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Intensification of dryland farming in Mali through mechanisation of sowing, fertiliser application and weeding

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Abstract

This study focuses on the role of mechanised sowing and weeding in combination with seed priming and fertiliser microdosing in Mali. Mechanised sowing and weeding were based on using a combined donkey-drawn planter/weeder and a motorised planter/weeder. The research methods included studies of seed delivery in manual and mechanised sowing, field experiments on different levels of mechanization/intensification, labour studies on mechanisation and an economic assessment of the different levels of intensification.
The average sorghum grain yield across three years increased by 352 kg ha^{-1} (43.7% increase) by combining mechanisation with seed priming and microdosing of 0.2 g NPK 15-15-15 fertiliser per pocket compared to a control with manual sowing but without seed priming and

microdosing. The labour demand (sowing and weeding) for manual, donkey-drawn and motorised operations was respectively 184, 67 and 47 hours ha^{-1}, respectively.

An economic analysis showed that the donkey-drawn planter/weeder is the appropriate mechanisation below six ha while above this land size it becomes increasingly interesting for the farmers to invest in a motorised planter. The use of mechanisation will result in earlier and uniform crop establishment, facilitate microdosing application, timelier weeding, higher yields, better economic return and reduced labour demand.

Keywords: sorghum, seed priming, microdosing, planter, weeder, labour-use, appropriate mechanisation

Introduction

The sequence of agricultural mechanisation goes usually from manual labour, through animal traction to the use of combustions engines (tractors). As annual cropping is developed, the necessity for mechanisation increases due to higher labour demand for tillage, fertilization and weeding (Pingali et al. 1987). The farmers in the drylands of West Africa are generally subsistence orientated and the surplus generated is very limited making savings difficult. This makes it challenging for farmers to invest in mechanisation and purchase of agricultural inputs. Additional constraints for adaptation of mechanisation include low prices for agricultural produce and high prices for agricultural input.

Despite some success stories with mechanisation particularly in relation to cultivation of cash crops, its introduction has encountered difficulties in the drylands of West Africa. The profitability of mechanisation increases if it can be used in multiple operations such as tillage, planting, weeding, threshing and transport (Williams 1997). In marginal environments it is suggested that animal traction should be used for the transportation of water, manure and farm produce (Williams 1997). In areas where the cropping season is short and the soil is sandy, the use of planters has been introduced without prior ploughing (Pingali et al. 1987).

In general, agricultural mechanisation in Africa has not given satisfactory results (Fonteh 2011). Definitions of agricultural intensification in Africa also often overlook the importance of mechanisation. An example is the Montpellier Panel Report (2014) which defines agricultural intensification as a combination of ecological, genetic and socio-economic processes while completely leaving out mechanisation from the intensification definition. Another recent definition states that agricultural intensification is about producing more yield, increasing the number of crops per year or cultivating more high-value crops (Pretty and Bharucha 2014).

Agricultural mechanisation has not been on the agenda of most development agencies since 1985 (Mrema 2011). However, there is currently a renewed interest in agricultural mechanisation among development actors such as the African Development Bank (AfDB 2016) and FAO (FAO 2016). The outlook for agricultural mechanisation may also have changed, as conditions have recently become more favourable for agricultural intensification than in the previous decades. Food prices are on the increase, wages are higher and young people go to the cities in search of jobs (Mrema 2011, Baudron et al. 2015). Mechanisation may make agriculture, which is currently associated with drudgery (Leavey and Hossain 2014), more attractive to young people. Appropriate mechanisation can reduce labour demand in peak periods and thereby even out the labour demand throughout the season.

Climate change also contributes to an increased need for mechanisation in Africa. The aridity of the climate is expected to increase in the Sahel due to increasing temperatures (Sylla et al. 2016) making it necessary for farm operations to be done faster as the time window for these operations will get shorter.

