Agricultural intensification in Mali and Sudan through improved soil fertility, integrated pest management and mechanization

Jens B. Aune¹, Belachew Asalf², Adama Coulibaly³ and Stig A. Borgvang²

¹Norwegian University of Life Sciences (NMBU), ²Norwegian Institute of Bioeconomy Research (NIBIO), ³Institute d'Economie Rurale, Bamako, Mali

Light case study report for the PROIntensAfrica Project, WP2

October 2016
Introduction

Agricultural production in Africa must be increased considerably to meet the food and feed demands of a rising human population. Amongst the many challenges facing agricultural production in Africa are farm power, poor soil fertility and pest damage. Improved soil fertility, farm power and pest control are essential to increase labour efficiency and land productivity in Africa.

It is a well accepted fact that agriculture production has to increase per unit area while preserving the environment (sustainable agricultural intensification). There are several pathways for the intensification of Agriculture in Africa. The high input agriculture (industrial food production), the agroecosystem, the organic and the sustainable intensification represent some of the pathways identified by PROIntenseAfrica. African agriculture does largely follow the agro-ecology pathway, not necessarily by choice, but more as a result of limited access to agrochemicals and market opportunities.

Integrated crop management and pest management are central to all pathways (Fig.1). In this case study, the role of improved farm power and mechanization, seed priming, improved soil fertility (microdosing) and Integrated Pest Management (IPM) practices in the intensification of agricultural production in Mali and Sudan are discussed.

Fig.1 Crop management and pest control are central to all agricultural intensification pathways.
Essential components of sustainable intensification of agriculture

Farm Power and mechanization of sowing

There is a great variability in sub-Saharan Africa with regard to agricultural mechanization. In many parts of Africa, up to 80% of primary land preparation is carried out by use of human muscle power (Mrema 2011). Draught animals for soil tillage were not used before the 1920-1930s and then in sub-Saharan Africa. The only exception is Ethiopia where ploughing has been in use for thousands of years (McCann 1995). Draught animals are normally first used for ploughing, as this is the most energy and labour demanding task in agriculture. Draught animals can also be used for sowing, weeding and threshing. Use of draught animals has been common in relation to cultivation of cash crops like groundnuts and cotton. Production of these crops often generate a surplus that can be used for purchasing and maintaining of these draught animals.

Mechanization and use of tractors are much less widespread in Africa than in for example Asia. Introduction of yield enhancing technologies has been slow in Africa and this may explain the slow uptake of mechanization. A central question in agricultural mechanization is if it is possible to bypass the animal traction stage and move directly to motorization of agriculture.

The first tractors were imported to Africa sometime between the two World Wars. They were mainly used on the fields of white settlers. There was a strong push for mechanization in Africa in the years following independence, but the success rates were low. Animal traction was at that time considered as an outdated and backward technology. Sudan is one of the few examples where introduction of tractors has been successful, this due to government subsidies and the need for destumping and land leveling (Pingali et al. 1987).

In French speaking part of West Africa, agricultural mechanization was promoted by the parastatal projects in cotton and groundnut (Ashburner and Kienzle 2011). These projects provided credit to farmers to be repaid after harvest; loan for agricultural machinery was repayable over several seasons. These parastatals also provided training and support for rural artisans supporting these value chains. However, these parastatals faced difficulties during the time of the structural adjustment program in the 1980s, and in the 1990s support to mechanization was abandoned. French research in West Africa concentrated on development of light weighted frames to which cultivators, weeders and ridgers were developed.
The farm operation first mechanized is normally ploughing. In the dryland of West Africa, ploughing has increased yield of groundnut, millet and sorghum by 19, 21 and 29% respectively (Pingali et al. 1987). The yield increase is, however, less on sandy soils and under drier conditions, as compared to more humid conditions with heavier soils. Profitability of ploughing is not only dependent on the yield increase, but also on the price of the crop grown. Ploughing millet (low priced crop) has therefore been less profitable compared to ploughing of a rice crop (high priced crop). On-farm studies show in general no difference in yield between hoe tillage and land tilled with animal traction (Pingali et al. 1987).

