

**Research Paper**

**AN AGRONOMIC AND ECONOMIC EVALUATION OF INTEGRATED USE  
OF *Calliandra callothyrsus* AND MAIZE STOVER WITH UREA IN WESTERN  
KENYA**

**ABSTRACT**

The agronomic effectiveness of integrating organic and inorganic nutrient sources has been demonstrated in Kenya but economic analysis is often lacking in such studies thus denying farmers the information required to make informed choices. We investigated the effect of two organic materials; leafy biomass of *Calliandra callothyrsus* (calliandra) or maize stover and urea on maize yield and economic benefits for three consecutive seasons. The following organic material:urea combinations were used so as to supply 75 kg N ha<sup>-1</sup>; 75:0, 60:15, 40:35, 35:40, 15:60 and 0:75. A control treatment where no nutrient inputs were applied was included. Economic analysis was conducted using partial budgeting, which considered only the added costs and added benefits of the treatments. The highest increase in maize yields relative to the control in the first (107%) and third seasons (142%) was with calliandra (30 kg N ha<sup>-1</sup>) applied with urea (45 kg N ha<sup>-1</sup>) while in the second season (163%) it was calliandra (45 N ha<sup>-1</sup>) combined with urea (30 kg ha<sup>-1</sup>). Maize failed to respond to maize stover when applied alone (75 kg N ha<sup>-1</sup>) or in combination with low rates of urea but only responded when the rates of N from urea in the combination were higher than the N from the maize stover likely due to N immobilization. The highest net benefits were obtained with Calliandra (30 kg N ha<sup>-1</sup>) plus urea (45 kg N ha<sup>-1</sup>) in all the seasons. None of the treatments gave a benefit cost

ratio (BCR) of  $> 2$  which is considered adequate if a farmer has to adopt a particular technology. Thus despite the good agronomic performance obtained by combining calliandra ( $30 \text{ kg N ha}^{-1}$ ) with urea ( $40 \text{ kg N ha}^{-1}$ ), it is unlikely that farmers would adopt the practice mainly because of the high labour costs involved.

*Keywords: Calliandra; maize stover; net benefits, urea, western Kenya.*

## 1.0. INTRODUCTION

Kenya is among the few countries in the world where poverty is increasing rather than declining and where human development indicators are worsening. This poses a major challenge to the achievement of the Millennium Development Goals (MDGs) by 2015. There is a strong nexus between Agriculture and several of the MDGs such as those related to poverty in general, hunger, health, child mortality, as well as environmental sustainability. Indeed, Agriculture remains the mainstay of Kenya's economy yet per capita food production has continued to decline over the past two decades thus posing a serious threat to food security. Staple cereal crop yields in many smallholder communities have remained  $< 1 \text{ t ha}^{-1}$ , despite the good climate in some areas [1]. Over the years, considerable efforts have been made amongst researchers to analyze this crisis and its root causes. [2] concluded that soil fertility depletion is the fundamental biophysical root cause of declining per capita food production in many parts of Africa. With population continuing to increase in many parts of Kenya, the need to reverse these declining trends has become more urgent.

Efforts and approaches to replenish soil fertility in Kenya are well documented [3]. Although judicious application of inorganic fertilizers is recognized as the most effective way for overcoming soil fertility decline or alleviating nutrient deficiencies,

47 their high cost, inaccessibility, and generalized recommendations resulting in low, erratic  
 48 and unprofitable crop responses limit their use, particularly on smallholder farms in  
 49 eastern Africa [4]. A paradigm shift in soil fertility management towards the integrated  
 50 soil fertility management (ISFM) has been proposed [5]. Integrated Soil Fertility  
 51 Management is the application of locally adapted soil fertility management practices to  
 52 optimize the agronomic efficiency of fertilizer and organic inputs in crop production [5].  
 53 Its technical backbone is the judicious combination of organic and inorganic sources of  
 54 nutrients.

