

*Full Length Research Paper*

# **Analysis of labor opportunity cost on the economic profitability of fertilizer microdosing (FM) in Burkina Faso**

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**This paper analyses the effect of labor opportunity cost on economic profitability of fertilizer microdosing (FM) in Burkina Faso. In order to assess the incremental change in net income when the investment cost increases and takes into account labor opportunity cost, the marginal value cost ratio (MVCR) approach is used. Using data from farmer's field, the results showed that for both crops, the median yield of the fertilizer microdosing plots is 500 kg.ha<sup>-1</sup>, which is slightly higher than yield from recommended dose plots. Moreover, the rate of fertilizer microdosing plots of millet with a marginal value cost ratio above 2 shifts from 50% (without labor opportunity cost) to 41% (with labor opportunity cost) and not even one recommended dose plots reached this threshold. These findings argued that fertilizer microdosing adopters remain economically profitable for farmers compared to traditional practices despite the opportunity cost of labor. However, because of its importance in the process of fertilizer microdosing adoption, labor costs must be included in its economic evaluation. The results of this study confirm the need to accelerate mechanization of fertilizer microdosing application.**

**Key words:** Fertilizer microdosing (FM), labor, marginal value cost ratio, Burkina Faso.

## **INTRODUCTION**

Agricultural innovation, which is defined as a new idea, technique or often modification of a traditional practice

seem to offer opportunities that substantially increase farmers' agricultural production and income (Adams,

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1982). The objective of fertilizer microdosing (FM) promoted throughout the semi-arid countries of West Africa since the 1990s was to achieve that outcome through an improvement in the fertilizer use efficiency and reduction in investment costs (Bationo et al., 1998).

Fertilizer microdosing is the application of mineral fertilizers in small doses per hill (Hayashi et al., 2008). This technology was developed to remove some obstacles due to the low rate of adoption of agricultural technologies, particularly mineral fertilizers, which have long been recognized as essential components for increasing agricultural productivity in semi-arid countries such as Burkina Faso (FAO, 2013; Crawford et al., 2006). One of the main problems was the high cost of fertilizer, which is often unaffordable for farmers, particularly smallholder's farmers (Holtzman et al., 2013; Abdoulaye and Sanders, 2005). Some studies further identified imperfect input and credits markets along with high transportation costs as impediments to the adoption and intensification of agricultural innovations (Liverpool-Tassie et al., 2015; Holtzman et al., 2013). Thus, Twomlow et al. (2011) perceived fertilizer microdosing as a pathway towards green revolution in Africa. Further, Aune and Bationo (2008) highlighted that the use of low-cost technologies like microdose could prompt farmers towards participating in agricultural intensification.

In terms of impacts, the results of previous studies showed a significant income increase for farmers who adopted fertilizer microdosing as well as an improvement of their food security (Okebalama et al., 2016; Fatondji et al., 2016; Bagayoko et al., 2011). However, the analysis of these studies revealed that not all the additional costs such as labor cost were taken into account particularly in the economic profitability evaluation of fertilizer microdosing. Indeed, the application of fertilizer microdosing generates an additional cost in terms of labor due to the greater effort needed to bury the fertilizer compared to the traditional practices (Liverpool-Tassie et al., 2015; Pender et al., 2008; Tovihoudji et al., 2018). In addition, analysis of the results of empirical studies indicated that labor availability would be one of the main constraints affecting fertilizer microdosing adoption (Okebalama et al., 2016; Tabo et al., 2007). This labor constraint led researchers to work on how to mechanize the application of fertilizer microdosing for a wider adoption by farmers (Tabo et al., 2007). Thus, an assessment of the economic profitability of hill placement technology without this factor could lead to an overestimation of its effect on yield level or even on economic profitability. To our knowledge, previous economic evaluation studies on fertilizer microdosing in Burkina Faso did not include this variable in their economic profitability analysis. Thus, the objective of this study is to analyze the effect of labor opportunity cost on the economic profitability of fertilizer microdosing in Burkina Faso.