In Mali, agricultural mechanisation has been promoted by the parastatal *Compagnie Malien de Développement de Textile* (CMDT) (Ashburner and Kienzle 2011). CMDT provided credit for agricultural inputs and loans for agricultural machinery that were repayable over several seasons. Planters were first introduced to Senegal in the 1920s and 1930s (Pingali et al. 1987) and later to Mali. The national factory *Societé Malienne d'Etudes et de Construction de Matériel Agricole* (SMECMA) was established in the 1970s in Mali for the production of planters. However, SMECMA was not able to survive the harsh economic and political conditions of the 1980s and 1990s, and the factory was closed down due to supply problems, great variation in demand and organizational problems (Le Thiec and Havard 1996). In addition, CMDT faced problems resulting from structural adjustment policies and support for mechanisation were abandoned. Despite this, the national factory has contributed greatly to mechanisation in Mali. In the 1990s, it was assessed that 70% of farm households were equipped with animal traction in southern Mali. However, only 17% of farmers cultivating the dryland cereal crops (sorghum and millet) had mechanised equipment (DNGR 2005). Manual sowing of millet and sorghum is a demanding operation that includes opening a small pocket in the soil with a thin-bladed hoe, taking a pinch of seeds, placing the seeds in the pocket and covering the seed with the foot. In recent times, farmers are increasingly combining sowing with the use of fertiliser microdosing. Local blacksmiths were trained by CMDT in the 1980s on the construction and maintenance of the planter. Since the demise of SMECMA, these blacksmiths have been ensuring the supply of planters in Mali. The blacksmiths can produce the equipment at 30-50% of the price of larger industrial producers (Pingali et al. 1987).

The central hypothesis in this paper is that agricultural intensification based on mechanised sowing and weeding in combination with seed priming and fertiliser microdosing is a feasible option for farmers in West Africa. The paper shows the effect of intensification on yield, labour use, investment needs and economic return. The sustainability of different levels of intensification is also discussed.

Materials and methods

The methods used in this study include studies on seed and fertiliser delivery in manual and mechanised sowing (1), field experiments to determine yields in treatments (2), time and fuel use studies of these treatments (3), and an economic assessment to compare the different levels of intensification and mechanisation options (4). These methods in combination with a national census were used to assess the feasibility of the different mechanisation options taking into consideration labour availability in the household and farm size.

Seed delivery in manual sowing and by planter

Seed and fertiliser application in manual sowing were based on measuring the quantity of seeds and fertiliser in a pinch between the thumb and the index finger of 75 different farmers. The quantities applied with the pinch were taken with different pearl millet and sorghum varieties, NPK (15-15-15) and diammonium phosphate fertiliser (DAP 18-46-0) and a 1:1 mixture of seeds and fertiliser. Assessment of the numbers of seeds applied when using the SMECMA planter was based on running the planter 61 times (corresponding to a row length of 390 m) for each treatment. The essential parts of the SMECMA planter consists of the hopper, the rotating disc with perforations that deliver seeds in the correct quantity and at appropriate spacing, seed delivery tubes, the furrow opener, tines that close the furrow, and a compaction wheel that compresses the soil to increase the contact between soil and seeds. Factors influencing the amount of seeds and fertiliser applied are distance between the perforations in the disc, the diameter of the perforations and the thickness of the disc.

Agronomic trials

One series of field experiments was conducted in two villages in the Koulikoro region during 2007 and 2008 to determine the yield effect of manual sowing compared to mechanised sowing using a donkey-drawn planter. In each village, 10 farmers hosted the test and the plot size for each treatment was 1000 m^2. Each farmer represented a replicate.

Another series of field experiments was conducted from 2013 to 2015 in Koulikoro region to assess the yield performance at different levels of intensification including mechanization.

The trial was conducted in the fields of 13 farmers and each farmer was considered as a replicate. The following treatments in sorghum were used:

1. Manual sowing without seed priming or fertiliser
2. Mechanised operations using donkey-drawn planter/weeder, and seed priming for 8 hours followed by 2 hours surface drying to reduce the stickiness of the seeds. The disc used in the planter had 7 mm diameter perforations and the disc thickness was 8 mm.
3. Mechanised operations using donkey-drawn planter/weeder, seed priming and 0.2 g NPK per pocket (5 kg NPK ha^{-1}). Seed priming and drying as in treatment 2, followed by mixing seeds and fertiliser at 1:1 volumetric ratio. The disc in the planter had perforations of 10 mm diameter and a disc thickness of 8 mm.

Labour assessment

Time use was measured for the treatments of manual sowing (1), use of a donkey-drawn planter (2) and motorised planter (3) in 2013, 2015 and 2016. The treatments were replicated in the fields of seven farmers and the plot size for each treatment was 1000 m^2. In the case of interruptions of the work, the chronometer was stopped. In the treatment with motorised sowing, the fuel use was measured by first emptying the tank of the planter, thereafter filling a measured quantity of fuel and measuring the remaining fuel again after the operation.
The calculation of labour use for sowing per farm was calculated based on the average farm size in Mali, the number of active labourers per farm and the labour demand per ha for the three different sowing methods.