55 In the last two decades, intensive soil fertility replenishment research has been  
 56 conducted in western Kenya by organizations such as Kenya Forestry Institute (KEFRI),  
 57 International Center for research in Agroforestry (ICRAF) and Tropical Soil Biology and  
 58 fertility programme (TSBF). A wealth of knowledge and technologies that form part of  
 59 the ISFM strategy to mitigate soil fertility depletion were generated and are available.  
 60 However, the recommendations did not take into account the dynamic nature of the  
 61 agricultural input and output prices and other economic changes [6] which influence the  
 62 uptake of technologies by farmers. This has rendered many of the recommendations  
 63 irrelevant to farmers, and hence their low adoption rates. There is need therefore to revise  
 64 the current soil fertility management recommendations such that they take into account  
 65 the cropping systems and the profitability of nutrient inputs. This will enable farmers to  
 66 make informed choices when deciding on which soil fertility technologies to adopt. This  
 67 study therefore aims at extending this evaluations by testing two of the most common  
 68 organic materials in western Kenya; maize stover and *Calliandra calothyrsus* (hereafter  
 69 referred to as calliandra) as sources of N for maize. It is recognized that the main

70 limitations of using organic inputs for soil fertility management is their low nutrient  
 71 content and hence they have to be applied in very large amounts. However, the quantities  
 72 available on most smallholder farms are often inadequate and therefore the need to  
 73 integrate them with inorganic fertilizers such as urea has been recommended [7]. There is  
 74 however paucity of information on the most efficient combinations between the  
 75 inorganic and organic sources of nutrients mainly because appropriate experimental  
 76 designs have not been used [8]. The objective of this study was therefore i) to determine  
 77 the effects of applying different rates of two organic materials; *Calliandra callothyrsus*  
 78 or maize stover and a commercial fertilizer, urea on maize grain yield and ii) compare  
 79 the economic benefits of application of *Calliandra* or maize stover with urea for maize  
 80 production.

81

## 82 **2.0. MATERIALS AND METHODS**

### 83 ***2.1. Study sites***

84 A field experiment was conducted for three consecutive seasons, from March  
 85 2008 to August 2009 at Bukura (N 0° 20', E 34° 15') in western Kenya. The site is at an  
 86 altitude of approximately 1430 m asl. and receives bimodal rainfall, with long rains  
 87 occurring from March to June and the short rains from August to November with a mean  
 88 annual rainfall is 1800 mm. The soils at the site are classified as Orthic Luvisols [9]. The  
 89 soil was low in N and P (Table 1). The organic matter level, as reflected by % organic  
 90 carbon was also low. The soil pH was however conducive for maize growth. The site  
 91 was chosen due to its demographic and agro-ecological characteristics, which are broadly  
 92 representative of the situation found in other tropical highlands of East Africa.

93 Table 1: Some selected chemical and physical characteristics of the soils at Bukura

| Parameter                                                | value |
|----------------------------------------------------------|-------|
| pH (1:2.5 soil: water)                                   | 6.5   |
| Exchangeable acidity ( $\text{cmol}_c \text{ kg}^{-1}$ ) | 0.10  |
| Organic carbon %                                         | 1.25  |
| Total N %                                                | 0.15  |
| Exchangeable Ca ( $\text{cmol}_c \text{ kg}^{-1}$ )      | 5.87  |
| Exchangeable Mg ( $\text{cmol}_c \text{ kg}^{-1}$ )      | 1.97  |
| Exchangeable K ( $\text{cmol}_c \text{ kg}^{-1}$ )       | 0.22  |
| Olsen extractable P ( $\text{mg kg}^{-1}$ )              | 7.7   |
| Clay (%)                                                 | 16    |
| Sand (%)                                                 | 65    |
| Silt (%)                                                 | 19    |

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## 95 2.2. Experimental layout and management

96 The experiment was laid out in a randomized complete block design with twelve  
 97 treatments replicated four times with plots of 6 m x 6 m in size. A substitution type of  
 98 experiment was used whereby the total N rate was fixed at the recommended rate of 75  
 99  $\text{kg ha}^{-1}$  for maize in the study area [10]. The following organic material:urea  
 100 combinations were used so as to supply 75  $\text{kg N ha}^{-1}$ ; 75:0, 60:15, 40:35, 35:40, 15:60  
 101 and 0:75 (Table 2). A control treatment where no nutrient inputs were applied was  
 102 included. The two OM's represent common alternatives to inorganic fertilizers on  
 103 smallholder farms, but vary in their chemical characteristics (Table 3).