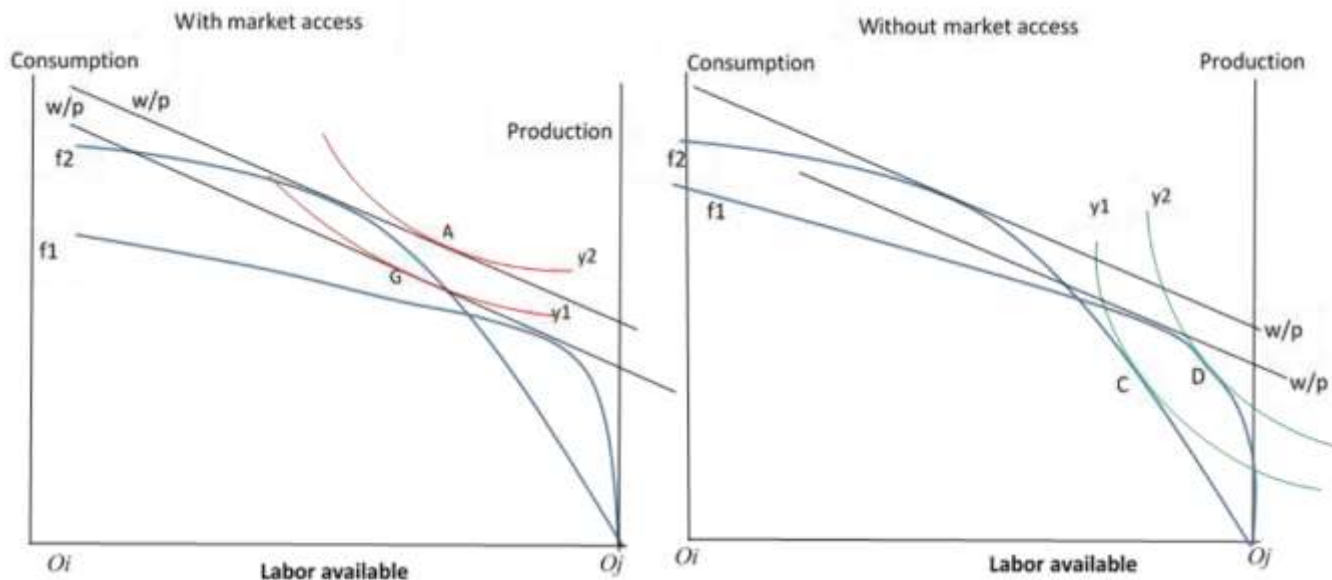
## MATERIALS AND METHODS

### Study areas and data

The study was conducted in the municipalities of Nagreongo and Kaya in the provinces of Ouhritenga (Plateau Central region) and Sanmatenga (Centre Nord region) respectively. The annual rainfall in Nagreongo is 700 - 800 mm and 450 - 750 mm in Kaya. The areas are characterized by low fertility soil and degradation; in addition, sorghum and millet are staple crop. The data used are from a research project called TARGET implemented in Burkina Faso from 2002 to 2003. One hundred and sixteen (116) farmers were chosen on a voluntary basis to conduct agronomic trial. The test crops were sorghum and millet. Both seeds were mostly local varieties and the choice was left to the farmers. The test consisted of three (3) plots per farmer and each plot was 300 m<sup>2</sup>. The three (3) treatments were the control plot, the fertilizer microdosing plot and the recommended fertilizer dose plot (as recommended by extension services for broadcasting fertilization). For the sorghum and millet fertilizer microdosing plots, the quantity of NPK (14-23-14) fertilizer was 62.5 kg.ha<sup>-1</sup> and 125 kg.ha<sup>-1</sup>, respectively. Urea quantity per hectare was 50 kg and NPK was 75 kg.ha<sup>-1</sup> for recommended plots. The dose of fertilizer per hill was 4 g. The fertilizer and labor opportunity costs were obtained from a survey conducted by the project in 2003 for impact assessment (270 FCFA for NPK and 250 FCFA for urea). The selling prices of sorghum and millet were 120 CFA.kg<sup>-1</sup> in the Northern region and 115 CFA.kg<sup>-1</sup> in the North-Central. For labor opportunity costs, the average cost was 7950 FCFA for fertilizer microdosing in both regions, 6400 FCFA, and 3000 FCFA for the recommended dose in the Northern and North-central regions respectively. For urea, the costs were 4000 FCFA and 2000 FCFA in the Northern and North-Central regions respectively. The high cost of recommended dose plot in Northern region is due to additional cost generated by the application of organic manure at tillage.

