were keeping improved dairy cattle breeds and were cultivating improved pasture species. Pasture cultivation among respondents showed the importance of improved forage species as feed resources and their potential to meet the high nutritional requirements of dairy cattle. The dairy breeds kept e.g. Friesian and Jersey have high milk yields and selected pasture species could maintain or

improve dairy production in African highlands sustainably (Maleko et al., 2019; Notenbaert et al., 2020; Hawkins et al., 2021; Mekonnen et al., 2022). Cows number in the current study (1.4 to 2.5 per household) was in the lower end of 1.8 to 6.1 cows per household reported among smallholder dairy farmers in Tanzania and Ethiopia (Swai and Karimuribo, 2011; Hailemariam et al., 2022). The variation between current and former studies is attributed to levels of household engagement in dairy farming as was indicated by land allocated for pasture cultivation in Figure 2. Farmers acknowledge that improved pasture led to increased milk yield, had high regrowth rate and were palatable (Figure 3). These selection criteria indicated good dairy management among respondents and they are well justified as selected pasture varieties were bred for high biomass yields and good nutritional values (Maass et al., 2015; Negawo et al., 2017; Ohmstedt and Mwendia, 2018).

Studied dairy farmers were weeding and harvesting their forage at 40 days after re-growth which was within 25 to 45 days but shorter than the 60 to 75 days rotation recommended for improved pasture varieties during rainy and dry seasons, respectively (Ohmstedt and Mwendia, 2018). The 40 days rotation is explained by the long rainy period (up to 9 months) in the studied area (Koskikala et al., 2020), hence farmers experienced prolonged rainy season. It could also be because at the younger stage pastures are highly digestible and have higher water soluble carbohydrates to meet the energy requirement of dairy cattle (Calvache et al., 2020). Some farmers (19%) were inter-cropping grass legume by mixing *D. intortum* with selected pasture varieties. This practice is well substantiated since *D. intortum* is compatible with selected pasture varieties hence reducing possible inter-species competition for light and soil nutrients (Mwangi and Wambugu, 2003; Negawo et al., 2017). The lack of wider grass legume inter-cropping practices in the

Table 2. Soil physical and chemical properties (mean \pm standard error) among selected households (n=38) in Southern Highlands, Tanzania.

Soil depth	District		
	Mufindi (n=12)	Njombe (n=15)	Rungwe (n=11)
Clay (%)			
Top soil	39.3 \pm 2.1 ^{a,‡}	43.4 \pm 2.1 ^a	15.5 \pm 2.2 ^b
Sub-soil	45.3 \pm 2.1 ^{a,§}	47.8 \pm 2.1 ^a	18.9 \pm 2.2 ^b
Silt (%)			
Top soil	11.6 \pm 2.0 ^a	8.7 \pm 2.0 ^a	27.9 \pm 2.0 ^b
Sub-soil	11.0 \pm 2.0 ^a	9.1 \pm 2.0 ^a	26.9 \pm 2.0 ^b
Sand (%)			
Top soil	49.3 \pm 1.8 ^{a,‡}	47.9 \pm 1.9 ^a	56.8 \pm 1.9 ^b
Sub-soil	43.8 \pm 1.8 ^{a,§}	43.2 \pm 1.9 ^a	54.4 \pm 1.9 ^b
pH			
Top soil	5.4 \pm 0.1	5.2 \pm 0.1	5.6 \pm 0.1 [‡]
Sub-soil	5.4 \pm 0.1 ^{a,b}	5.2 \pm 0.1 ^a	5.9 \pm 0.1 ^{b,§}
Total Nitrogen (%)			
Top soil	0.26 \pm 0.06 [‡]	0.16 \pm 0.06	0.33 \pm 0.06 [‡]
Sub-soil	0.20 \pm 0.06 [§]	0.12 \pm 0.06	0.26 \pm 0.06 [§]
Phosphorus (mg/kg)			
Top soil	8.7 \pm 1.7 [‡]	2.9 \pm 1.8	0.03 \pm 1.8
Sub-soil	2.2 \pm 1.7 [§]	0.8 \pm 1.8	0.04 \pm 1.8
Potassium (Cmol+/kg)			
Top soil	0.22 \pm 0.05 ^a	0.19 \pm 0.05 ^a	0.56 \pm 0.06 ^b
Sub-soil	0.16 \pm 0.05 ^a	0.15 \pm 0.05 ^a	0.60 \pm 0.06 ^b
Calcium (Cmol+/kg)			
Top soil	5.1 \pm 1.7	0.9 \pm 1.7	3.3 \pm 1.7
Sub-soil	3.9 \pm 1.7	0.8 \pm 1.7	3.1 \pm 1.7
Magnesium (Cmol+/kg)			
Top soil	0.6 \pm 0.1	0.3 \pm 0.1	0.5 \pm 0.1
Sub-soil	0.5 \pm 0.1	0.2 \pm 0.1	0.6 \pm 0.1
Sodium (Cmol+/kg)			
Top soil	0.03 \pm 0.02	0.04 \pm 0.02	0.08 \pm 0.02 [‡]
Sub-soil	0.03 \pm 0.02	0.04 \pm 0.02	0.04 \pm 0.02 [§]