104 Table 2. The experimental treatments

| Treatment<br>no | Organic material | N from<br>organics | N from<br>urea      | Total N |
|-----------------|------------------|--------------------|---------------------|---------|
|                 |                  |                    | kg ha <sup>-1</sup> |         |
| 1               | None             | 0                  | 0                   | 0       |
| 2               | Calliandra       | 75                 | 0                   | 75      |
| 3               | Calliandra       | 60                 | 15                  | 75      |
| 4               | Calliandra       | 45                 | 30                  | 75      |
| 5               | Calliandra       | 30                 | 45                  | 75      |
| 6               | Calliandra       | 15                 | 60                  | 75      |
| 7               | Maize stover     | 75                 | 0                   | 75      |
| 8               | Maize stover     | 60                 | 15                  | 75      |
| 9               | Maize stover     | 45                 | 30                  | 75      |
| 10              | Maize stover     | 30                 | 45                  | 75      |
| 11              | Maize stover     | 15                 | 60                  | 75      |
| 12              | none             | 0                  | 75                  | 75      |

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106 The organic materials were analyzed to determine their chemical characteristics which  
 107 are presented in Table 3. The N content was used to calculate the rates of the organic  
 108 materials to be applied.

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110

111

112 Table 3. Selected chemical characteristics of the organic materials

| Organic material  | Parameter |      |      |      |      |    |              |         |     |
|-------------------|-----------|------|------|------|------|----|--------------|---------|-----|
|                   | %N        | %P   | %K   | %Ca  | %Mg  | %C | % Polyphenol | %Lignin | C:N |
| <i>Calliandra</i> | 3.0       | 0.09 | 0.59 | 0.56 | 0.15 | 45 | 14           | 25      | 15  |
| Maize stover      | 0.65      | 0.05 | 0.81 | 0.29 | 0.22 | 42 | 0.95         | 5.3     | 65  |

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114 The appropriate rates of organic materials were weighed, chopped and  
 115 incorporated into the soil at a depth of 15 cm one day prior to planting in all the seasons.  
 116 The first season was from March to August 2008, the second season from August to  
 117 December 2008 and the third season from March to August 2009. In the appropriate  
 118 treatments, urea was applied in splits with one third being applied at planting time while  
 119 the rest was applied as a topdress six weeks later. Phosphorus and potassium were  
 120 uniformly applied to all plots at the rate of 40 kg P and 20 kg K ha<sup>-1</sup> as triple super  
 121 phosphate and muriate of potash respectively at planting time in each season to ensure  
 122 that P and K were not limiting factors while studying the N effects. Commercial maize  
 123 variety WH 502, commonly grown by farmers in the area, was planted as a test crop at a  
 124 spacing of 75 cm between rows and 25 cm within the rows. Two seeds were planted per  
 125 hill and later thinned to one seedling per hill two weeks after emergence to give a total  
 126 maize population of 53,333 plants ha<sup>-1</sup>. The maize was managed using the recommended  
 127 agronomic practices for the area and harvested at maturity.

128 All the maize grain yield data were subjected to Analysis of variance (ANOVA)  
 129 using the Genstat statistical package [11] to determine the effects of treatments. The

standard error of difference between means (*s.e.d.*) was used to compare the treatment means. Mention of statistical significance refers to  $p = 0.05$  unless otherwise stated.

## 2.3. Economic analysis

Cost and benefits associated with each treatment were compared using partial budgeting, which included only costs and benefits that varied from the control, i.e. costs of inputs and increased maize yield [12]. The values of the costs used are presented in Table 4. The prices of maize and urea and fertilizer transport costs were determined through a market survey in the area. Amounts of labour for application of fertilizer, stover and *Calliandra* were determined from findings of [13] and observation of the performance of specific activities in each season. Discount rates of capital was estimated at 10% per season (20% per year) and applied only to cash costs [14]. This discount rate reflects a farmer's preference to receive benefits as early as possible and postpone costs. The net benefit for each treatment was then determined as the difference between added benefits and added costs. *Calliandra* and maize were costed in terms of labour involved in their harvesting, transportation and incorporation [12]. To evaluate the economic benefits of the use of nutrient inputs, the benefit cost ratio (BCRs), calculated as the value of the additional maize yield after application of the nutrient input divided by the cost of the nutrient inputs to achieve this, were used [15]. The values of the costs used are presented in Table 4.