### Theoretical framework and empirical approach

Several studies analyzed the relationship between labor availability and the decision of farmers to adopt agricultural technologies (Mwangi and Kariuki, 2015; Jack, 2013; Feder, 1985). These studies argued that adoption depends on the intensity of the technology in terms of labor demand. For labor-intensive technologies such as fertilizer microdosing, studies found that households with labor constraints or access to opportunities from labor market are likely not to adopt it. On the other hand, farmers engaged in non-agricultural activities could adopt less labor-intensive technologies. Using household size as a proxy for labor availability, Samboko (2011) obtained a negative effect of labor on the economic profitability of improved cowpea seeds production because most family members were engaged in off-farm activities. The results of the study carried out by Akinola and Owombo (2012) showed that availability of hired labor had a positive effect on the decision to apply the dry straw spreading technique for Nigerian farmers because of the lack of opportunities on labor market. Moreover, some farmers opt for income diversification through off-farm activities as production risk management strategy (Cervantes-Godoy et al., 2013). This requires that available labor be shared between on-farm and off-farm activities. Thus, some households will tend to allocate more time to off-farm activities because they are well-paid (Venance et al., 2016). In addition, they may only apply agricultural technologies that require little working time. As for fertilizer microdosing, Liverpool-Tassie et al. (2015) noted that labor costs for fertilizer application are a key factor for low adoption rate in Niger.



**Figure 1.** Decision to apply fertilizer microdosing according to the nature of labor market. Source: Authors (2019).

Indeed, findings of these studies highlighted that households in developing countries often take into account opportunity cost of agricultural technology in their adoption decisions, particularly for labor-intensive technologies. With regard to fertilizer microdosing in Burkina Faso, the opportunity cost is likely to be decisive for many reasons. Firstly, in fertilizer microdosing dissemination areas, the market sometimes offers opportunities (daily worker, off-farm activities and mining activities) which could help farmers to meet their needs during agricultural season. Secondly, because farmers are risk averse, they sometimes adopt strategies to prevent production losses such as crop diversification and spatial diversification of fields. In the event of overlapping crop calendars and imperfect labor markets, they could favor traditional practices over fertilizer microdosing for an efficient allocation of available labor.

Furthermore, in developing countries, family labor requirements, which are the main source of labor, are sometimes difficult to assess due to the small size of plots and the particular requirements for agronomic trial (Crawford and Kamuanga, 1991). This is why in some studies, labor costs are not included in economic profitability analyses. However, for agricultural labor-intensive technologies such as fertilizer microdosing where the difference in application labor is substantial, it is crucial to estimate and include it into the analysis of economic profitability (Crawford and Kamuanga, 1991). Thus, the labor cost for fertilizer spreading is estimated in terms of opportunity cost. The opportunity cost of labor is defined as the wage received for off-farm work, or the estimated value of working time spent on an activity on the farm (Perrin et al., 1976). Based on this meaning, the labor opportunity cost to apply fertilizer microdosing could be the value of sowing time on one of farmers' plot. Indeed, the time required to apply fertilizer microdosing on one hectare is approximately similar to the time required to sow the same area.

From the aforementioned, using a farm household model, let us show the influence of labor opportunity cost in the decision to adopt fertilizer microdosing. Due to imperfect markets in developing countries, production and consumption decisions are often not

separable (Sadoulet and De Janvry, 1995). Figure 1 is a representation of the household model to explain the adoption of fertilizer microdosing. Let  $w/p$  be the same relative labor wage for all farmers,  $f1$  the production function with fertilizer microdosing,  $f2$  the production function without fertilizer microdosing and  $U(.)$  the utility function. Consider the following cases.

Firstly, assume the farmer has access to labor market. The application of fertilizer microdosing is desirable because  $U(A) > U(G)$  but involves an adjustment. Indeed, if the farmer decides not to apply fertilizer microdosing, his production is  $y1$  and  $G$  the consumption. The current production does not suffice for his consumption needs. In this case, he will have to work as an off-farm worker to satisfy his remaining consumption needs. Thus, his time is devoted on the one hand, to his field ( $t1 = y2 - O_j$ ) and on the other hand to off-farm activities or to work as an employee ( $t2 = G - y2$ ). By applying fertilizer microdosing, its production level shifts from  $y1$  to  $y2$ , which totally responds to the consumption needs  $A$ . This requires him to allocate all his labor time to his field and hire labor.