Means in the same row and column with different letters and symbols were statistically different.

Source: Study

studied area denied farmers a potential cheap source of protein since selected pastures have lower protein than the amount required by improved dairy cattle breeds (Salah et al., 2014; Maass et al., 2015; Maleko et al., 2019). Also, lack of farmers' awareness, planting materials, and poor germination as mentioned by

respondents could affect dairy production in the highlands. This is because farmers would have to use alternative feedstuffs such as agricultural by-products or crop residues (Asimwe et al., 2015; Criscioni and Fernández, 2016). These feedstuffs could increase dairy production costs or lower productivity which will affect

farmers' livelihoods and food security.

Low awareness on existing improved pastures as was mentioned by 62.5% of respondents is attributed to inadequate livestock extension service which limits education and technology transfer to farmers (Cadilhon et al., 2016; Kilelu et al., 2017). There was upscaling of pasture cultivation from initial CSDP farmers whilst more dairy farmers in the area used improved pasture stems/cuttings to establish their own plots. Lack of planting materials and poor establishment rate are due to the recent introduction of selected pasture varieties and lack of proper pasture seeds supply which forced adapting farmers to use cuts from established plots as was also reported by Kizima et al. (2014) and Bhatt et al. (2020). There is a need to involve private actors in pasture seeds marketing to ensure technologies transfer to targeted farmers as was done through dairy innovation platforms elsewhere in Tanzania (Rao et al., 2019; Twine et al., 2019).

Improved pasture varieties were attacked by banana weevil (*Cosmopolites sordidus*) look-alike beetle in Kichiwa ward, Njombe district (Figure 4). There have been reports of banana weevil infestation in Tanzanian southern highlands before (Nsemwa, 1991; Mwaitulo et al., 2011) but it is the first time similar species was noticed affecting forage in the area. Although it was not mentioned as the major challenge since it was seen in one district, it was recommended that further studies to identify it and its life cycle be done before upscaling susceptible pasture variety in the whole area as there were no active interventions currently done to effectively control this pest.

Soil condition

Dairy farmers in this study were using organic and inorganic fertilizers regularly on their pasture plots. This is due to high biomass yield and regular pasture harvest hence the need to replenish utilised soil nutrients. Exchangeable potassium concentration was higher in Rungwe top and sub-soil (0.56 and 0.60 Cmol+/kg, respectively) compared to other districts. The variation is due to differences in soil types whereas soil in Rungwe was volcanic (andosols) which is young and rich in exchangeable potassium (Lubis et al., 2021; Rajmi et al., 2021) while that in Njombe and Mufindi was acrisols which are old and weathered (Abera and Wolde-Meskel, 2013). Use of fertilisers could have influenced the soil particle size and contributed to exchangeable potassium variations. Njombe and Mufindi had high clay particles (Table 2) than Rungwe whilst clay is known to bind K hence render it non-exchangeable or structural (Akbas et al., 2017; Shakeri and Abtahi, 2018). Also, simultaneous use of inorganic fertiliser and manure as mentioned by the extension officer added organic matter which binds K⁺ to soil and led to K⁺ leaching to sub-soil (Rosolem and