In areas where the cropping season is short and the soil is sandy, mechanized sowing has been introduced, but not ploughing. The window available for sowing is short, and if ploughing delays sowing the yield benefit of ploughing is reduced. Delayed ploughing can be caused by shortage of traction animals and/or poor conditions of the traction animals at the onset of the growing due to fodder shortage. The yield benefit of ploughing on a heavy soil is higher than ploughing a sandy soil. Mechanized sowing was introduced in groundnut production in Senegal in the 1920s and 1930s. The use of the seeders allows sowing of a large area in short time. The seeders were introduced to Senegal in 1920 and 1930 (Pingali et al. 1987). National factories for production of seeders were established in both Senegal (SISCOMA) and Mali (SMECMA). The number of seeders in Senegal increased from 20,000 in 1940 to about 220,000 in 1980. However, these factories were parastatals and were not able to survive the harsh economic and political conditions in the 1980s and 1990s. Since then, local blacksmiths have to some extent taken over the maintenance of this equipment. These craftsmen can produce equipment at a price 30 to 50% lower than the price of larger industries (Pingali et al. 1987). In the 1990s, 70% of the farm household in southern Mali were equipped with animal traction.

The government in Mali has, in recent times, subsidized the purchase of tractors for young farmers. However, the payback of the loans have been low despite the fact that the loans were given at a subsidized interest rate (Fonteh 2010).

The work can be done faster whenever traction animals are used. The work speed for most draught animals when working at optimum pull is about 3½ km/hour and the animals can pull 13 to 15% of their body weight (Aschburner and Kienzle 2011). It takes about a year to train one draught animal. Different types of farm animals can be used in animal traction. The cost of donkey traction has been found to be about 30 to 40% of bovin traction (Williams 1997). Donkey traction is particularly useful in connection with lighter task such as weeding. There is
a considerable cost in keeping draught animals linked to feed, veterinary services and training. The profitability of draught animals can be increased if the animals are used for multiple purposes such as transport, ploughing, sowing, weeding and threshing. There is still a need for agricultural equipment particularly suitable for animal traction.

Despite some success stories with mechanization, its introduction has not been without problems, and the uptake has been slow. The first forms of mechanization in rural Africa were related to stationary tasks such as water pumping and ploughing. The benefits of mechanization increases if the equipment can be used for different purposes such as tillage, planting and weeding.

Up to the 1990s, there was strong interest in animal traction in West Africa, as evidenced by the many papers written and the number of workshops organized. However, as animal traction was often connected to cultivation of cash crops like cotton and groundnut, it became difficult to develop animal traction further as a consequence of the low economic return of these crops in the 1990s. The decline in the support to these value chains was also enhanced as a consequence of structural adjustment programs implemented during the 1990s. The international research centers discontinued, to a large extent, research on animal traction; likewise national research centers on mechanization experienced limited support. The research was not able to make any significant impact on agriculture. Furthermore, it seems as if biological/economical research has more prestige and there is a higher number of papers on biological/economical issues in tropical agriculture than on mechanization. To our knowledge, there is no journal on animal traction with a high impact factor, but some journals may still accept papers on animal traction.

The time may now be ripe for having a second look at agricultural mechanization in Africa. Climate change contributes to this end. Climate variability is expected to increase as result of climate change and thus farm operations need to be carried out faster. The food prices are on the increase, young people leave the countryside to go to the cities in search for jobs. Furthermore, the technical competence in rural has increased and motorcycles and cars have become more common even in rural areas. Development of low cost biological technologies may facilitate the use of animal traction. However, mechanization may make agriculture more attractive for young people as agricultural work is currently associated with drudgery.
Drivers for mechanization/intensification

There are several reasons for the increasing interest in mechanization. As in other continent, young Africans people are not so interested in agriculture (Leavey and Hussain 2014). They have seen and used modern technologies like mobile phones, PC and modern transport facilities such as motorbikes and cars.