Economic assessment

In the economic assessment, we used the yield from the experiments conducted from 2013 to 2015. We also introduced a fourth level of intensification that is based on the use of a motorised planter in combination with seed priming and fertiliser microdosing (video). This is the same planter that was used at the third intensification level, but in this case the planter is not pulled by traction animals, but by a 5.2 KW (6.8 horsepower) combustion engine (small motorcycle engine). The motorised planter is constructed by "*Agric Construction Cissé et Frerès*" in Koutiala Mali. We do not have the yield data for the fourth step in the intensification ladder, but the same yield data as in the third level of intensification was used because the seed delivery system is the same as in the planter drawn by traction animals. The economic assessment of the different levels of mechanisation was undertaken using the method described by Sims and Kienzle (2015). This method takes into consideration the depreciating value of the machine, useful life, interest costs, repair costs and the cost of operating the machine. The useful life of the machine was set at 10 years and the interest rate was 12%, a rate typically used in small-scale agricultural credit schemes in Mali. The annual depreciation cost was set to 9% of the price of the machine while the annual repair cost was set to 13% of the sales price of the machine. The sorghum grain price used was 119 CFA-Franc kg^{-1}, which is the average grain price for 2015 across cereal growing regions in Mali. The price of the straw was set to 20 CFA-Franc kg^{-1} (obtained from a survey). The time for manual weeding in the control was set to 120 hours ha^{-1}, which is the average time for manual weeding estimated in Mali, Burkina Faso and Niger (Memento de l'Agronome 2009). Manual weeding within the row for the mechanised treatment was set to 36 hours ha^{-1} (Memento de l'Agronome 2009). A survey among 29 farmers showed that the average price for renting a donkey and hiring a man is 3200 CFA-Franc day^{-1}. To calculate the farm partial income for different farm sizes, we calculated the value of the straw and grain yield for farm sizes varying from 1 to 12 ha and subtracted the variable cost related to sowing and weeding for the corresponding farm size and then subtracted the fixed cost related to mechanization.

Results

Manual and mechanised seed and fertiliser application

The seeding rate in manually application and by the planter were assessed. One pinch of seeds taken between the thumb and the index finger (farmers practice) gave 35 (standard deviation 17) and 11 (standard deviation 5) seeds respectively for the Toroniou millet variety and the CSM sorghum variety (Table 1). When Toroniou seeds and NPK fertiliser (15-15-15) were mixed, one pinch equated to 20 seeds and 0.28 g fertiliser. DAP fertiliser was also tested, and the rate applied was similar to that of NPK fertilizer.

Insert Table 1.

In mechanised sowing, the application of seeds and fertiliser is determined by distance between perforations in the disc, the diameter of the perforations and the thickness of the disc. Table 2 shows the relationship between the diameter of perforation and the number of seeds delivered for the Toroniou pearl millet variety. The number of seeds delivered increased with 3.5 seeds for every mm increase in the perforation diameter. The disc recommended for sowing pearl is a disc with perforations of 8 mm diameter and a thickness of 8 mm, as this disc gave an appropriate number of seeds.

Insert Table 2

The number of seeds and quantity of fertiliser applied was determined when seeds and fertiliser were mixed in a 1:1 ratio and applied by the planter. This disc had an 8 mm thickness and perforations with a diameter of 10 mm delivering approximately 10 seeds of sorghum or millet and 0.2 g of fertiliser per planting pocket.

Use of the planter gave a more uniform sowing rate. The standard deviation for the number of seeds delivered was 16.9 for the manual pinch and whereas as it is 6.8 for the planter. The disc with 13 mm perforations delivered a number Toroniou millet seeds equivalent to a pinch of seeds (Tables 1 and 2).

Agronomic effects

Mechanisation increased sorghum yield by an average of 14.6% in 2007 ($p<0.05$) and by 13.0% in 2008 ($p<0.01$). In the trail with three levels of intensification (2013-2015), the average grain yields were 804, 1058 and 1156 kg ha^{-1} in the treatments manual sowing (without priming and microdosing (1), mechanised sowing and seed priming (2) and mechanised sowing, seed priming and microdosing (3), respectively (Figure 1, Figure 2). The boxplot also showed that there were no yields below 600 kg ha^{-1} when the highest level of intensification is used.

Insert figure 1 and 2.