Secondly, the farmer does not have access to labor market. As the opportunity cost of labor is high, he does not apply the fertilizer microdosing because  $U(D) > U(C)$ .

### Marginal value cost ratio approach

Previous studies examined the economic profitability of fertilizer microdosing using various approaches. Some studies used net income (Tabo et al., 2007), the benefit-cost ratio (Bielders and Gérard, 2015; Sime and Aune, 2014) and marginal value cost ratio (Camara et al., 2013; Liverpool-Tassie et al., 2015; Tovihoudji et al., 2018). Compared to other approaches, marginal value cost ratio (MVCR) examines the incremental change in net income when the investment cost increases and it takes into account additional costs generated by the new technology (Kelly, 2006; Boughton et al., 1990). In other words, it is the ratio (in percentage) between marginal net profit and marginal net cost (Tefft, 1991; Crawford and Kamuanga, 1991). For this study, we use the MVCR.

The marginal value cost ratio is formulated as:

$$\text{MVCR} = \frac{(Y_m - Y_t)P_y}{CT_m - CT_t}$$

with  $Y_m$ , yield of fertilizer microdosing plot,  $Y_t$  yield of control plot,  $P_y$  price of agricultural product,  $CT_m$  total cost of applying fertilizer microdosing,  $CT_t$  total cost related to control plot. The total cost is equal to the fertilizer acquisition cost and the average labor opportunity cost. The average labor opportunity cost is equal to average number of hours needed to apply the fertilizer times the hourly cost of labor. We used the average costs of labor of each study area because the cost differs from one region to another.

For the MVCR threshold, the researcher must set the rate with farmers based on available information (Kelly, 2006). Crawford and Kamuanga (1991) suggest that the threshold can be set taking into account the current interest rate and risk premium of the study area. The treatment with the highest net benefit and high MVCR could be recommended (Kelly, 2006). Previous studies conducted in similar countries like Burkina Faso, suggest the threshold be set up at 2, especially for risk-averse farmers (Kelly, 2006). Indeed, at that threshold, the risk-averse farmers can be able to achieve a return on investment and to hedge against possible production and market risks. The MVCR is compared to 1 for risk-neutral farmers.

## RESULTS AND DISCUSSION

### Sorghum and millet yield analysis

The box plots (a) and (b) of Figure 2 represents respectively the yield distribution of millet and sorghum plots. The graphs show that 50% of fertilizer microdosing plots of millet have more than 500 kg.ha<sup>-1</sup> compared to control plots. For both crops, based on the result of mean difference test that is not significant ( $p > 0.05$ ), the difference of yield fertilizer microdosing over recommended dose plot is relatively low. Nevertheless, the both crop yield compared to control plots yield is statistically significant. It is also noted that almost all plots, regardless of the treatment, have yields less than 1000 kg.ha<sup>-1</sup>. In addition, the median yield of the fertilizer microdosing is 500 kg.ha<sup>-1</sup>, which is slightly higher than the recommended dose plots. About 25% of fertilizer microdosing plots of sorghum have a yield close to 1000 kg.ha<sup>-1</sup> compared to 75% for control plots with more than 500 kg.ha<sup>-1</sup>. Compared to control plots, the use of fertilizer contributed to increasing millet and sorghum yields. These results could be explained by the agro-ecological characteristics of the areas such as annual precipitation and soil texture as well as its fertility level (Tabo et al., 2007; Garner et al., 2014; Biielders and Gérard, 2015). According to Tabo et al. (2007), better yields from fertilizer microdosing were found where an annual precipitation is more than 1000 mm (sorghum) and between 600 and 1000 mm (millet). In addition, the

results of a study carried out in Niger by Biielders and Gérard (2015) argued that the low millet yield was not only due to low soil fertility but also to farmer's crop management strategies. That means that beyond some factors sometimes out of their control, farmers have to adopt the best agricultural innovations in order to get better yield.