Agriculture is still mainly practiced using manual labour. However, mechanization can make agriculture more appealing to young farmers. When farmers see that many of the farm operations like sowing and weeding can be done using animal traction or motorized traction, interest increases. The effect of mechanization is reduced workload at the time of peak labour demand. At the time of sowing and weeding there is no surplus in labour in African agriculture. Mechanization can therefore level out labour demands throughout the season. Another important objective of mechanization is to reduce the workload and the drudgery of agricultural work. To sow pearl millet and sorghum with optimum plant population, 25 000 planting holes (pockets) need to be dugged with optimum depth per hectare (central and southern Mali). The sowing process has four operations including digging a little hole with a thin bladed hoe, placing the seeds in the hole, applying fertilizer in the planting hole and covering the seeds in the hole. In total, there are therefore 100000 operations (25000*4) to sow one ha. The average farms size in Mali is about 4 hectares and 400000 operations are required to sow all the land on the farm. In order to place the seed and fertilizer correctly in the planting pocket, the farmers have to bend down to the soil. Groundnut is an even more labour demanding crop to sow than the cereals as the population density is above 66000 plants/ha (Ousman and Aune 2011). These manual operations can be avoided if mechanized sowing is practiced. Further advantages of mechanized operations include precise sowing depth, accurate distance between plants and appropriate number of seeds per pocket.

Effects of new technology on yields and labour demand

A whole range of technologies has been introduced to increase agricultural production in Mali. The technology developments presented in this report have been going on since the turn of the century. In the first years, the emphasis was on seed treatment with fungicide/insecticide, seed priming and microdosing. This type of agricultural intensification can be compared to climbing a ladder (Aune and Bationo 2008). For the last 10 years, the research has also included mechanization in combination with these technologies. The idea to develop a package of technologies that can mutually strengthen each other and fit together. The most low cost
technology introduced is seed priming. The method consists of soaking the seed in water prior to sowing. Optimal soaking times for the crops have previously been developed (Harris 2006). For pearl millet and sorghum, the optimal soaking time is 8 hours while for cowpea and groundnut the optimal soaking time is 4 hours. Field experiments have shown that yield benefit of seed priming averages a yield increase of 30%. Seed priming should start as soon as there is sufficient rain to sow. Seeds need to be sun dried for one hour prior to sowing to reduce the stickiness of the seeds. This is particularly important if mechanized sowing is practiced. The effect of seed priming varies from year to year, but is particularly important when the conditions for crop establishment are difficult. It can also be very useful if planting is delayed and there is a need to kick-start the crop. Seed priming reduces the germination time by 1 to 2 days and ensures a more uniform plant stand.

Treatment of seeds should be combined with an insecticide/fungicide such as Apron Plus. This treatment can ensure crop establishment and has been found to increase yields in the order of 15% in experiments in Mali (Aune et al. 2012).

Microdosing of mineral Fertilizer is another technology that can increase yield. There are different forms of microdosing. ICRISAT has been recommending microdosing rates of 2 g Fertilizer per pocket if di-ammonium phosphate (DAP) is used, while 6 g Fertilizer is recommended if NPK (15-15-15) is used (ICRISAT 2009). In the drier parts of Sahel, the farmers use 10000 pocket per hectare or less, while in more humid parts of the Sahel (average above 600 mm) farmers use about 25000 pocket per hectare. This result in 50 and 150 kg Fertilizer per hectare if respectively 2 g DAP or 6 g NPK are applied per pocket. A research collaboration in Mali between Institute Economie Rural, ElObeid Research Station and the Norwegian University of Life Science showed that good results can be achieved with rates as low as 0.3 g Fertilizer per pocket (Aune and Ousman 2011). When so low rates of Fertilizer are applied, it is also possible to mix the seeds and Fertilizer, and sow this mixture directly. In Sudan, it was shown that 0.25 g Fertilizer was sufficient in pearl millet, while in sorghum the optimal rates was 0.8 g Fertilizer per pocket. In southern Mali, with rainfall in the range of 800 to 900 mm, it has been found that top-dressing of 1 g per pocket provides an additional yield benefit.

The technologies’ mechanization, seed priming, seed treatment and microdosing should be combined in order to achieve a satisfactory yield. Yields more than doubled when seed priming and microdosing were combined (Aune and Ousman 2011). Other effects of these technologies
are a more secure crop establishment, shorter time to maturity and less attacks of the parasitic weed striga. It appears that plants having received microdosing outgrow the striga and thereby reduce its effect (Aune et al. 2012). The effect of microdosing will be reduced if the plant stand is low as a result of insect attack or diseases. It is therefore safer to use microdosing if the seeds are primed and treated with a combined insecticide and fungicide. The benefit of mechanization will also be much reduced if the crop stand and the yields are low.

