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Mgeta Steven Merumba
Tanzania Agricultural Research Institute, Bukoba

Ernest Semu
Sokoine University of Agriculture (SUA)

Johnson Semoka
Sokoine University of Agriculture (SUA)

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Profitability of Using Different Rates of Farmyard Manure and Potassium Fertilizer for Cassava Production in Bukoba, Missenyi and Biharamulo Districts, Tanzania

Mgeta Steven Merumba [a*], Ernest Semu [b], Johnson Mashambo Semoka [b], Balthazar Michael Msanya [b], Jojianas Kokulamka Kibura [a] and Joyce Siima Blandes [a]

[a] Tanzania Agricultural Research Institute (TARI), Maruku Research Centre, P.O. Box 127, Bukoba, Tanzania.
[b] Department of Soil and Geological Sciences, P.O. Box 3008, Sokoine University of Agriculture, Morogoro, Tanzania.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The resolution of using or not using a particular technology in crop production is governed by the profitability of that technology being used. A study was conducted in Bukoba, Missenyi and Biharamulo districts in the Kagera region during the 2018/19 and 2019/20 cropping seasons to determine the economic benefit of using different rates of farmyard manure (FYM) and potassium (K) fertilizer in cassava production. One village potential for cassava production was selected in each district for establishment of cassava trials. Three tillage methods [flat tillage, tied ridging and open ridging] and eleven fertilizer rates [FYM at 4 or 8 MT ha^{-1}, $N_{40}P_{30}$ + K at 40, 80 or 120 kg ha^{-1}, FYM at 4 or 8 MT ha^{-1} + K at 40, 80 or 120 kg ha^{-1}] and the control, were arranged in a Randomized Complete Block Design (RCBD) with three replications using a split-plot design. Tillage methods were the main plots and fertilizer rates were the subplots. Cassava yields (MT ha^{-1}) were collected

*Corresponding author: E-mail: smerumbason@gmail.com;

at harvesting (12 months after planting). Partial budget analysis was carried out to estimate the gross values using the adjusted yields at market price for cassava and fertilizers. Costs and benefits were calculated on a hectare basis, in Tanzania Shillings (TShs) ha^{-1}, and converted to USD ha^{-1} based on the prevailing exchange rate of 1 USD, equivalent to 2 300 TShs. All variable costs were summed up to total variable cost (TVC). The net benefits (NB) [gross benefit (GB) - TVC] ha^{-1} of the tested treatments were calculated and used to assess the profitability of each treatment. Moreover, the benefit-cost ratios (BCR) [net benefit ÷ TVC] of the tested treatments were compared to the acceptable value of greater than 2 for the technology to be adopted by farmers. The results indicated that in both cropping seasons, and in all studied sites, all the tested fertilizer types and rates gave acceptable BCR of greater than 2, implying that all the fertilizer types and rates could be used for cassava production in the study area. The results on net benefit indicated that the combined use of FYM at 8 MT ha^{-1} and potassium fertilizer at 80 kg K ha^{-1} gave higher net benefit (3 020 500 – 9 168 000 TShs ha^{-1} (1 313.3 – 3 986.1 USD ha^{-1}) than the other fertilizer types and rates (1 915 000 – 9 024 500 (832.6 – 3 923.7 USD ha^{-1}) and is therefore, desirable for increasing cassava root yield and net benefit. However, for the resource-poor farmers, the combined use of farmyard manure at 8 MT ha^{-1} and potassium fertilizer at 40 kg K ha^{-1} can still be adopted because, for some reason, not all the famers can afford the best treatment.

Keywords: Partial budget; net benefit; benefit-cost ratio; total variable cost; gross benefit; cassava root yield.

ABBREVIATIONS

AGRA	:	*Alliance for Green Revolution in Africa*
ANOVA	:	*Analysis of variance*
BCR	:	*Benefit-cost ratio*
°C	:	*Degree Celsius*
DAP	:	*Di-ammonium phosphate*
FYM	:	*Farmyard manure*
GB	:	*Gross benefit*
GENSTAT	:	*General Statistics*
kg ha^{-1}	:	*Kilogram per hectare*
m	:	*meter*
masl	:	*meter above sea level*
MOP	:	*Muriate of potash*
MT ha^{-1}	:	*Metric ton per hectare*
MRP	:	*Minjingu Rock Phosphate*
N, P, K, Mg, S	:	*Nitrogen, phosphorus potassium, magnesium, sulphur*
NB	:	*Net benefit*
%	:	*Percent*
RCBD	:	*Randomized Complete Block Design*
SA	:	*Sulphate of ammonia*
SUA	:	*Sokoine University of Agriculture*
TARI	:	*Tanzania Agricultural Research Institute*
TSP	:	*Triple superphosphates*
TVC	:	*Total variable cost*
URT	:	*United Republic of Tanzania*
USD	:	*United States Dollar*

1. INTRODUCTION

The decision on whether or not to use a particular technology in crop production with a defined production system is governed by the economic profitability of using the respective technology. For example, use of appropriate fertilizer types and rates, high yielding varieties and appropriate agronomic practices is desirable for increasing crop yields [1, 2]. However, increase in yield per se, may not be sufficient to guarantee increased adoption of improved technologies, particularly by poor farmers, when the costs of such inputs are relatively higher compared to income so obtained. Therefore, the economic return from use of improved agricultural technologies, including appropriate fertilizers, is considered to be more critical than yield when assessing technology adoption [3].

Evaluation of the profitability of using different fertilizers in cassava production has been done in different countries in the world, but only few have been done in African countries, including Tanzania, because few soil-fertility studies have been undertaken in cassava-based farming systems [4, 5]. For example, studies conducted by [6] in Ghana in cassava monoculture and cassava-legume rotation farming systems showed that use of N, P and K compound fertilizer at 60, 40 and 40 kg ha^{-1}, respectively, gave the highest net benefit of USD 1578.95 as opposed to non-fertilized cassava-legume farming systems. [4], working on cassava in soils of six different locations in Latin America and

Asia, reported the following different economic rates of using N, P and K fertilizers: in Kerala State in India, the economic rates of N, P and K were 100 kg N ha^{-1}, 11 kg P ha^{-1} and 83 kg K ha^{-1}; in Java and Southern Sumatra in Indonesia, were 100 kg N ha^{-1}, 22 kg P ha^{-1} and 83 kg K ha^{-1}; in Eastern Plain in Colombia, were 80 kg N ha^{-1}, 43 kg P ha^{-1} and 83 kg K ha^{-1} and in the Eastern-Central States and Campo Cerrado in Brazil, were 30 kg N ha^{-1}, 36 kg P ha^{-1} and 50 kg K ha^{-1}. In addition, [5], working on the soils of Western Kenya and Central-Eastern Uganda, reported that combined use of N, P and K fertilizers at 100 kg N ha^{-1}, 22 kg P ha^{-1} and 83 kg K ha^{-1} in cassava, gave a benefit-cost ratio (BCR) greater than 2 in 90% of the experimental sites, though they did not determine the economic rates of applied fertilizers since only one rate of each type of fertilizer was tested. Moreover, [7] working on the soils of Soga and Bungu villages in Kibaha and Rufiji districts, respectively in Coast region, Tanzania, reported economic rates of 40 kg N ha^{-1}, 15 - 30 kg P ha^{-1} and 40 kg K ha^{-1} upon use of sulphate of ammonia (SA) for N, triple superphosphate (TSP) or Minjingu rock phosphate (MRP) for P, and muriate of potash (MOP) for K in cassava production.