153 Table 4. Values used for cost benefit analysis

| Parameter                                                       | Value (USD) |          |          |
|-----------------------------------------------------------------|-------------|----------|----------|
|                                                                 | Season 1    | Season 2 | Season 3 |
| Price of Urea kg <sup>-1</sup>                                  | 1.80        | 2.10     | 2.10     |
| Transport of urea to the farm 100 kg <sup>-1</sup>              | 1.75        | 1.75     | 1.75     |
| <u>Labor cost</u>                                               |             |          |          |
| Baseline cost for urea application ha <sup>-1*</sup>            | 1.37        | 1.37     | 1.37     |
| Cost for application of additional fertilizer ha <sup>-1¶</sup> | 0.30        | 0.30     | 0.30     |
| Baseline cost for calliandra application ha <sup>-1†</sup>      | 350         | 350      | 350      |
| Cutting and application of 10 t ha <sup>-1</sup> maize stover   | 430         | 430      | 430      |
| Price of maize kg <sup>-1</sup>                                 | 0.32        | 0.40     | 0.35     |

154 \* Cost of application of 10 kg ha<sup>-1</sup> as urea. Includes cost of transport of fertilizer within  
 155 the homestead.

156 ¶ Cost of application of fertilizer above or below the baseline rate of 10 kg ha<sup>-1</sup> as urea  
 157 Calculated at 0.2 % of the baseline cost per additional kg of fertilizer.

158 † Cost of application of 15 kg N ha<sup>-1</sup>. Includes cost for collection and transport of  
 159 materials within the homestead. Cost for application of rates above or below 15 kg N ha<sup>-1</sup>  
 160 was directly proportional to the quantity of material applied.

161

## 162 3.0. RESULTS AND DISCUSSIONS

### 163 3.1. Maize grain yields

164 The maize grain yields varied among the seasons (Table 5). The mean grain yields of the  
 165 third season (3.4 t ha<sup>-1</sup>) were higher than those of the second season (2.1 t ha<sup>-1</sup>) but

lower than those of the first season ( $3.7 \text{ t ha}^{-1}$ ). The variation in maize grain yields observed among the seasons is attributed mainly to the differences in rainfall. In the first season, the rainfall was adequate ( $>1000 \text{ mm}$ ) during the growing period of maize and the uptake of nutrients by the crop was thus not inhibited leading to high grain yields. In the second season, the rainfall was low and poorly distributed. The total rainfall amount was  $< 500 \text{ mm}$  in this season with only  $48 \text{ mm}$  being received in November, when the crop was tasselling. Uptake of nutrients was therefore constrained by low available moisture in this season. The lower yields observed in the third season compared to the second season, despite that both were long rainy seasons with adequate total rainfall, is attributed to the little rainfall ( $230 \text{ mm}$ ) received in June and July in the third season. This coincided with the tasselling period of maize and, therefore, led to a reduction in grain yield compared to the first season when rainfall was higher during the two months.

Treatments with Calliandra when combined with urea tended to be the best performers across the seasons. For example, The highest increase in maize yields relative to the control in the first (107%) season and third seasons (142%) was with calliandra applied to provide  $30 \text{ kg N ha}^{-1}$  in combination with urea ( $45 \text{ kg N ha}^{-1}$ ) while in the second season, calliandra ( $45 \text{ N ha}^{-1}$ ) combined with urea ( $30 \text{ kg ha}^{-1}$ ) gave the highest increase (163%) in yields relative to the control. Maize significantly responded to Calliandra when applied alone or urea alone in all the seasons but failed to respond to maize stover when applied alone or in combination with low rates of urea. In fact maize stover when combined with urea gave significant increases in maize yields only when the rates of urea in the combination were higher than the N from the maize stover i.e. 45 and  $60 \text{ kg N ha}^{-1}$ . In general, the maize yields in the maize stover treatments increased with