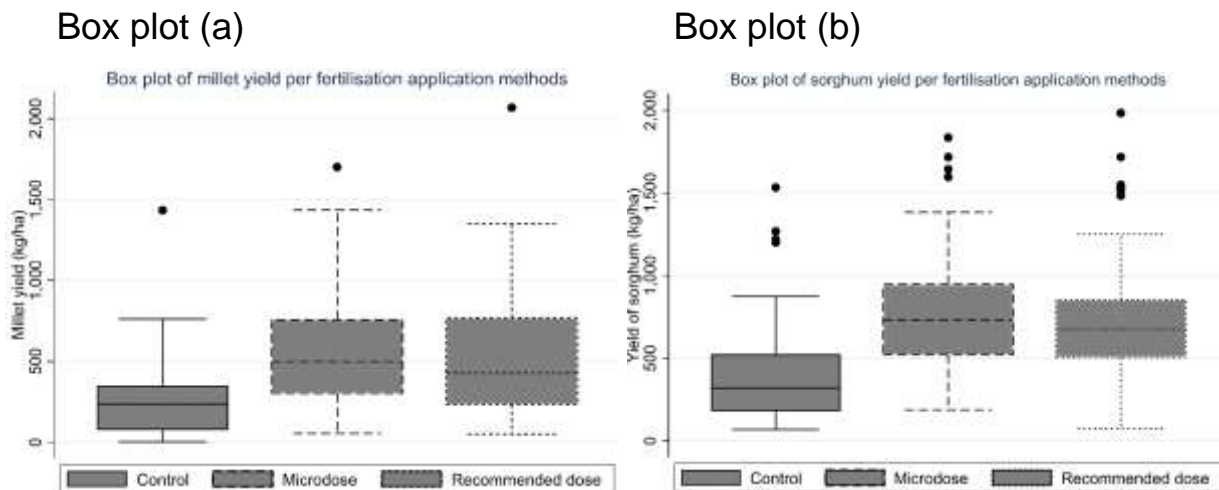
The results of this finding are consistent with the results of some studies, which noted that the difference between sorghum and millet grain yields from fertilizer microdosing and recommended dose plots is not significant (Saba et al., 2017; Fatondji et al., 2016; Tabo et al., 2007; Hayashi et al., 2008). Similar results found that millet yields from fertilizer microdosing plots could reach 1000 kg or even about 2000 kg per hectare (Saba et al., 2017; Tabo et al., 2007).

### Analysis of the economic profitability of fertilizer microdosing

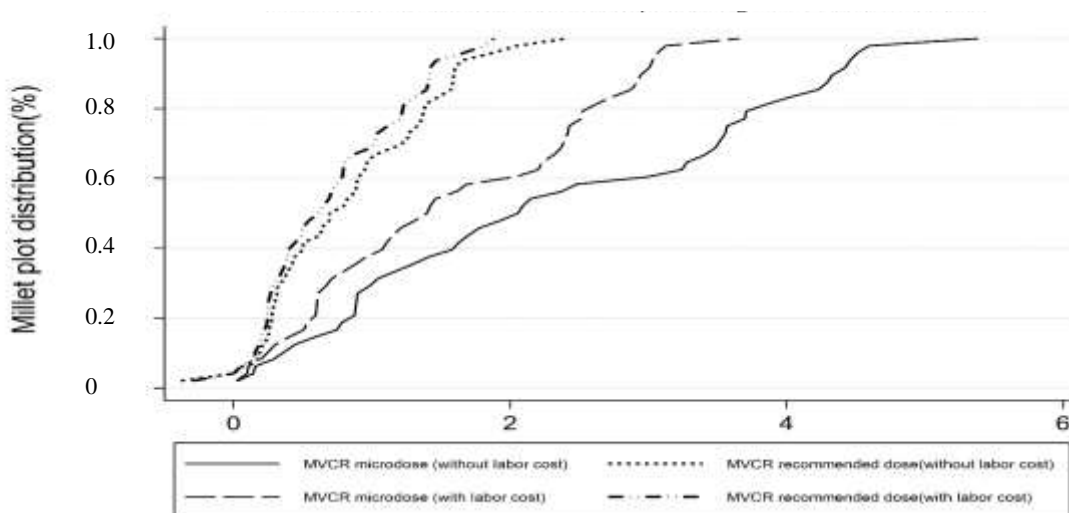
Figure 3 represents the cumulative distributions of the MVCR of millet. The difference between both technologies in terms of economic profitability is significant at the 1% threshold with or without the opportunity cost of labor. Without taking into account labor opportunity cost, the results show that 70% of fertilizer microdosing plots have a MVCR higher than 1 compared to 35% for recommended dose plots. Considering the risk aversion of farmers compared to recommended dose plots, we note that 50% of fertilizer microdosing plots have a MVCR above 2, the conventional profitability threshold assumed to cover themselves against possible production risks. However, including the opportunity cost of labor, the rate of fertilizer microdosing plots with a MVCR above 2 shifts from 50 to 41% and not even one recommended dose plots reached the threshold of 2.