However, it has been noted that the above studies focused mostly on inorganic fertilizers and did not include organic fertilizer such as farmyard manure (FYM) or the combination of inorganic and organic fertilizers. This study, therefore, aimed at assessing the economics of using different rates of farmyard manure and potassium fertilizer in cassava production, and propose economic rates of farmyard manure or combinations of farmyard manure and potassium fertilizers, which are profitable for cassava production in Bukoba, Missenyi and Biharamulo districts in Kagera region, Tanzania.

In Kagera region, about 12.5% of smallholder farmers use inorganic fertilizers mostly, in maize production however, very few farmers use potassium (K) fertilizers [8] though the soils of Kagera region are low in K [9]. The low use of fertilizer is attributed to inadequate knowledge on fertilizer use such as appropriate type, rate, time and method of application and benefits [9]. Other factors include unavailability of fertilizers, farmers' financial constraints, high prices of fertilizers, transportation problems of manure due its bulkiness per unit area [8, 10]. In addition, farmers believe that cassava does not require fertilizers as the crop can grow in marginal environments [11].

2. MATERIALS AND METHODS

2.1 Description of the Study Area

2.1.1 Location of the study area

Kagera region is located in the north-western corner of Tanzania on the western shore of Lake Victoria between latitudes 1°00′ and 3°45′ south of Equator and between longitudes 30°25′ and 32°40′ east of Greenwich. It is the fifteenth largest region in Tanzania with an area of about 3 568 600 ha of land, which accounts for approximately 3.3% of Tanzania's total land area. Out of the region's area, 10 173 ha are covered by water of the Lake Victoria, Ikimba and Burigi, and of the river Kagera and Ngono [12, 13]. Administratively, the region has seven districts, namely Biharamulo, Bukoba, Karagwe, Kyerwa, Missenyi, Muleba and Ngara, and borders four countries, namely Uganda, Rwanda, Burundi, and Kenya across Lake Victoria. However, this study was conducted in three districts, namely Bukoba, Missenyi and Biharamulo The selection of these districts were based on the representative of agro-ecological zones of Kagera region and the potential for cassava production. The representative study sites were Tanzania Agricultural Research Institute (TARI), Maruku Centre in Butairuka village (Bukoba district), Mabuye Primary School in Mabuye village (Missenyi district) and Rukaragata Farmers' Extension Centre in Rukaragata village (Biharamulo district) [13].

Bukoba district covers an area of 284,100 ha and is situated between latitudes 1° 00′ and 3° 00′ S and between longitudes 30° 45′ and 31° 00′ E with altitude between 1200 - 1400 meters above sea level. Missenyi district covers an area of 270 875 ha and is situated between latitudes 1° 00′ and 1° 30′ S and between longitudes 30° 48′ and 31° 49′ E with attitude between 1100 - 1400 meters above sea level. Biharamulo district covers an area of 374 400 ha and is situated between latitudes 2° 15′ and 3° 15′ S and between longitudes 31° 00′ and 32° 00′ E with altitude ranging from 1100 - 1700 meters above sea level (masl) [8, 9]. Based on rainfall, three agro-ecological zones namely high, medium and low rainfall zones are found in Kagera region [13, 14, 15], which in this study are represented by Bukoba district (high rainfall), Missenyi district (medium rainfall) and Biharamulo district (low rainfall) [16]

2.1.2 Climate and soils of the study area

The districts in Kagera region experience bimodal rainfall distribution between September and December (short rains) and between March and June (long rains). The mean annual rainfall ranges from 900 - 3000 mm in Bukoba district, 600 - 2000 mm in Missenyi district and 700 - 1000 mm in Biharamulo district [14, 16, 17]. The mean annual temperature ranges from 16 - 28 °C. However, Missenyi district has higher annual temperature (28 °C) than Bukoba and Biharamulo (26 °C). In terms of soil texture, the soils range from sandy clay loam to sandy clay and clay [14, 18]. However, the soils of the study area indicate that P, K and Mg deficiencies were widely spread in Bukoba district while N and S deficiencies were widely spread in Missenyi district and N, P and K deficiencies were widely spread in Biharamulo district [18].

2.2 Site Selection

This study was conducted in Bukoba, Missenyi and Biharamulo districts. In each district, one ward and one village in each ward were selected. In each selected village, one site was selected for the establishment of the experimental trial. The selected experimental sites were Tanzania Agricultural Research Institute (TARI)-Maruku Centre, Mabuye Primary School, and Rukaragata Extension Centre in Bukoba, Missenyi and Biharamulo districts, respectively [13, 16]. The locations of the experimental trial sites are presented in Fig. 1.

2.3 Experimental Layout and Treatments Application

Three field experimental trials, one in each study site were established in two consecutive seasons (2018/19 and 2019/20) in Bukoba, Missenyi and Biharamulo districts. In each trial site, land was prepared before trial establishment, followed by plowing and harrowing. Ridges were prepared by heaping up the soil to about 60 cm within 1 m wide (0.5 m from each side of the ridge top) using hand hoe; so that the spacing from the top-canter of one ridge to the top-center of another ridge was 1 m wide. The plot size was 6 m x 5 m and the separation between plots and blocks was 1.5 m and 2 m apart, respectively.

For the tied ridges, the soil was raised at each end of the ridges and at the center (2.5 m from each end of the ridge) to form three ties [16]. The treatments were arranged in Randomized Complete Block Design (RCBD) with three replications using the split-plot design; with three tillage methods (flat tillage, open ridging and tied ridging) as the main plots and eleven fertilizer rates [FYM at 4 MT ha^{-1}, 8 MT ha^{-1}, N at 40 kg ha^{-1} + P at 30 kg ha^{-1} + potassium fertilizer at 40, 80 or 120 kg K ha^{-1}, the combination of FYM at 4 MT ha^{-1} or 8 MT ha^{-1} + potassium fertilizer at 40, 80 or 120 kg K ha^{-1}] and the control as the subplots (Table 1). The combinations of N at 40 kg ha^{-1} + P at 30 kg ha^{-1} [7] + potassium fertilizer at 40, 80, or 120 kg K ha^{-1}; were applied as inorganic fertilizer treatments and FYM at 4 MT ha^{-1} or 8 MT ha^{-1} + potassium fertilizer at 40, 80 or120 K kg ha^{-1} were applied as the combinations of organic and inorganic fertilizer treatments [16].

Table 1. The applied treatments in the split-plot design

Main plots		
Flat tillage	**Open ridge tillage**	**Tied ridge tillage**
Subplots		
Co	Co	Co
FYM_4	FYM_4	FYM_4
FYM_8	FYM_8	FYM_8
K_{40} $N_{40}P_{30}$	K_{40} $N_{40}P_{30}$	K_{40} $N_{40}P_{30}$
K_{80} $N_{40}P_{30}$	K_{80} $N_{40}P_{30}$	K_{80} $N_{40}P_{30}$
$K_{120}N_{40}P_{30}$	$K_{120}N_{40}P_{30}$	$K_{120}N_{40}P_{30}$
FYM_4K_{40}	FYM_4K_{40}	FYM_4K_{40}
FYM_4K_{80}	FYM_4K_{80}	FYM_4K_{80}
FYM_4K_{120}	FYM_4K_{120}	FYM_4K_{120}
FYM_8K_{40}	FYM_8K_{40}	FYM_8K_{40}
FYM_8K_{80}	FYM_8K_{80}	FYM_8K_{80}
FYM_8K_{120}	FYM_8K_{120}	FYM_8K_{120}

Source: [16]