189 increasing substitution of maize stover with urea in the combinations in the first and third  
 190 season. However, there was no consistent pattern in the second season where the low  
 191 moisture levels may have confounded the effects. The low yields obtained when maize  
 192 stover was applied to supply N at higher rates is attributed to immobilization of N by the  
 193 maize stover. The maize stover had a C:N ratio of 65 which is way above the minimum  
 194 threshold of  $< 20$  that is required for mineralization to occur. In addition, the stover was  
 195 high in lignin and polyphenol content which are likely to have exacerbated the  
 196 immobilization. The maize growing in these treatments therefore suffered N deficiency.  
 197 Combining the maize stover with urea at high rates reduced the C:N ratio to lower than  
 198 20 and effected mineralization that overcame the N deficiency. Calliandra on the other  
 199 hand had a high N content (3%) and low C:N ratio (15:1) hence would be expected to  
 200 mineralize even without the addition of a readily soluble source of N e.g. urea if other  
 201 factors were constant. However, due to its high polyphenol (14%) and lignin contents  
 202 (25%) the rate of mineralization is likely to have been slowed down when applied alone  
 203 without urea. According to [7] OM<sub>s</sub> with a polyphenol content of  $> 4\%$  and lignin  
 204 content of  $> 16\%$  will immobilize N and have therefore to be supplemented with  
 205 inorganic N fertilizers. Hence addition of urea even in modest amounts to calliandra was  
 206 enough to overcome the deleterious effects of these compounds and enabled  
 207 mineralization to occur at faster rates to provide enough N for the maize and therefore  
 208 the high yields in the calliandra/urea combinations. The generally good response to urea  
 209 when applied alone ( $75 \text{ kg N ha}^{-1}$ ) is to be expected since this site was N deficient and  
 210 urea provided N in readily available form. However, the slight superiority of the  
 211 treatments where urea was integrated with calliandra is attributed to synergistic effects

212 often observed when appropriate organic and inorganic sources of nutrients are  
213 combined. For example, organic materials confer other advantages e.g. moisture  
214 retention, provision of micronutrients and alleviation of mineral toxicities [7, 13].

215 Table 5. Maize grain yields at Bukura

| Treatment no | Organic material | N from organics (kg ha <sup>-1</sup> ) |    | N from urea (kg ha <sup>-1</sup> ) |  | Total N (kg ha <sup>-1</sup> ) | Season1                           | Season 2 | Season 3 |  |
|--------------|------------------|----------------------------------------|----|------------------------------------|--|--------------------------------|-----------------------------------|----------|----------|--|
|              |                  |                                        |    |                                    |  |                                | Grain yield (t ha <sup>-1</sup> ) |          |          |  |
| 1            | None (control)   | 0                                      | 0  | 0                                  |  |                                | 2.6                               | 1.1      | 1.9      |  |
| 2            | Calliandra       | 75                                     | 0  | 75                                 |  |                                | 3.8                               | 2.0      | 3.2      |  |
| 3            | Calliandra       | 60                                     | 15 | 75                                 |  |                                | 4.1                               | 1.9      | 3.6      |  |
| 4            | Calliandra       | 45                                     | 30 | 75                                 |  |                                | 4.7                               | 2.9      | 4.2      |  |
| 5            | Calliandra       | 30                                     | 45 | 75                                 |  |                                | 5.4                               | 2.7      | 4.6      |  |
| 6            | Calliandra       | 15                                     | 60 | 75                                 |  |                                | 3.8                               | 2.4      | 4.2      |  |
| 7            | Maize stover     | 75                                     | 0  | 75                                 |  |                                | 2.0                               | 1.6      | 2.1      |  |
| 8            | Maize stover     | 60                                     | 15 | 75                                 |  |                                | 3.0                               | 1.8      | 2.4      |  |
| 9            | Maize stover     | 45                                     | 30 | 75                                 |  |                                | 2.7                               | 1.6      | 2.9      |  |
| 10           | Maize stover     | 30                                     | 45 | 75                                 |  |                                | 3.9                               | 2.2      | 3.4      |  |
| 11           | Maize stover     | 15                                     | 60 | 75                                 |  |                                | 4.5                               | 1.9      | 4.0      |  |
| 12           | None             | 0                                      | 75 | 75                                 |  |                                | 4.3                               | 2.5      | 4.5      |  |
|              | SED              |                                        |    |                                    |  |                                | 0.58                              | 0.36     | 0.51     |  |
|              | Cv%              |                                        |    |                                    |  |                                | 5.9                               | 8.0      | 5.9      |  |