Both animal drawn and motorized mechanization (Figure 2) have been developed. The basic unit in the planter is a disk that turns around in the hopper were the seeds are placed (Coulibaly et al. 2010). This disk is turned by the wheels (energy transmitted by chain) of the planter and the planter is pulled by an ox or a donkey (Figure 2). The disk has holes connected to tubes through which the seeds are delivered. Special disks have been developed to allow for sowing of different crops by changing the width of the hole and/or thickness of the disk. The distance between the pocket/plants can be regulated by number of holes in the disk. Different disks are therefore available for sowing millet, sorghum, cotton, groundnut and maize.

Fig. 2. Motorized planter developed by IER.
If mechanized sowing is compared to manual sowing the increase in yield is in the order of 15 to 20%. This increase in yield is related to more precise sowing depth, appropriate number of seeds per pocket and uniform planting distance.

In Mali. The use of mechanized sowing is practiced in relation to cotton production, but is less common in the cultivation of pearl millet and sorghum. The development of microdosing has also made it necessary to develop discs suitable for simultaneous sowing of seeds and fertilizer.

**Experiences on the use of mechanization in Mali**

Mechanized sowing in Mali was previously mainly associated with the cultivation of cotton and maize. However, it is possible to sow all the major sahelian crops like pearl millet, sorghum, groundnut and cowpea using the planter. The major advantages of mechanized sowing include uniform and appropriate sowing depth, uniform number of seeds applied to each pocket and uniform distances between the rows. Manual sowing is practiced by taking a pinch between the thumb and the index fingers. A pinch of seed of pearl millet and sorghum was on average found to contain 35 and 11 seeds, respectively. However, the number of seeds delivered in a pinch will vary from person to person whilst the use of a planter will provide a uniform sowing rate. Standard deviation for number of seeds delivered was higher in manual sowing as compared to sowing using the planter. One further advantage of mechanized sowing as compared to manual sowing is that it is difficult for rats and birds to localize where the seeds are placed when mechanized planting is practiced. The reason that these predators can observe the placement of the pocket in manual sowing while this is impossible when the seeds are placed along a uniform row.

One of the major advantages of mechanized sowing is, however, a reduction in labour demand in sowing and weeding. The labour demand is dependent on the planting density. There is more labour saving on mechanized sowing in southern Mali where the planting density is 25000 pockets per hectare as compared to in northern Mali where the planting density is 10000 pockets per hectare. Labour studies in Mali have shown that the labour demands for manual sowing, animal traction based sowing and motorized planting are 96, 8 and 3.5 hours per ha respectively. It has been calculated that it takes 480 hours to sow manually an average farm in Mali with sorghum or millet. Most farmers do not have sufficient labour and sowing is, for this reason, often delayed. There are not many days per season optimal for sowing and the high labour demand in sowing result is delayed sowing and lower yields.
In order to ensure optimal sowing time for most crops, the farmer should have the capacity to sow all their land in 3 to 4 days. In southern Mali, it has been found that sorghum and maize are more vulnerable to delayed sowing than pearl millet (Traoré et al. 2014). If sowing is undertaken using animal traction based planting, the land can be sown in 5 days, whereas if motorized planting is practiced the land can be sown in 2 days (based on 5 ha farm and 25000 pocket/ha). In the case of motorized planting, the farmer who owns the machine will also have the capacity to use the machine to sow for one of his/her neighbours. High capacity of sowing is particularly important when the rainfall of the beginning of the season is erratic as is often the case in the drylands of West Africa.

The planter can also be used for weeding purposes by mounting tines to the planter. The labour demand for manual weeding, animal drawn weeding and motorized weeding is 129, 60 and 44 hours /ha respectively. The relative high labour demand even when motorized weeding is used is related to the demand for weeding within the row and in the vicinity of the pocket. The total labour demand for sowing and weeding is therefore 216, 68 and 48 hours per hectare for manual operations, animal drawn operations and motorized mechanization.