CO = control (no fertilizer application); FYM4 = farmyard manure at 4 MT ha^{-1}; FYM8 = farmyard manure at 8 MT ha^{-1}; K40N40P30 = potassium at 40 kg K ha^{-1}, nitrogen at 40 kg N ha^{-1} and phosphorus 30 kg P ha^{-1}; K80N40P30 = potassium at 80 kg K ha^{-1}, nitrogen at 40 kg N ha^{-1} and phosphorus 30 kg P ha^{-1}; K120N40P30 = potassium at 120 kg K ha^{-1}, nitrogen at 40 kg N ha^{-1} and phosphorus 30 kg P ha^{-1}; FYM4K40 = farmyard manure at 4 MT ha^{-1} and potassium at 40 kg K ha^{-1}; FYM4K80 = farmyard manure at 4 MT ha^{-1} and potassium at 80 kg K ha^{-1}; FYM4K120 = farmyard manure at 4 MT ha^{-1} and potassium at 120 kg K ha^{-1}; FYM8K40 = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; FYM8K80 = farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1}; FYM8K120 = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}

Farmyard manure was applied at planting along the planting rows in the flat tillage treatment and along the ridges in the open and tie-ridging treatments followed by incorporation into the soils. Farmyard manure applied in each experimental site was collected from one farmer in each site. The chemical composition and the amount of N, P and K added annually in the soil from the applied FYM in each district are presented in Table 2. In all districts, the distance from the source of farmyard manure to the experimental sites ranged from 20 – 30 km [16]. Inorganic fertilizers, namely di-ammonium phosphate (DAP) for N and P and muriate of potash (MOP) for K were applied in two splits; the first split at one month after planting for allowing fibrous roots development on cassava cuttings for nutrients uptake since sprouting of cassava cuttings starts at 2 – 3 weeks after planting. The second split of inorganic fertilizer was applied in three months after planting by banding the fertilizers around each cassava plant [16]. Improved cassava variety (*Mkumba*), was the test variety. Cassava cuttings of 25 to 30 cm length were planted at a spacing of 1 m x 1 m in the flat tillage and ridging treatments. The duration (cassava growing period) of the trial from planting to harvesting was 12 months. The experimental plots were maintained free from weeds, throughout the growing period, and repeated in the following season while maintaining the same plots.

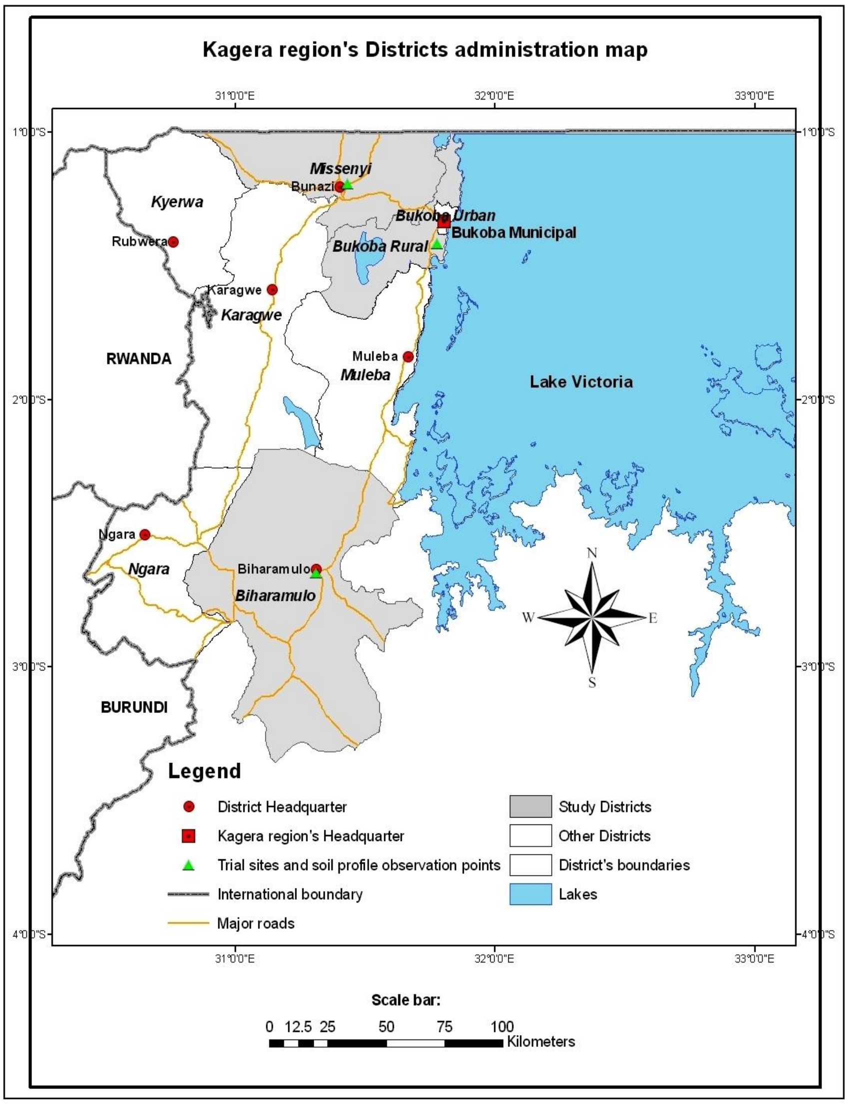

Fig. 1. Location of experimental trial sites in Bukoba, Missenyi and Biharamulo districts
Source: [13, 16]

Table 2. The contents of N, P and K in the applied farmyard manure and annual addition of N, P and K in the soil from farmyard manure

Experimental site	Cropping season	Content of N, P and K in FYM (%)			Addition of N, P and K (kg ha^{-1}) in soil from FYM					
					4 MT			8 MT		
		N	P	K	N	P	K	N	P	K
Bukoba	2018/19	0.50	0.09	1.21	20.00	3.56	48.40	40.00	7.12	96.80
	2019/20	0.52	0.09	1.25	20.80	3.44	50.00	41.60	6.88	100.00
Missenyi	2018/19	0.54	0.12	1.51	21.60	4.80	60.40	43.20	9.60	120.80
	2019/20	0.56	0.11	1.54	22.40	4.40	61.60	44.80	8.80	123.20
Biharamulo	2018/19	0.58	0.08	1.78	23.20	3.04	79.20	46.40	6.08	142.40
	2019/20	0.57	0.08	1.83	22.80	3.00	73.20	45.60	6.00	146.40

Source [16]

2.4 Data Collection and Analysis

Cassava root yields were collected from the net plot (4 m x 3 m) during harvesting (12 months after planting). Whereby, in each treatment, the weight of cassava root was recorded after detaching the roots from the plants and weighed using a weighing balance. The weights of cassava roots in each treatment were converted into MT ha^{-1}. Thereafter, cassava root yields from each treatment were subjected to analysis of variance (ANOVA) using GENSTAT 15th edition statistical packages based on the statistical model for the split-plot design [19].

Assessment of the profitability of using different rates of farmyard manure and potassium fertilizers in cassava production was done using the benefit cost ratio and gross margin/net benefit [3, 6, 5, 20]. In determining the most economically acceptable treatment, partial budget analysis was carried out to estimate the gross values using the adjusted yields at market price for cassava and fertilizers as described by [21]. Economic analysis was done using the prevailing market prices for inputs at planting and for outputs at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Tanzania shillings (TShs) ha^{-1}, and converted to USD ha^{-1} based on the then prevailing exchange rate of 1 USD equivalent to 2 300 TShs.