216 **3.2. Economic analysis**

217           Total variable costs of using the OMs when applied alone were higher than using  
 218 urea alone (Table 6). Maize stover applied alone ( $75 \text{ kg N ha}^{-1}$ ) had the highest added  
 219 costs followed by calliandra when applied alone. The added costs for integrating the  
 220 inorganic and organic sources of nutrients were in between the extremes. The higher  
 221 costs for the OM treatments resulted mainly from the high labour cost associated with  
 222 their use because of the large amounts that had to be harvested and applied. For example,  
 223 approximately  $8.33 \text{ t ha}^{-1}$  of fresh *Calliandra* biomass was required to supply  $75 \text{ kg N}$   
 224 per  $\text{ha}^{-1}$ . At the practical farming level, the labour costs for harvesting, transporting and  
 225 incorporating it were therefore quite high. These costs are likely to further increase if  
 226 many farmers were to adopt the *Calliandra* biomass transfer technology as the amount of  
 227 *Calliandra* available will not be sufficient to meet the demand. Added costs for the use  
 228 of maize stover were also high mainly because of the low N (0.65 %) content of the  
 229 stover used in this study. At the rate of  $75 \text{ kg N per ha}^{-1}$  used in this study, almost  $12.5 \text{ t}$   
 230  $\text{ha}^{-1}$  of maize stover was applied.

231           Cost of labour form a major part of the total cost in the use of organic materials in  
 232 western Kenya [13]. Labour forms more than half of the total variable costs of  
 233 production when organic matter technologies are used. This is because the use of organic  
 234 materials is labour intensive. Labour cost constituted 100% of the added costs  
 235 (input+labour) when stover was applied alone and 42-94% of the added cost when it was  
 236 integrated with inorganic N sources. Labour costs constituted 100% of the added costs  
 237 when *Calliandra* was applied alone and 29-80% of the added cost when it was integrated

238 with urea. Labour costs for inorganic N when not integrated with organic materials, were  
239 small and represented approximately 1% of the total added costs in all seasons.

240 In all the seasons the highest net benefits were obtained with *Calliandra* applied  
241 at 30 kg N ha<sup>-1</sup> plus urea applied at 45 kg N ha<sup>-1</sup> (Table 7). All treatments in which  
242 maize stover supplied 45 kg N ha<sup>-1</sup> or more, had negative net financial benefits in all  
243 seasons mainly to the high labour costs and associated low yields due to N  
244 immobilization. However, when the maize stover was used to provide only 30 kg N ha<sup>-1</sup>  
245 or less, the financial benefits were generally positive indicating that the increase in yields  
246 as a result of increasing rate of urea in the combination was enough to offset the added  
247 costs associated with the integration (Table 7). Net financial benefits were low in the  
248 second season mainly due to low grain yields realized in these seasons. Adequate extra  
249 yield that would offset the high costs of using organic residues and allow subsequent  
250 economic benefit was hardly achieved under the prevailing low rainfall conditions of the  
251 second season. Similar season specific responses have been reported by others [16].

252 Table 6. Total variable costs associated with different treatments at Bukura

| Treatment no | Organic material | N from organics (kg ha <sup>-1</sup> ) | N from urea (kg ha <sup>-1</sup> ) | Total N (kg ha <sup>-1</sup> ) | Season1 | Season 2 | Season 3 |
|--------------|------------------|----------------------------------------|------------------------------------|--------------------------------|---------|----------|----------|
| 1            | None             | 0                                      | 0                                  | 0                              | -       | -        | -        |
| 2            | Calliandra       | 75                                     | 0                                  | 75                             | 350     | 350      | 350      |
| 3            | Calliandra       | 60                                     | 15                                 | 75                             | 345     | 359      | 367      |
| 4            | Calliandra       | 45                                     | 30                                 | 75                             | 340     | 349      | 385      |
| 5            | Calliandra       | 30                                     | 45                                 | 75                             | 264     | 290      | 337      |
| 6            | Calliandra       | 15                                     | 60                                 | 75                             | 383     | 394      | 382      |
| 7            | Maize stover     | 75                                     | 0                                  | 75                             | 546     | 559      | 555      |
| 8            | Maize stover     | 60                                     | 15                                 | 75                             | 520     | 522      | 515      |
| 9            | Maize stover     | 45                                     | 30                                 | 75                             | 470     | 487      | 472      |
| 10           | Maize stover     | 30                                     | 45                                 | 75                             | 446     | 469      | 455      |
| 11           | Maize stover     | 15                                     | 60                                 | 75                             | 410     | 429      | 421      |
| 12           | None             | 0                                      | 75                                 | 75                             | 336     | 394      | 394      |