Labour assessment

Mechanisation reduced the time used for sowing and weeding. Table 3 shows that the labour demand in sowing and weeding decreased from 184 hours ha^{-1} in manual sowing, to 67 hours ha^{-1} when using donkey-drawn traction (Supplemental Figure 1) and to 47 hours ha^{-1} when using motorised traction (Supplemental Figure 2). The labour demand was therefore 3.9 times higher for manual sowing and weeding compared to motorised sowing and weeding. Labour demand related to sowing is particularly reduced. The reason for this is that even if mechanical weeding is practiced, there is still a need for manual weeding within rows.

Insert Table 3

Economic assessment

Table 4 shows the major fixed and variable cost items related to the different treatments. It appears that the manual treatment has lower fixed costs (independent of area cultivated) while the variable cost per ha is higher for the manual treatment compared with the mechanised treatments. The price of the donkey-drawn planter was 70,000 CFA-Franc (106 Euro) while for the motorised planter the cost was 525,000 CFA-Franc (800 Euro). The major fixed costs for the donkey-drawn planter and motorised planter are connected to depreciation of the machines, interests and repair costs. The fixed costs for the donkey-drawn planter/weeder was 20,020 CFA-Franc while it was 150,150 CFA-Franc for the motorised planter/weeder. The variable cost items differed between the treatments. As Table 4 shows, the variable cost decreased from 36,800 CFA-Franc ha^{-1} in the manual treatment to 13,145 CFA-Franc ha^{-1} in the motorised treatment. The major reason for this was the higher labour costs in the manual treatment. Mechanised weeding reduced the weeding time to half of that for manual weeding (Table 3). The cost of donkey rental was quite low for the treatments using animal traction. The fertiliser and fuel costs were also low in comparison to the other costs. The amount of petrol consumed per was 3.5 l ha^{-1} (standard error= 0.03) for sowing and weeding, which was equivalent to 2,625 CFA-Franc.

Insert Table 4

The partial farm net income (including only the variables investigated in this study) was calculated for cultivated areas ranking from one to twelve ha in order to assess appropriate mechanisation for different farm sizes (Table 5). The data used to calculate the partial income at the farm level were taken from Figure 1, Table 3 and Table 4. The data showed that even if the farmers were cultivating only one ha, it was more profitable to use mechanised sowing, priming and microdosing than to use manual cultivation without seed priming and microdosing. Furthermore, it was shown that if the farmer is cultivating between one and six ha, it was less profitable to use the motorised planter than the other treatments. When farmers cultivate six ha, the partial income in motorised mechanisation and donkey-drawn mechanisation were almost equal (1.8% higher in donkey-drawn mechanisation). Above six ha, the partial farm net income was higher using the motorised planter, compared with the use of the donkey-drawn planter.

Insert Table 5

Discussion

Manual and mechanised seed and fertiliser application

The higher variability observed in seed and fertiliser delivery in manual application as compared with mechanised application was related to the size of the fingers of the person taking the pinch and how the pinch was taken. In addition, use of the planter gave a more uniform planting distance and sowing depth.

Agronomic effects

More uniform sowing may explain why the use of the planter gave 14% higher yield than manual sowing. The trial with increasing levels of intensification showed that the highest level of intensification (use of the planter, seed priming and microdosing) increased yield by 43.8% compared to farmers' practice. Seed priming has previously been found to increase yield by about 20-30% compared to farmers' practices under Sahelian conditions (Aune et al. 2017). The seed priming effect was related to a more uniform plant stand and faster crop establishment. Seed priming combined with microdosing has previously been found to increase yield by 106% compared to farmers practice under Sahelian conditions (Aune et al. 2012), and this is clearly higher than the yield effects observed in the experiments running from 2013 to 2015.

Labour assessment

The labour study showed that labour use was 3.9 times higher in manual sowing and weeding as compared to using the motorized planter/weeder, and 2.7 times higher than using the donkey-drawn planter/weeder. Speed of sowing is particularly important in the Sahel as there are few days appropriate for sowing. In order to assess labour availability at sowing for a typical Malian farm, we used data from the national census of farm households in Mali that showed that the average planted areas per farm is 4.7 ha (Direction National d'Agriculture 2007). A typical farm household in Mali with four available workers can sow the farm manually in 9.4 days compared to 4.2 and 1.8 days for use of the donkey-drawn and the motorized planter, respectively. This shows that manual sowing will, in many cases, lead to sub-optimal sowing time while the donkey-drawn planter and particularly the motorized planter can ensure timely sowing. The high capacity of the motorized planter may also allow for leasing the planter to other farmers. The lesson from Asia is that small-scale mechanisation has mainly spread through service delivery by owners of 2-wheels tractors (2 WT) (Mottaleb et al. 2016, Baudron et al. 2015) and service delivery is also likely to be the most efficient way for promoting mechanisation for African small-scale farmers (Baudron et al. 2015).