It is better to note that the evaluation of the three tillage methods was done in based on the costs involved during land preparation, which were the same for all the three tillage methods in all three districts (Tables 3, 4, 5, 6, 7 and 8) in both cropping season. The partial budget of the tested fertilizer types and rates in each district was prepared with the following components: average cassava root yield, which is the average yield (MT ha^{-1}) for each treatment in each study site, the field price of cassava roots (TShs kg^{-1}) which is the point-of-sale retail price of cassava roots (farm gate price), the gross benefit (GB) ha^{-1} which is the product of field price of cassava root and the average cassava root yield for each treatment, and all costs (fixed and variable costs) involved in cassava production including cost of seeds/cassava cuttings per hectare, cost of inorganic fertilizers or FYM ha^{-1}, transportation cost of fertilizers or FYM ha^{-1}, cost of land preparation per hectare (bush clearing, ploughing, harrowing and ridging), cost of inorganic fertilizers or FYM and its application, cost of planting per hectare, cost of weeding per hectare, cost of harvesting per hectare and transportation cost of cassava roots. All variable costs (costs which change as output changes) were summed up to give the total variable cost (TVC) [22]. Thereafter, the net benefit (NB) ha^{-1} for each treatment was calculated as the difference between the GB and the TVC (i.e., gross benefit - total variable cost) [22]. In addition, Benefit-cost ratio (BCR), calculated as the ratio between the net benefit and the total variable cost as per Equation 1 below, was compared to the recommended value of greater than 2 for the technology to be recommended for adoption by farmers in developing countries where crop yields are low under small scale agriculture [3].

$$\mathrm{BCR} = \frac{\mathrm{GB} - \mathrm{TVC}}{\mathrm{TVC}} \quad (1)$$

Where: BCR is the benefit-cost ratio, GB is the gross benefit and TVC is the total variable cost.

3. RESULTS AND DISCUSSION

3.1 Partial Budget and Benefit-cost Ratios (BCR) of the Tested Fertilizer Rates during the 2018/19 and 2019/20 Cropping Seasons in the Bukoba District

The results on net benefits and benefit-cost ratios of the tested fertilizer types and rates during the 2018/19 and 2019/20 cropping seasons in the Bukoba site are presented in Tables 3 and 4. During the 2018/19 cropping season, the net benefits of the fertilizer rates ranged from 2 315 000 - 5 178 000 Tanzania Shillings per ha^{-1} (TShs ha^{-1}) (Table 3), equivalent to 1 006. 5 - 2 251.3 USD ha^{-1} while during the 2019/20 cropping season, the net benefits ranged from 2 120 000 - 6 024 000 TShs ha^{-1} (Table 4), equivalent to 921.7 5 - 2 619.1 USD ha^{-1}.

In both cropping seasons, the low net benefits were recorded in the control, whereas the high net benefits were recorded in the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg K ha^{-1}. This was be attributed to the low cassava yield in the control and the high cassava yield in the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg K ha^{-1} (Tables 2 and 3), implying that the use of fertilizers increased the net benefit. The results indicated that the use of fertilizer types and rates tested in this study, increased the net benefit by 40.3 to 55.3% during the 2018/19 cropping season, and by 54.3 to

64.8% during the 2019/20 cropping season, with annual NB increase of 9.5 to 14%, due to increased cassava root yield. The increased cassava root yield was attributed to the continued use of the same fertilizers in the second cropping season. Thereby, continued addition of fertilizers led to residual accumulation of essential nutrients such as N, P and K in the soil [23, 24].

The results also indicate that among the tested fertilizer treatments, the highest NB was recorded in the combined use of high rate of FYM and potassium fertilizers. Thereby, combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg ha^{-1} gave the highest NB (5 178 000 - 6 023 000 TShs ha^{-1}, equivalent to 2 251.3 - 2 619.1 USD ha^{-1}) followed by the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 120 kg ha^{-1} (4 939 500 - 5 997 000 TShs ha^{-1}, equivalent to 2 147.6 - 2 607.4 USD ha^{-1}) and the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 40 kg ha^{-1}(4 901 500 - 5 921 500 TShs ha^{-1}, equivalent to 2 251.3 - 2 574.6 USD ha^{-1}). Therefore, for the high cassava root yield, and net benefit, the combination of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg K ha^{-1} followed by the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 120 kg K ha^{-1}, and the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 40 kg K ha^{-1}, could be used for cassava production in the study area.

In both cropping seasons, the results on benefit-cost ratio (BCR) of the tested fertilizer types and rates indicated that all the fertilizer rates and the control, gave BCR greater than 2, which according to [3] and [5]), are acceptable BCR in any technology. Hence, farmers can adopt any technology that gives BCR value greater than 2. Therefore, the results of this study indicated that cassava producing farmers in the study area could adopt any of the treatments tested in this study. This implied that even the control treatment could be used for cassava production as, according to [3] and [5], it gave acceptable BCR, probably due to its low TVC (Tables 3 and 4). This conforms to what reported by other researchers, for example [4] and [25], that cassava is a famine crop, which can be grown and produce a reasonable yield in a marginal land with adverse climatic and soil conditions, due to its tolerance to drought, acid soil and poor soil fertility where other crops fail.

The lower net benefit recorded in the control than in the other tested treatments can be a result of not using fertilizer during cassava production in the study area. Therefore, for the good cassava growth, high cassava root yield and ultimately high net benefit, the use of fertilizer and most specifically, the combination of FYM at 8 MT ha^{-1} and potassium fertilizer at 80 kg K ha^{-1} is indispensable in the study as it gave the high net benefit (Tables 3 and 4). However, the results on cassava root yields indicated no significant (P = .08) difference among the combined use of FYM at 8 MT ha^{-1} and potassium fertilizer at 40, 80 or 120 kg K ha^{-1} [16]. Based on those findings therefore, for the resource-poor farmers, the combined use of farmyard manure at 8 MT ha^{-1} and potassium fertilizer at 40 kg K ha^{-1} could still be adopted because, for some reason, not all the famers can afford the best treatment.

3.2 Partial Budget and Benefit-cost Ratios of the Tested Fertilizer Rates during the 2018/19 and 2019/20 Cropping Seasons in the Missenyi District

The results on net benefit (NB) and benefit-cost ratio (BCR) of the tested fertilizer types and rates during the 2018/19 and 2019/20 cropping seasons in the Missenyi experimental sites are presented in Tables 5 and 6. During the 2018/19 cropping season, the net benefits of the tested fertilizer types and rates ranged from 3 040 000 - 8 673 00 TShs ha^{-1} (Table 5), equivalent to 1 321.7 - 3 770.9 USD ha^{-1} while during the 2019/20 cropping season, the net benefits ranged from 3 032 500 - 9 168 000 TShs ha^{-1} (Table 6), equivalent to 1 318. 5 - 3 986.1 USD ha^{-1}.

In both cropping seasons, the low net benefits were recorded in the control treatments, whereas the high net benefits were recorded in the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg K ha^{-1}. This was attributed to the low gross benefit recorded in the control, and the high gross benefit recorded in the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg K ha^{-1} due to the low cassava yield in the control and the high cassava yield in the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg K ha^{-1} (Tables 5 and 6). The results indicated that the use of fertilizers tested in this study, increased the net benefit by 55.4 to 64.9% during the 2018/19 cropping season and by 55.7 to 66.9% the during 2019/20 cropping season.