In Niger, Hayashi et al. (2008) obtained MVCR up to 5 when fertilizer microdosing is applied 57 days after planting on millet plots compared to plots with different application dates after planting. However, in Niger, Liverpool-Tassie et al. (2015) noted that the MVCR of fertilizer microdosing to millet could be slightly below MVCR of mixing fertilizer and seed estimated at 8. Taking into account all costs as well as the additional costs of fertilizer microdosing, Camara et al. (2013) showed that the marginal rate of return on fertilizer microdosing applied to millet is between 1 and 2 in Mali. On the other hand, the benefit-cost ratio of millet can reach up to 18 during the dry season in Mali where the market price is higher (Fatondji et al., 2016).

Figure 4 represents the cumulative distributions of the MVCR of sorghum. The difference between both technologies in terms of economic profitability is significant at the 1% threshold with or without the



**Figure 2.** Sorghum and millet plot yield distribution.  
Source: Authors' Computation from Survey Data (2019).



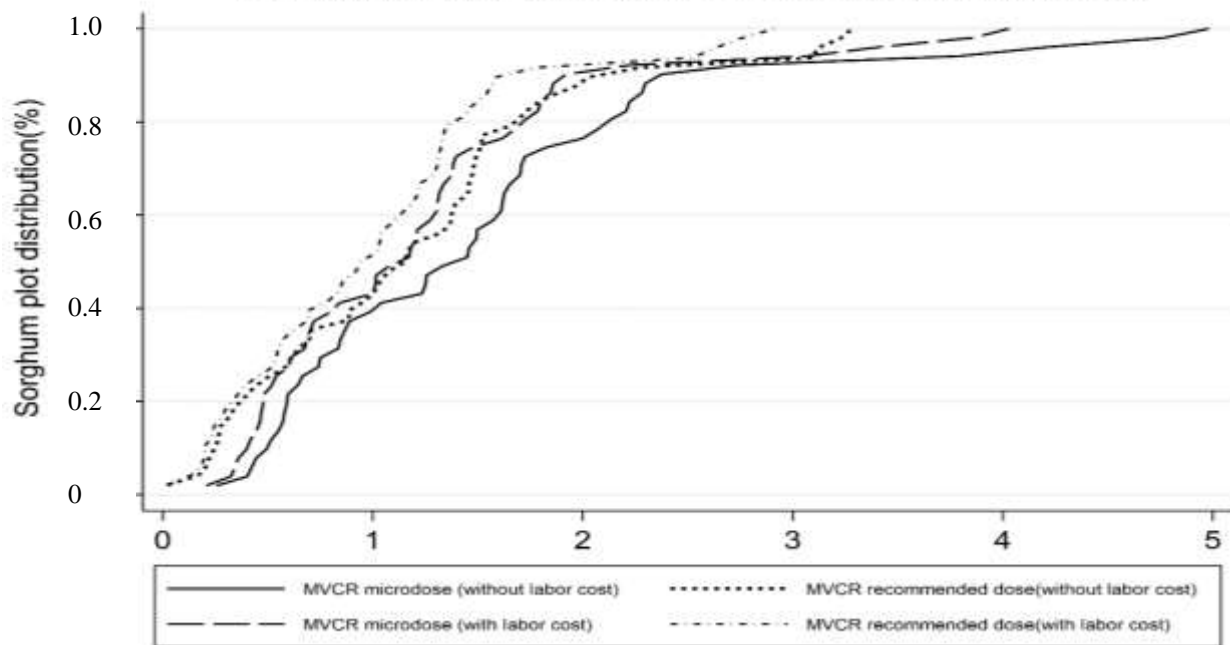
**Figure 3.** Cumulative distribution of the MVCR of millet plots.  
Source: Authors' Computation from Survey Data (2019).