Economic assessment

The economic return to mechanisation will depend on machine costs (depreciation), area cultivated, running cost and yield level. Even if a farmer was only planting one ha, it was better to use the donkey-drawn planter/weeder in combination with seed priming and microdosing than to use manual sowing without seed priming and microdosing. The reason was that manual sowing without seed priming and microdosing will had a labour costs of 36,800 CFA-Franc ha^{-1} while the combined costs of donkey hire and labour in the treatment with the use a donkey drawn planter was 18,720 CFA-Franc ha^{-1} (Table 4). In addition, the yield was 14% higher with mechanised sowing compared to manual sowing. The cost of fertiliser was very low compared to the labour costs. The benefit of mechanised sowing and weeding increased with increasing planted area as shown in Table 5. The average planted area per farm in Mali is 4.7 ha, making mechanised sowing/weeding an attractive option for the larger farms. It was shown that if farmers cultivate less than six ha it is advisable to use animal traction combined with the yield enhancing technologies, compared to the use of the motorised planer/weeder. Beyond six ha, farmers may choose the donkey-drawn planter/weeder or the motorised planter/weeder combined with the yield enhancing technologies. However, as the farm size increases it becomes more and more difficult to use donkey-drawn mechanisation, because this form of mechanisation does not have the same capacity as motorised mechanisation. For a farm size of six ha, the partial income increased by about 60% when using the donkey-drawn planter combined with the yield-enhancing technologies compared to manual farm operation without any use of the yield enhancing technologies. The exact threshold level at which it becomes interesting to use motorised mechanisation is difficult to determine as there are uncertainties related to depreciation and repair costs when the machines are used more intensively.

For some farmers it might be interesting to skip the animal traction stage (stages 2 and 3) and adopt motorised mechanisation since there are many hidden costs in relation to traction animals. These costs are difficult to quantify, but represent significant costs for the farmers in terms of veterinary services, fodder and labour for feeding, herding and training the traction animal. Supplementary feeding at the start of the working period is often needed as the local feed resources are of low quality at this time of the year. A pair of oxen cannot work more than six hours/day and an ox can on average, only deliver traction services for three years (Cattin 1986).

Sustainability of intensification- overall assessment

Intensification of agriculture in the Sahel has been described as "climbing a ladder or a stairway" (Aune and Bationo 2008). This ladder was based on a stepwise introduction of seed priming, organic fertiliser, microdosing and agroforestry (Figure 3). However, the problem with this ladder is that labour demand increases as new yield enhancing technologies are added to the ladder. Here, we suggest an alternative pathway characterized by combining mechanisation with yield enhancing technologies (seed priming and microdosing) that are compatible with mechanised sowing (Supplemental Figure 2). The steps in the revised ladder were arranged according to increasing costs as in the previous ladder. Donkey-drawn traction and motorized mechanisation represent the second highest and the highest levels of intensification, respectively in the revised ladder. Farmers may choose any step on the ladder depending on their resources and priorities. By climbing the ladder, farming becomes more attractive, particularly for young people, as labour demand is decreased and yield is increased.

A combination of mechanisation and yield-enhancing technologies is a well-proven pathway of intensification. The early stages of agricultural intensification in developed countries were also characterized by crop livestock integration, use of farm-yard manure, the introduction of legumes, grazing management and mechanisation (Vos and Meekes 1999, Pretty and Bharucha 2014). Intensification of farming should not increase the probability of crop failure and farmers economic risk. Figure 1 shows that the risk of a low yield is higher in the treatment with farmers practice compared to the treatment with mechanization, seed priming and microdosing. Motorized mechanisation represents a rather high financial cost for the farmer, and many farmers will be in need of credit financing for purchasing a motorized planter.

Insert figure 3

Motorised mechanisation can be criticised because it will increase CO_2 emission. However, these emissions are modest as the total fuel consumption for sowing and weeding was 3.5 lha^{-1} corresponding to 8 kg CO_2 ha^{-1}. The amount of CO_2 released for sowing and weeding an average farm of 4.7 ha was therefore about 38 kg CO_2. It is also important to keep in mind that there will also be GHG emission if traction animals are used.