Table 3. The partial budget and benefit-cost ratios of the applied fertilizers during the 2018/19 cropping season in the Bukoba district

Parameter	Treatments											
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
Fixed costs (‘000’ TShs ha^{-1})												
Cassava cuttings/seeds	300	300	300	300	300	300	300	300	300	300	300	300
Weeding	175	175	175	175	175	175	175	175	175	175	175	175
Land preparation	375	375	375	375	375	375	375	375	375	375	375	375
Harvesting	125	125	125	125	125	125	125	125	125	125	125	125
Variable costs (‘000’ TShs ha^{-1})												
Inorganic fertilizer or FYM	0	40	80	246.8	358.8	470.8	152	264	376	192	304	416
Transport (inorganic fertilizer or FYM)	0	80	160	62.1	86.1	110.1	104	128	152	184	208	232
Loading and off-loading of FYM	0	40	80	-	-	-	40	40	40	80	80	80
Application (inorganic fertilizer or FYM)	0	150	150	75	75	225	225	225	220	225	225	225
Transportation of cassava roots	185.2	334.4	339	350.4	351.4	336.6	398.2	400	444.2	446.6	479.6	471.4
Total variable cost	**185.2**	**644.4**	**809.4**	**734.3**	**871.3**	**992.2**	**919.2**	**1 057**	**1 237.2**	**1 127.6**	**1 296.6**	**1 424.4**
Revenue (‘000’ TShs ha^{-1})												
Average cassava root yield (MT ha^{-1})	9.26	16.72	16.97	17.52	17.57	16.83	19.91	20	22.21	22.33	23.98	23.57
Average cassava root yield (kg ha^{-1})	9 260	16 720	16 970	17 520	17 570	16 830	19 910	20 000	22 210	22 330	23 980	23 570
Adjusted cassava root yield (kg ha^{-1})	8 334	15 048	15 273	15 768	15 813	15 147	17 919	18 000	19 989	20 097	21 582	21 213
Price of cassava roots (Tshs kg^{-1})	300	300	300	300	300	300	300	300	300	300	300	300
Gross befit (GB)	**2 500.2**	**4 514.4**	**4 581.9**	**4 730.4**	**4 743.9**	**4 544.1**	**5 375.7**	**5 400**	**5 996.7**	**6 029.1**	**6 474.6**	**6 363.9**
Net benefit (NB)	**2 315**	**3 870**	**3 772.5**	**3 996.1**	**3 872.6**	**3 551.6**	**4 456.5**	**4 343**	**4 759.5**	**4 901.5**	**5 178**	**4 939.5**
Benefit:cost ratio (BCR)	**12.5**	**6.0**	**4.7**	**5.4**	**4.4**	**3.6**	**4.8**	**4.1**	**3.8**	**4.3**	**4.0**	**3.5**

TShs = Tanzania shillings; T1 = control (no fertilizer application); T2 = farmyard manure at 4 MT ha^{-1} (FYM_4); T3 = farmyard manure at 8 MT ha^{-1} (FYM_8); T4 = potassium at 40 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{40}N_{40}P_{30}$); T5 = potassium at 80 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{80}N_{40}P_{30}$); T6 = potassium at 120 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{120}N_{40}P_{30}$); T7 = farmyard manure at 4 MT ha^{-1} and potassium at 40 kg K ha^{-1} (FYM_4K_{40}); T8 = farmyard manure at 4 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_4K_{80}); T9 = farmyard manure at 4 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_4K_{120}); T10 = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; T11 = farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_8K_{80}); T12 = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_8K_{120})

Table 4. The partial budget and benefit-cost ratios of the applied fertilizers during the 2019/20 cropping season in the Bukoba district

Parameter	Treatments											
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
Fixed costs ('000' TShs ha^{-1})												
Cassava cuttings/seeds	300	300	300	300	300	300	300	300	300	300	300	300
Weeding	175	175	175	175	175	175	175	175	175	175	175	175
Land preparation	375	375	375	375	375	375	375	375	375	375	375	375
Harvesting	125	125	125	125	125	125	125	125	125	125	125	125
Variable costs ('000' TShs ha^{-1})												
Inorganic fertilizer or FYM	0	40	80	246.8	358.8	470.8	152	264	376	192	304	416
Transport (inorganic fertilizer or FYM)	0	80	160	62	86	110.1	104	128	152	184	208	232
Loading and off-loading of FYM	0	40	80	-	-	-	40	40	40	80	80	80
Application (inorganic fertilizer or FYM)	0	150	150	75	75	225	225	225	225	225	225	225
Transport of cassava roots	169.6	396.2	411.2	402.8	409.2	417.8	511.2	501.8	517.2	536.2	539.2	556
Total variable cost	**169.6**	**706.2**	**881.2**	**786.7**	**929.1**	**1 073.7**	**1 032.2**	**1 158.8**	**1 310.2**	**1 217.2**	**1 364.2**	**1 509**
Revenue ('000' TShs ha^{-1})												
Average cassava root yield (MT ha^{-1})	8.48	19.81	20.56	20.14	20.46	20.89	25.59	25.09	25.86	26.41	27.36	27.80
Average cassava root yield (kg ha^{-1})	8 480	19 810	20 560	20 140	20 460	20 890	25 590	25 090	25 860	26 410	27 360	27 800
Adjusted cassava root yield (kg ha^{-1})	7 632	17 829	18 504	18 126	18 414	18 801	23 004	22 581	23 274	23 769	24 624	25 020
Price of cassava roots (Tshs kg^{-1})	300	300	300	300	300	300	300	300	300	300	300	300
Gross befit (GB)	**2 289.6**	**5 348.7**	**5 551.2**	**5 437.8**	**5 524.2**	**5 640.3**	**6 901.2**	**6 774.3**	**6 982.2**	**7 130.7**	**7 387.2**	**7 506**
Net benefit (NB)	**2 120**	**4 642.5**	**4 670**	**4 651.1**	**4 595.1**	**4 566.6**	**5 869**	**5 615.5**	**5 672**	**5 921.5**	**6 023**	**5 997**
Benefit:cost ratio (BCR)	**12.5**	**6.6**	**5.3**	**5.9**	**4.9**	**4.3**	**5.7**	**4.8**	**4.3**	**4.9**	**4.4**	**4.0**

TShs = Tanzania shillings; T1; T1 = control (no fertilizer application); T2 = farmyard manure at 4 MT ha^{-1} (FYM_4); T3 = farmyard manure at 8 MT ha^{-1} (FYM_8); T4 = potassium at 40 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{40}N_{40}P_{30}$); T5 = potassium at 80 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{80}N_{40}P_{30}$); T6 = potassium at 120 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{120}N_{40}P_{30}$); T7 = farmyard manure at 4 MT ha^{-1} and potassium at 40 kg K ha^{-1} (FYM_4K_{40}); T8 = farmyard manure at 4 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_4K_{80}); T9 = farmyard manure at 4 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_4K_{120}); T10 = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; T11 = farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_8K_{80}); T12 = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_8K_{120})

Table 5. The partial budget and benefit-cost ratios of the applied fertilizers during the 2018/19 cropping season in the Missenyi district