opportunity cost of labor. Some plots have a negative MVCR regardless of the fertilization technique. Without the labor opportunity cost, the rate of MVCR of fertilizer microdosing plots can be as high as 5 to 3 for recommended dose plots over control. The inclusion of labor cost induces 1 point decrease in fertilizer microdosing plots. In addition, without labor costs, the proportion of fertilizer microdosing plots and recommended dose plots greater than 1 are the same, that is, 63%. By setting the threshold at 2, the proportions slightly differ, that is, 28% (fertilizer microdosing plots) and 22% (recommended dose plots). On the other hand, by including the opportunity cost of labor, the proportion

of fertilizer microdosing plots with MVCR above 2 decreased from 28 to 15% compared with 22% to 19% for recommended dose plots. Moreover, the difference between the MVCR of both plots is significant at 5%.

Using the benefit-cost ratio, Saba et al. (2017) noted that the ratio could reach 7.3 for fertilizer microdosing versus 4.3 for recommended dose method for sorghum. In that analysis, only the acquisition cost of the fertilizer was recorded. In contrast, in Mali, Fatondji et al. (2016) obtained a benefit-cost ratio of 3 and 7 for sorghum under fertilizer microdosing at harvest and during the dry season respectively.

From the analysis of Figures 3 and 4, fertilizer



**Figure 4.** Cumulative distribution of the MVCR of sorghum plots.  
Source: Authors' Computation from Survey Data (2019).

microdosing was found to be a more labor-intensive technology than recommended dose. That is consistent with the findings of some studies, which highlighted that fertilizer microdosing application needs additional labor (Pender et al., 2008; Sime and Aune, 2019). By contrast, in Niger, Liverpool-Tassie et al. (2015) found that fertilizer mixed with seed is more labor-intensive than fertilizer microdosing. In addition, it appears that including labor opportunity cost decreases the economic profitability rate of fertilizer microdosing regardless of the crop in Burkina Faso. However, despite the labor opportunity cost, the fertilizer microdosing remains economically profitable compared to the recommended dose. These results could be explained by the quantity of fertilizer applied on fertilizer microdosing plots, which is 12 kg less per hectare compared to the recommended dose plots. In other words, application of this technique reduces the fertilizer purchased cost, which is consistent with previous studies (Aune and Ousman, 2011; Camara et al., 2013; Tabo et al., 2007). Another explanation could be the high labor cost of recommended dose application. For example, in the Northern region, this cost does not include fertilizer microdosing labor cost because of organic manure application cost during tillage. Indeed, the tillage is usually carried out manually and that leads to an additional cost (Barro et al., 2002). Williams (1999) showed that the use of manure in West Africa is labor-intensive and thus results in higher labor costs.

This finding seems inconsistent with the results of

Liverspool-Tassie et al. (2015) in Niger, who found that the marginal product of labor does not vary significantly with fertilization techniques. Thus, despite the decrease in investment cost associated with the application of fertilizer microdosing, it generates an additional cost including labor cost that must necessarily be assessed in economic profitability studies.

## Conclusion

Unlike other studies, this paper focuses on understanding the effect of labor opportunity cost on the economic profitability of fertilizer microdosing in Burkina Faso. Using experimental farm field data, the results indicate that yields vary from one plot to another for any fertilizer technique. This result also shows that despite the control of variability factors, some heterogeneity factors did not include socio-economic factors, which should have been necessary during yield analysis, owing to their interaction with agronomic factors.

In terms of economic profitability, analysis of the marginal value cost ratio reveals that fertilizer microdosing remains economically profitable for some farmers despite the opportunity cost of labor. Thus, the opportunity cost of labor should be included in economic profitability analysis of fertilizer microdosing because of its significant effect on farmers' decision to adopt it. In addition, the results show that farmers who applied

fertilizer microdosing could realize a return on investment. For future studies on fertilizer microdosing, the labor opportunity cost should be included in the analysis of economic profitability. In addition, mechanization of fertilizer microdosing has become undeniable for large adoption and one of *sine qua none* conditions of its sustainability.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENTS

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