Steiner, 2017; Bader et al., 2021). The results further reveal that available P in Njombe and Rungwe was <8 mg/kg required to support optimum pasture yield (Landon, 1991). Therefore, there is a need to investigate the relation between fertilisers used and available Phosphate and exchangeable potassium in the studied areas as they are essential for energy metabolisms in plants, stress response, nitrogen use and nutrient transport (Xu et al., 2020; Sardans and Peñuelas, 2021). It is also imperative to evaluate on-farm pasture growth so as to determine the effects of these soil nutrients on yields.

The observed higher pH in sub-soil (5.9, $p < 0.05$) compared to top-soil (5.6) in Rungwe could be due to leaching of exchangeable bases, that is, Na⁺, Mg⁺, Ca and K and their subsequent deposition in sub-soil as the result of heavy rainfalls (2500-3500 mm/year) in the district. Soil pH was very acidic in Njombe (5.2) and Mufindi (5.4) which is known to bind phosphates to the soil, reduce nitrification as the result of arrested bacterial activities and limit the absorption of some exchangeable cations which could reduce growth performance (Landon, 1991). It is difficult in the current study to establish clearly how established pastures were affected by soil pH but selected pasture varieties are known to be tolerant to acidic soils (Ohmstedt and Mwendia, 2018). Moreover, the lack of N, P and K⁺ differences between two soil depths except for TN in Rungwe showed the presence of essential plant nutrients in sub-soil which are not utilised. Farmers can utilise these nutrients by planting deep rooted fodder trees e.g. *Calliandra* species which could provide protein rich feedstuffs (Mwangi and Wambugu, 2003). It seems farmers in the study area are already aware of this as some of them were cultivating pasture with other woody plants, that is, timber and avocado trees. There has been increased changes in land use as farmers are diversifying their income and engaging in the cultivation of multiple farm products (Sanga et al., 2021).

Land allocation

Most farmers had set aside less land for pasture production than for crop and timber production in the studied area (Figure 2). This could be because of high productivity of improved pasture species and the small number of cows per household (Table 1). Also, the presence of communal grazing areas and the use of crop residues might have limited land allocated for pasture production (Rao et al., 2015). In Rungwe, dairy farming was perceived to be less important as source of household income probably resulting from low milk prices which act as a disincentive to adopt forage technologies. Thus some respondents have switched to other lucrative ventures such as avocado and timber plantation (Juma et al., 2019; Kalinga et al., 2019).

Such attitudinal shift in Africa emanate from market

force and increasing number of contract farming schemes on different cash crops and horticultural products with a promise to capture export markets (West and Haug, 2017; Ncube, 2020; Nsimbila, 2021). In this regard dairy farmers must re-establish or strengthen the existing formal dairy value chain through a dairy marketing hub, as has been done in eastern and northern Tanzania (Cadilhon et al., 2016; Kilelu et al., 2017). This could lead to high economic return and encourage farmers to increase managerial intensification of their pasture plots in order to increase dairy productivity.

Conclusion

Farmers were cultivating different improved pasture varieties and applied fertilizers on their established pasture plots which were supposed to maintain soil nutrients. Soil results, indicated that soil conditions were not sufficient to support optimum pasture production despite fertilizer uses. Pasture plot sizes were least compared to areas set for other activities probably and some farmers mentioned that dairy income was of moderate importance hence small area was allocated for pasture. There is a need to promote farmers' access to planting materials in order to encourage intensive pasture management which will enhance food security and improve livelihoods among smallholder dairy farmers.

CONFLICT OF INTERESTS

International Centre for Tropical Agriculture (CIAT) which funded this project developed improved pasture varieties that were assessed in this study.

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