Parameter	Treatments											
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
Fixed costs (‘000’ TShs ha^{-1})												
Cassava cuttings/seeds)	300	300	300	300	300	300	300	300	300	300	300	300
Weeding	175	175	175	175	175	175	175	175	175	175	175	175
Land preparation	375	375	375	375	375	375	375	375	375	375	375	375
Harvesting	125	125	125	125	125	125	125	125	125	125	125	125
Variable costs (‘000’ TShs ha^{-1})												
Inorganic fertilizer or FYM	0	40	80	246.8	358.8	470.8	152	264	376	192	304	416
Transport (inorganic fertilizer or FYM)	0	80	160	62.1	86.1	110.1	104	128	152	184	208	232
Loading and off-loading of FYM	0	40	80	-	-	-	40	40	40	80	80	80
Application (inorganic fertilizer or FYM)	0	150	150	75	75	225	225	225	225	225	225	225
Transport of cassava roots	243.2	570	581.2	605.4	609.2	592.4	722.6	736.6	729.4	740.2	759.2	763.2
Total variable cost	**243.2**	**880**	**1 051.2**	**989.3**	**1 129.1**	**1 248.3**	**1 243.6**	**1 393.6**	**1 522.4**	**1 421.2**	**1 576.2**	**1 716.2**
Revenue (‘000’ TShs ha^{-1})												
Average cassava root yield (MT ha^{-1})	12.16	28.50	29.06	30.27	30.46	29.62	36.13	36.83	36.47	37.01	37.96	38.16
Average cassava root yield (kg ha^{-1})	12 160	28 500	29 060	30 270	30 460	29 620	36 130	36 830	36 470	37 010	37 960	38 160
Adjusted cassava root yield (kg ha^{-1})	10 944	25 650	26 154	27 243	27 414	26 658	32 517	33 147	32 823	33 309	34 164	34 344
Price of cassava roots (Tshs kg^{-1})	300	300	300	300	300	300	300	300	300	300	300	300
Gross befit (GB)	**3 283.2**	**7 695**	**7 846.2**	**8 172.9**	**8 224.2**	**7 997.4**	**9 755.1**	**9 944.1**	**9 846.9**	**9 992.7**	**10 249.2**	**10 303.2**
Net benefit (NB)	**3 040**	**6 815**	**6 795.5**	**7 183.7**	**7 095.1**	**6 749.1**	**8 511.5**	**8 550.5**	**8 342.5**	**8 571.5**	**8 673**	**8 587**
Benefit:cost ratio (BCR)	**12.5**	**7.7**	**6.5**	**7.3**	**6.3**	**5.4**	**6.8**	**6.1**	**5.5**	**6.0**	**5.5**	**5.0**

TShs = Tanzania shillings; T1 = control (no fertilizer application); T2 = farmyard manure at 4 MT ha^{-1} (FYM_4); T3 = farmyard manure at 8 MT ha^{-1} (FYM_8); T4 = potassium at 40 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{40}N_{40}P_{30}$); T5 = potassium at 80 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{80}N_{40}P_{30}$); T6 = potassium at 120 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{120}N_{40}P_{30}$); T7 = farmyard manure at 4 MT ha^{-1} and potassium at 40 kg K ha^{-1} (FYM_4K_{40}); T8 = farmyard manure at 4 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_4K_{80}); T9 = farmyard manure at 4 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_4K_{120}); T10 = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; T11 = farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_8K_{80}); T12 = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_8K_{120})

Table 6. The partial budget and benefit-cost ratios of the applied fertilizers during the 2019/20 cropping season in the Missenyi district

Parameter	Treatments											
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
Fixed costs (‘000’ TShs ha^{-1})												
Cassava cuttings/seeds	300	300	300	300	300	300	300	300	300	300	300	300
Weeding	175	175	175	175	175	175	175	175	175	175	175	175
Land preparation	375	375	375	375	375	375	375	375	375	375	375	375
Harvesting (Tshs ha^{-1})	125	125	125	125	125	125	125	125	125	125	125	125
Variable costs (‘000’ TShs ha^{-1})												
Inorganic fertilizer or FYM	0	40	80	246.8	358.8	470.8	152	264	376	192	304	416
Transport (inorganic fertilizer or FYM)	0	80	160	62.1	86.1	110.1	104	128	152	184	208	232
Loading and off-loading of FYM	0	40	80	-	-	-	40	40	40	80	80	80
Application (inorganic fertilizer or FYM)	0	150	150	75	75	225	225	225	225	225	225	225
Transport of cassava roots	242.6	572.6	590.4	578.6	587.4	558.2	694	703.8	716.0	764.8	798.8	798.2
Total variable cost	**246.6**	**882.6**	**1 060.4**	**962.5**	**1 107.3**	**1 214.1**	**1 215.0**	**1 360.8**	**1 509.0**	**1 445.8**	**1 615.8**	**1 751.2**
Revenue (‘000’ TShs ha^{-1})												
Average cassava root yield (MT ha^{-1})	12.13	28.63	29.52	28.93	29.37	27.91	34.60	35.19	35 80	38.24	39.94	39.91
Average cassava root yield (kg ha^{-1})	12 130	28 630	29 520	28 930	29 370	27 910	34 600	35 190	35 800	38 240	39 940	39 910
Adjusted cassava root yield (kg ha^{-1})	10 917	25 767	26 568	26 037	26 433	25 119	31 140	31 671	32 222	34 416	35 946	35 919
Price of cassava roots (Tshs kg^{-1})	300	300	300	300	300	300	300	300	300	300	300	300
Gross befit (GB)	**3 275.1**	**7 730.1**	**7 970.4**	**7 811.1**	**7 929.9**	**7 535.7**	**9 369**	**9 501.3**	**9 666**	**10 324.8**	**10 783.8**	**10 775.7**
Net benefit (NB)	**3 032.5**	**6 847.5**	**6 910**	**6 848.7**	**6 822.7**	**6 321.7**	**8 154**	**8 140.5**	**8 157**	**8 879**	**9 168**	**9 024.5**
Benefit:cost ratio (BCR)	**12.5**	**7.8**	**6.5**	**7.1**	**6.2**	**5.2**	**6.7**	**6.0**	**5.4**	**6.1**	**5.7**	**5.2**

TShs = Tanzania shillings; T1 = control (no fertilizer application); T2 = farmyard manure at 4 MT ha^{-1} (FYM_4); T3 = farmyard manure at 8 MT ha^{-1} (FYM_8); T4 = potassium at 40 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{40}N_{40}P_{30}$); T5 = potassium at 80 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{80}N_{40}P_{30}$); T6 = potassium at 120 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{120}N_{40}P_{30}$); T7 = farmyard manure at 4 MT ha^{-1} and potassium at 40 kg K ha^{-1} (FYM_4K_{40}); T8 = farmyard manure at 4 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_4K_{80}); T9 = farmyard manure at 4 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_4K_{120}); T10 = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; T11 = farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_8K_{80}); T12 = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_8K_{120})

Among the fertilizer treatments, the highest NB was recorded in the combined use of high rates of FYM and potassium fertilizer thereby, the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg ha^{-1} gave the highest NB (8 673 000 - 9 168 000 TShs ha^{-1}, equivalent to 3 770.9 - 3 986.1 USD ha^{-1}) followed by the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 120 kg ha^{-1} (8 587 000 - 9 024 500 TShs ha^{-1}, equivalent to 3 733.5 - 3 923.7 USD ha^{-1}) and the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 40 kg ha^{-1}(8 571 500 - 8 879 000 Tshs ha^{-1}, equivalent to 3 726.7 - 3 860.4 USD ha^{-1}). This trend was similar to that observed in Bukoba district. These results, therefore, indicated that for the high cassava root yield and net benefit, the use of the combination of FYM at 8 MT ha^{-1} and potassium fertilizer at 80, 120 or 40 kg K ha^{-1} for cassava production in the study area is of greater economic benefit as compared to the other fertilizer types and rates tested in this study.