To increase the profitability of mechanization, it should be combined with improved agricultural technologies Seed priming and microdosing are two technologies that are compatible with mechanization. Field experiments in sorghum from 2013 to 2015 showed that the sorghum yield increased from 705 kg/ha with manual sowing without microdosing and priming, to 1061 kg/ha with mechanized sowing combined with seed priming and microdosing; corresponding to a grain yield increase of 51%. At the same time, there was a corresponding increase in sorghum stover yield.

However, mechanization comes at a cost and may not be feasible for all farmers, at least not without support. The price for a planter drawn by animals is about 110 Euro, while the motorized planter is sold at a price of 800 Euro. The categories of costs in manual and mechanized sowing and weeding are different. In manual operations, the labour is the major cost component whilst in motorized operations the major cost will be related to depreciation and repair of the machines. Cost in using animal drawn mechanization also include cost for feeding, training and keeping traction animals, while in motorized mechanization there will also be cost related to purchase of petrol. However, the consumption of petrol for sowing one hectare is quite low as the consumption is only 3.5 liter/ha for sowing and weeding. The fertilizer cost is also very low when 0.2 g fertilizer is used per pocket. The fuel and fertilizer costs are low as
compared to the depreciation cost of the planter and the repair costs. It therefore makes sense to use microdosing, treated seeds and seed priming when mechanization is used. Microdosing and seed priming will greatly improve the profitability of farming.

Appropriate mechanization will vary according to the farm size. Economic and labour analyses show that motorized sowing is an interesting option for farmers if the farm size is above 5 hectare. Below a farm size of 5 ha, the most appropriate mechanization is animal drawn mechanization. Even if the farm size is as low as one hectare, it makes economically sense to use animal drawn mechanization in combination with seed priming and microdosing instead of manual sowing without seed priming and microdosing. This is an effect of high yield and labour saving in connection with mechanization.

**Upscaling intensification**

There are several factors that have to be in place for successful agricultural intensification, including mechanization. One important condition for intensification is easy access to fertilizer. The access to fertilizer has improved in recent years in Mali, and the government is providing subsidized fertilizer on credit. Currently, there are also more outlets for fertilizer in the villages. These outlets would not exist if there was no demand for fertilizer. This is probably an effect of the various projects on microdosing of mineral fertilizer. This includes projects by AGRA, Sasakawa Global 2000, CARE and Dryland Coordination group.

The planters are produced by local blacksmiths on demand. These blacksmiths have been trained by the Companie Malienne pour le Développement du Textile (CMDT). There is one blacksmith in Koutiala in southern Mali that has specialized on producing motorized planter. This planter was firstly developed by l’Institut d’Economie Rurale. The engine for the planter is from a motorcycle engine (Chinese model). This is a very common motorcycle engine in Mali and spare parts are easily available. IER trained the blacksmith on the production of this motorized planter. We are now aware that the blacksmith has a demand for about 1000 motorized planters, so the capacity for producing the motorized planter has to be increased.

The motorized planters have so far mostly been distributed through projects that have financed the purchase of the planters. It is therefore difficult to know the real demand for such planters. The planter can be used for sowing and weeding, hence the tasks it can do is limited. One major advantage is, however, that it is reassembled in Mali and the farmers and the blacksmiths know how to maintain and repair the machine. It is also possible to buy power tillers that can be used
for additional farm operation like soil tillage. These power tillers have also a power outlet that can be used for pumping water or running a mill. However, the disadvantages are higher costs and a heavier machine. The motorized planter will therefore be easy entry point for mechanization for the majority of the farmers because of the lower cost and the ease of handling.

As a comparison, mechanization in Asia is much ahead of mechanization in Africa. In a country like Bangladesh, the machines are typically not own by the farmers themselves, but by service providers (Baudron et al. 2015). Farmers pay the service providers for undertaking different farm operation on their farm. It is also possible that service providers can transport the planter using a modified motorcycle (Figure 3). However, this require that the farmers are able to produce an economic surplus. Many farmers in Mali and Sudan are not able to produce such a surplus and will therefore have problems paying for mechanization. For this reasons, mechanization should not be introduced as a stand-alone technology, but rather introduced in combination with yield enhancing technologies such as seed priming, microdosing and treatment of seeds with fungicide/insecticides.