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255 Table 7. Net financial benefits and benefit cost ratios associated with different treatments at Bukura

| Treat. | Organic material | N/<br>organics | N/<br>urea | Total N<br>(kg ha <sup>-1</sup> ) | Season<br>1  | Season<br>2 | Season<br>3 | Season<br>1        | Season<br>2 | Season<br>3 |
|--------|------------------|----------------|------------|-----------------------------------|--------------|-------------|-------------|--------------------|-------------|-------------|
|        |                  |                |            |                                   | Net benefits |             |             | Benefit cost ratio |             |             |
| 1      | None             | 0              | 0          | 0                                 | -            | -           | -           | -                  | -           | -           |
| 2      | Calliandra       | 75             | 0          | 75                                | 110          | 44          | 71          | 0.31               | 0.13        | 0.20        |
| 3      | Calliandra       | 60             | 15         | 75                                | -44          | -9          | 181         | -0.12              | -0.02       | 0.49        |
| 4      | Calliandra       | 45             | 30         | 75                                | 116          | 444         | 344         | 0.34               | 1.27        | 0.89        |
| 5      | Calliandra       | 30             | 45         | 75                                | 227          | 502         | 471         | 0.59               | 1.73        | 1.40        |
| 6      | Calliandra       | 15             | 60         | 75                                | 16           | 156         | 330         | 0.06               | 0.40        | 0.86        |
| 7      | Maize stover     | 75             | 0          | 75                                | -608         | -494        | -584        | -1.11              | -0.88       | -1.05       |
| 8      | Maize stover     | 60             | 15         | 75                                | -518         | -521        | -515        | -0.10              | -0.99       | -1.00       |
| 9      | Maize stover     | 45             | 30         | 75                                | -470         | -486        | -471        | -1.00              | -1.00       | -0.99       |
| 10     | Maize stover     | 30             | 45         | 75                                | 163          | 5.7         | 30          | 0.36               | 0.01        | 0.06        |

|    |              |    |    |    |     |     |     |      |       |      |
|----|--------------|----|----|----|-----|-----|-----|------|-------|------|
| 11 | Maize stover | 15 | 60 | 75 | 2.9 | -88 | 258 | 0.01 | -0.21 | 0.61 |
| 12 | None         | 0  | 75 | 75 | 16  | 190 | 470 | 0.05 | 0.48  | 1.19 |

The benefit cost ratios (BCRs) were low and varied between seasons and treatments. None of the treatments gave a BCR of 2 and above which is considered the minimum that should be attained if a farmer has to adopt a particular soil fertility technology [17]. However, Calliandra when applied at a rate of 30 kg ha<sup>-1</sup> in combination urea at 45 kg ha<sup>-1</sup> showed promise especially in the second and third seasons with BCRs of 1.78 and 1.40 respectively.

## 4.0. CONCLUSION

Maize yields varied with season and treatments. Treatments with Calliandra when combined with urea tended to be the best performers across the seasons. Despite the good agronomic performance by the calliandra treatments, it is unlikely that farmers would adopt its use as a source of nutrients for maize mainly because of the high labour costs associated with its use which led to low BCRs. Maize stover tended to depress yields when applied in large quantities likely due to N immobilization. This is likely the reason why farmers prefer to burn it. However due to its importance in maintain soil organic matter, it should be retained in the fields and urea applied at higher rates to overcome N immobilization where it economically feasible. This calls for the Kenya Government to reintroduce fertilizer subsidies which were scrapped in the 1990's. This study highlights the importance of economic analysis in agronomic studies. Practices that may appear agronomically effective may turn out to be economically unattractive hence hindering their adoption by farmers.

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