In both cropping seasons, the results on the benefit-cost ratio (BCR) of the tested fertilizers indicated that all the treatments gave acceptable BCR of greater than 2 [3, 5] and thus any treatment could be used by farmers for cassava production in the study area. These results were similar to those reported in the Bukoba district (subsection 3.1). Therefore, as observed in the Bukoba district, the results of the BCR of the tested fertilizers types and rates in Missenyi district indicated that even the control treatment could be used for cassava production as it gave acceptable BCR. These results also conform to what has been reported by other researchers for example, [4] and [25] that cassava can grow and produce reasonable yield in the marginal land with poor soil fertility where other crops fail.

Although cassava can grow and give modest yield in adverse soil and climatic conditions, the lowest net benefit recorded in the control treatment in this study as for Bukoba could limit its uses for sustainable cassava production since the results indicated that if fertilizers could not be used there could be a decrease in the net benefit by 55.4 - 66.9%. Therefore, for the good cassava growth, high cassava root yield and ultimately high net benefit, the use of fertilizer and most specifically, the combination of FYM at 8 MT ha^{-1} and potassium fertilizer at 80 kg K ha^{-1} is indispensable as it gave the higher net benefits than the other fertilizer types and rates (Tables 5 and 6). These results are similar to those recorded in Bukoba district in this study.

However, as reported in the Bukoba district (subsection 3.1), the results on cassava root yields indicated no significant (P = .08) difference among the combined use of FYM at 8 MT ha^{-1} and potassium fertilizer at 40, 80 or 120 kg K ha^{-1} [16]. Based on those findings therefore, for the resource-poor farmers, the combined use of farmyard manure at 8 MT ha^{-1} and potassium fertilizer at 40 kg K ha^{-1} can still be adopted in the study area because, for some reason, not all the famers can afford the best treatment.

3.3 Partial Budget and Benefit-cost Ratios of the Tested Fertilizer Rates during the 2018/19 and 2019/20 Cropping Seasons in the Biharamulo District

The results on net benefit (NB) and benefit-cost ratio (BCR) of the tested fertilizer rates during the 2018/19 and 2019/20 cropping seasons in Biharamulo experimental sites are presented in Tables 7 and 8. During the 2018/19 cropping season, the net benefits of the tested fertilizer types and rates ranged from 1 342 500 - 3 020 500 TShs ha^{-1} (Table 7), (equivalent to 583.7 - 1 313.3 USD ha^{-1}) while during the 2019/20 cropping season, the net benefits ranged from 1 445 000 - 3 810 500 TShs ha^{-1} (Table 8), (equivalent to 628.3 - 1 656.7 USD ha^{-1}).

In both cropping seasons, the low Snet benefits were recorded in the control, whereas the high net benefits were recorded in the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg K ha$^{-1.}$ This was due to the low gross benefit recorded in the control and the high gross benefit recorded in the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg K ha^{-1}. As explained before, and this was attributed to the low cassava yield in the control and the high cassava yield in the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 80 kg K ha^{-1}. Therefore, the use of fertilizers in this study increased the net benefit by 25.3 to 55.5% during the 2018/19 cropping season and by 42.6 to 62.1% during the 2019/20 cropping season, with annual NB increase of 6.6 to 17.3% due to increased cassava root yield upon continued use of the fertilizers types and rates tested in this study.

The results indicated that among the fertilizer treatments, the highest NB was recorded in the combined use of high rates of FYM and potassium fertilizer. Thereby, the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer

Table 7. The partial budget and benefit-cost ratios of the applied fertilizers during the 2018/19 cropping season in the Biharamulo district

Parameter	Treatments											
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
Fixed costs (‘000’ TShs ha^{-1})												
Cassava cuttings/seeds	300	300	300	300	300	300	300	300	300	300	300	300
Weeding	175	175	175	175	175	175	175	175	175	175	175	175
Land preparation	375	375	375	375	375	375	375	375	375	375	375	375
Harvesting	125	125	125	125	125	125	125	125	125	125	125	125
Variable costs (‘000’ TShs ha^{-1})												
Inorganic fertilizer or FYM	0	40	80	246.8	358.8	470.8	152	264	376	192	304	416
Transport (inorganic fertilizer or FYM)	0	80	160	62.1	86.1	110.1	104	128	152	184	208	232
Loading and off-loading of FYM	0	40	80	-	-	-	40	40	40	80	80	80
Application (inorganic fertilizer or FYM)	0	150	150	75	75	225	225	225	225	225	225	225
Transport of cassava roots	107.4	178	181.4	204.4	236.4	235.4	258.2	276.8	280.4	291.2	299	314.4
Total variable cost	**107.4**	**488**	**651.4**	**588.3**	**756.3**	**891.3**	**779.2**	**933.8**	**1 073.4**	**972.2**	**1 124**	**1 267.4**
Revenue (‘000’ TShs ha^{-1})												
Average cassava root yield (MT ha^{-1})	5.37	8.9	9.07	10.22	11.82	11.77	12.91	13.84	14.02	14.56	15.35	15.72
Average cassava root yield (kg ha^{-1})	5 370	8 900	9 070	10 220	11 820	11 770	12 910	13 840	14 020	14 560	15 350	15 720
Adjusted cassava root yield (kg ha^{-1})	4 833	8 010	8 163	9 198	10 638	10 593	11 619	12 456	12 618	13 104	13 815	14 148
Price of cassava roots (Tshs kg^{-1})	300	300	300	300	300	300	300	300	300	300	300	300
Gross befit (GB)	**1 449.9**	**2 403**	**2 448.9**	**2 759.4**	**3 191.4**	**3 177.9**	**3 485.7**	**3 736.8**	**3 785.4**	**3 931.2**	**4 144.5**	**4 244.4**
Net benefit (NB)	**1 342.5**	**1 915**	**1 797.5**	**2 171.1**	**2 435.1**	**2 286.6**	**2 706.5**	**2 803**	**2 712**	**2 959**	**3 020.5**	**2 977**
Benefit:cost ratio (BCR)	**12.5**	**3.9**	**2.8**	**3.7**	**3.2**	**2.6**	**3.5**	**3.0**	**2.5**	**3.0**	**2.7**	**2.3**

TShs = Tanzania shillings; T1 = control (no fertilizer application); T2 = farmyard manure at 4 MT ha^{-1} (FYM_4); T3 = farmyard manure at 8 MT ha^{-1} (FYM_8); T4 = potassium at 40 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{40}N_{40}P_{30}$); T5 = potassium at 80 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{80}N_{40}P_{30}$); T6 = potassium at 120 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{120}N_{40}P_{30}$); T7 = farmyard manure at 4 MT ha^{-1} and potassium at 40 kg K ha^{-1} (FYM_4K_{40}); T8 = farmyard manure at 4 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_4K_{80}); T9 = farmyard manure at 4 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_4K_{120}); T10 = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; T11 = farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_8K_{80}); T12 = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_8K_{120})

Table 8. The partial budget and benefit-cost ratios of the applied fertilizers during the 2019/20 cropping season in the Biharamulo district