There is a possibility for using imported 2WT and attachment like planters to promote mechanisation in West Africa, but the advantage with the motorised planter developed by IER is that it can be produced and maintained locally and that the seed delivery system is fine-tuned to deliver seeds and fertiliser at appropriate spacing and quantity. Furthermore, the motorized planter is built on a planter that is well known in Mali.

Conclusion

The suggested intensification pathways based on using mechanised sowing and weeding in combination with the yield enhancing technologies of seed priming and microdosing have clear benefits for the farmer in terms of higher yields, more timely sowing, increased profitability, the saving of labour and reduced drudgery. This intensification pathway therefore increases both land and labour productivity thereby increasing the attractiveness of intensification. This central hypothesis is thus confirmed. The appropriate level of intensification depends on the yield obtained, farm size, labour force of the household, prices of input and output, interest rates and availability of capital. The use of the donkey-drawn planter/weeder combined with seed priming and microdosing seems to be an appropriate level of intensification for farms under six ha while for farmers with land size beyond six ha, the use the donkey-drawn planter or the motorised planters are feasible options. For a farm size of six ha, the partial income will increase by about 60% when using the donkey-drawn planter combined with the yield-enhancing technologies, compared to manual farm operations without any use of yield enhancing technologies.

Disclosure statement

There is no conflict of interest in this study.

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Figure 1. Effect of different levels of intensification on stover yield in sorghum

Figure 2. Effect of different levels of intensification on grain yield in sorghum

Figure 3. Intensification ladder without mechanization (left) and revised intensification ladder including mechanization (right)

Table 1. The amount of seeds and gram fertilizer applied by taking a pinch between the thumb and the index finger

	Pinch with seed or fertilizer			Pinch with seed and fertilizer	
	Toroniou millet (nbr.)	CSM63 Sorghum (nbr)	NPK fertilizer g	Toroniou grains (nbr.)	NPK fertilizer g
Mean	35	11	0.37	20	0.28
Standard deviation	16.8	4.6	0.21	10	0.17

Table 2. Relationship between diameter of perforations in the disc and quantity of seed delivered of the Torounio pearl millet variety.

	8 mm	10 mm	12 mm	13 mm
Number of seeds	16.1	23.4	29.7	32.9
Standard deviation	4.0	5.4	6.3	6.8

Table 3. Labour demand in h ha^{-1} for sowing and weeding in the treatments. Standard error for time use in sowing in parenthesis.

	Manual sowing and weeding	Donkey drawn planter+ seed priming	Donkey drawn planter+ seed priming+microdosing	Motorized planter+ seed priming + microdosing
Labour use per hectare sowing hours	64 (4.3)	7.1 (0.9)	7.1 (0.9)	3.1 (1.2)
Labour use per hectare for weeding	120	60[1]	60[1]	44[2]
Total labour use sowing and weeding per hectare	184	67.1	67.1	47.1

[1] Includes 24 hours mechanized weeding between rows and 36 hours manual weeding within rows

[2] Includes 8 hours mechanized weeding between rows and 36 hours manual weeding within rows

Table 4. Fixed and variable cost for using manual planting, donkey drawn planter and motorized planter in CFA-Franc (1 Euro=656 CFA-Franc).

Fixed costs	Manual sowing	Donkey drawn planter+ seed priming	Donkey drawn planter, seed priming and microdosing	Motorized planter, seed priming, and microdosing
Depreciations costs	0	6,300	6,300	47,250
Interests costs	0	4,620	4,620	34,650
Repairs costs	0	9,100	9,100	68,250
Total fixed costs per year		**20,020**	**20,020**	**150,150**
Variable costs per hectare				
Fertilizer costs	0	0	1,100	1,100
Fuel costs	0	0	0	2,625
Donkey rental cost	0	11,520	11,520	0
Labour costs	36,800	7,200	7,200	9,420
Total variable costs per hectare	**36,800**	**18,720**	**19,820**	**13,145**

Table 5. Effect of level of intensification and area cultivated on partial farm income in sorghum in 1000 CFA-Franc.

ha	Manual	Donkey drawn planter + priming	Donkey drawn planter + priming + microdosing	Motorized sowing + priming + microdosing
1	119	163	175	62
2	239	345	369	276
4	472	710	759	702
6	716	1,075	1,148	1,128
8	954	1,440	1,537	1,555
10	1,193	1,805	1,927	1,981
12	1,431	2,170	2,316	2,408