Parameter	Treatments											
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
Fixed costs (‘000’ TShs ha^{-1})												
Cassava cuttings/seeds	300	300	300	300	300	300	300	300	300	300	300	300
Weeding	175	175	175	175	175	175	175	175	175	175	175	175
Land preparation	375	375	375	375	375	375	375	375	375	375	375	375
Harvesting	125	125	125	125	125	125	125	125	125	125	125	125
Variable costs (‘000’ TShs ha^{-1})												
Inorganic fertilizer or FYM	0	40	80	246.8	358.8	470.8	152	264	376	192	30	416
Transport (inorganic fertilizer or FYM)	0	80	160	62.1	86.1	110.1	104	128	152	184	208	232
Loading and off-loading of FYM	0	40	80	-	-	-	40	40	40	80	80	80
Application (inorganic fertilizer or FYM)	0	150	150	75	75	225	225	225	225	225	225	225
Transport of cassava roots	115.6	226.2	250.8	228.2	248.8	240.8	288	293.8	310	325.2	370.2	360.2
Total variable cost	**115.6**	**536.2**	**720.8**	**618.9**	**768.7**	**896.7**	**809**	**950.8**	**1 103**	**1 006.2**	**1 187.2**	**1 313.2**
Revenue (‘000’ TShs ha^{-1})												
Average cassava root yield (MT ha^{-1})	5.78	11.31	12. 54	11.65	12.44	12.04	14.40	14.69	15 50	16.26	18.51	18.01
Average cassava root yield (kg ha^{-1})	5 780	11 310	12 540	11 650	12 440	12 040	14 400	14 690	15 500	16 260	18 510	18 010
Adjusted cassava root yield (kg ha^{-1})	5 202	11 310	11 286	10 485	11 196	10 836	12 960	13 221	13 950	14 634	16 659	16 209
Price of cassava roots (Tshs kg^{-1})	300	300	300	300	300	300	300	300	300	300	300	300
Gross befit (GB)	**1 560.6**	**3 053.7**	**3 385.8**	**3 145.5**	**3 358.8**	**3 250.8**	**3 888**	**3 966.3**	**4 185**	**4 390.2**	**4 997.7**	**4 862.7**
Net benefit (NB)	**1 445**	**2 517.5**	**2 665**	**2 528.6**	**2 590.1**	**2 354.1**	**3 015.5**	**3 079**	**3 082**	**3 384**	**3 810.5**	**3 549.5**
Benefit:cost ratio (BCR)	**12.5**	**4.7**	**3.7**	**4.1**	**3.4**	**2.6**	**3.8**	**3.2**	**2.8**	**3.4**	**3.2**	**2.7**

TShs = Tanzania shillings; T1 = control (no fertilizer application); T2 = farmyard manure at 4 MT ha^{-1} (FYM_4); T3 = farmyard manure at 8 MT ha^{-1} (FYM_8); T4 = potassium at 40 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{40}N_{40}P_{30}$); T5 = potassium at 80 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{80}N_{40}P_{30}$); T6 = potassium at 120 kg K ha^{-1} + nitrogen at 40 kg N ha^{-1} + phosphorus 30 kg P ha^{-1} ($K_{120}N_{40}P_{30}$); T7 = farmyard manure at 4 MT ha^{-1} and potassium at 40 kg K ha^{-1} (FYM_4K_{40}); T8 = farmyard manure at 4 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_4K_{80}); T9 = farmyard manure at 4 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_4K_{120}); T10 = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; T11 = farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1} (FYM_8K_{80}); T12 = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} (FYM_8K_{120})

at 80 kg ha^{-1} gave the highest NB (3 020 500 - 3 810 500 TShs ha^{-1}; equivalent to 1 313.3 - 1 656.7 USD ha^{-1}) followed by the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 120 kg ha^{-1} (2 977 000 - 3 549 500 TShs ha^{-1}, equivalent to 1 294.3 - 1 543.3 USD ha^{-1}) and the combined use of FYM at 8 MT ha^{-1} + potassium fertilizer at 40 kg ha^{-1} (2 959 000 - 3 384 000 TShs ha^{-1}, equivalent to 1 286.5 - 1 471.3 USD ha^{-1}). The same trends were observed as for Bukoba and Missenyi districts (subsections 3.1 and 3.2) Therefore, for the high cassava root yield and net benefit, the use of the combination of FYM at 8 MT ha^{-1} and potassium fertilizer at 80, 120 or 40 kg K ha^{-1} for cassava production in the study area is indispensable

In addition, the results indicated that similar trends of BCR recorded in the Bukoba and Missenyi districts were also observed in the Biharamulo district whereby, all treatments gave acceptable BCR of greater than 2 [3, 5] and thus could be used by farmers for cassava production in the study area. The higher the BCR is compared to 2, the more favorable the treatment. Therefore, as reported in the Bukoba and Missenyi districts, during both cropping seasons, the results on the BCR for Biharamulo district indicated also that even the control treatment could be used for cassava production. However, if fertilizers could not be applied during cassava production in the study area, there could be a decrease in NB by 29.9 - 62.1%. Therefore, this implied that for the good cassava growth, high cassava root yield and ultimately high net benefit, the use of fertilizer and specifically, the combination of FYM at 8 MT ha^{-1} and potassium fertilizer at 80 kg K ha^{-1} is indispensable in the study area as it gave the higher net benefit than the other fertilizer types and rates tested in this study.

However, as also reported in the Bukoba and Missenyi districts (subsections 3.1 and 3.2), the results on cassava root yields indicated no significant (P = .08) difference among the combined use of FYM at 8 MT ha^{-1} and potassium fertilizer at 40, 80 or 120 kg K ha^{-1} [12]. Therefore, for the resource-poor farmers, the combined use of farmyard manure at 8 MT ha^{-1} and potassium fertilizer at 40 kg K ha^{-1} can also still be adopted in the study area because, for some reason, not all the famers can afford the best treatment.

Generally, during both cropping seasons and, in all studied sites, the higher NB were recorded in the Missenyi district than in the Bukoba and Biharamulo districts due to the higher cassava yield in the Missenyi district than in Bukoba and Biharamulo districts. These results reflect the soils of the three experimental sites. Missenyi district experimental site has sandy loam soil texture, Bukoba experimental site has sandy clay loam soil texture and Biharamulo experimental sites has sandy clay soil texture [13], Therefore, according to [26] cassava performs better in soils with light to medium soil texture like sandy loam, sandy clay loam and other loamy soils. In addition, all the soils of the experimental sites responded well to the applied fertilizer types and rates since all the soils of the experimental sites had low fertility status. However, the lowest NB recorded in the Biharamulo district during both cropping seasons was attributed to the low cassava root yields caused by low rainfall, accompanied by the dry spells, during 1 - 2 months after planting [16], which affected the performance of cassava plants in the Biharamulo experimental site as compared to the Bukoba and Missenyi experimental sites. This conforms to what was reported by other researchers, for example [27] and [28] that cassava requires sufficient water supply during shoot and root initiation phase, during 1 - 5 months after planting, and water deficit for at least two months during this stage, can affects cassava growth and decreases root yields by 30 to 60%.

4. CONCLUSION

In both cropping seasons, and in all studied sites, all fertilizer types and rates tested in this study gave acceptable BCR of greater than 2, implying that all the fertilizer types and rates can be used for cassava production in the study area. However, based on the results on the net benefits, the use of combination of FYM at 8 MT ha^{-1} and potassium fertilizer at 80 kg K ha^{-1} gave the higher net benefit than the other fertilizer types and rates. The order of the three most favorable treatments was as FYM at 8 MT ha^{-1} and potassium fertilizer at 80 kg K ha^{-1} > FYM at 8 MT ha^{-1} and potassium fertilizer at 120 kg K ha^{-1} > FYM at 8 MT ha^{-1} and potassium fertilizer at 40 kg K ha^{-1}. Therefore, the use of combination of FYM at 8 MT ha^{-1} and potassium fertilizer at 80 kg K ha^{-1} is desirable for increasing cassava root yield and net benefit in the study area. However, for the resource-poor farmers, the combined use of farmyard manure at 4 MT ha^{-1} and potassium fertilizer at 40 kg K ha^{-1} can still be adopted in the study area because, for some reason, not all the famers can afford the best treatment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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