Fig. 3. Mechanization kit for small-scale farm service providers (a); (b & c) sorghum field planted by the motorized seeder, (IER).

The sustainability of seed priming, microdosing and mechanization technologies has recently been assessed in Mali. It was found that the grain yield increase is of the order of 50 to 100% as a results of seed priming and microdosing (Djiga 2016). This allows the farmers to generate an economic surplus and improve food security. Many of the families were food insecure before starting to use the new technologies. The economic surplus generated through these technologies allowed the farmers to purchase more livestock, ploughs, donkeys and charrettes. Furthermore, this will strengthen agricultural production as farmers will have access to more manure, traction power and transport facilities. The seasonal outmigration of young girls was also reduced due to the fact that the food security situation in the households was improved.
Farmers also provided grain to the cantines of the local schools. Many of these positive impacts were beyond project expectations.

The uptake is a result of successful demonstrations at the farms, extension work of the NGOs and the national extensions systems, and radio and TV program highlighting these technologies. The NGOs involved in the upscale of the technologies include CARE international, Sasakawa Global 2000, ADRA, YAGTU; AMAPROS, ADAF/GALLE, AFAD and CARE. These organizations have received funding from USAID, Australian Government, IFAD, EU, SIDA (Sweden), JIRCAS (Japan) and the Ministry of Foreign Affairs in Norway. The technologies seed priming, microdosing, and mechanization are also recommended by the Comité National de la Recherche Agricole in Mali. This gives the technologies additional credibility, facilitating their diffusion. In Sudan, these technologies have received a recommendation from the National Crop Research Committee.

The proposed technologies will not only increase grain yield in the order of 50 to 100%, but also increase straw yield in the same order of magnitude. This can be used to strengthen crop livestock integration, as it will result in more manure and stronger traction animals. Additionally, the increased biomass production will increase the recycling of organic matter. Experience shows that when organic matter production is increased, more recycling of straw is possible.

Many factors affects the speed of intensification of agriculture in Mali and Sudan. One important issue is the availability and the price of fertilizer. Availability is probably a more important issue because the use of microdosing will be profitable even if fertilizer prices double or triple. Fertilizer subsidies, in combination with packages of fertilizer, have been introduced in Mali. Fertilizer is therefore more easily available as compared to as the situation was 5 to 10 years ago. Table 1 summarizes the major advantages and disadvantages of manual sowing, use of animal traction and motorized traction. As seen in the table, the advantages of mechanization are many, while the major benefits of manual sowing is the low cost. In order to adopt agriculture to climate change in the drylands of Africa, agriculture should move towards mechanized agriculture as this will ensure more timely and precise sowing. Furthermore, the labour demands for weeding are considerably reduced. Grain legumes have a particularly high labour demand and mechanization of cultivation of these crops will make them more attractive to grow.
Table 1. Advantages and disadvantages of manual sowing, use of animal drawn planter and motorized planter

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<th>Manual</th>
<th>Animal traction</th>
<th>Motorized traction</th>
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<td><strong>Advantages</strong></td>
<td>Easy to understand</td>
<td>Uniform density pockets</td>
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<td>Low cost</td>
<td>Uniform sowing depth</td>
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<td>Uniform number of seeds per pocket</td>
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<td>Precise fertilizer application</td>
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<td>Fast sowing and weeding</td>
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<td>Correct sowing and weeding time</td>
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<td><strong>Disadvantages</strong></td>
<td>High labour demand</td>
<td>Week animals beginning of the season</td>
<td>Maintenance of planter and its motor</td>
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<td>Delayed sowing</td>
<td>Animal sickness of diseases</td>
<td>Purchase of fuel</td>
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<td>Animal lost beginning of the season</td>
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<td>High labour demand</td>
<td>Feeding and watering the traction animals during the year</td>
<td>High cost of planter</td>
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<td></td>
<td>Fertilizer application</td>
<td>Training of animals required</td>
<td>Require capital</td>
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<td>Technical problems planter</td>
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<td>Attack of birds and rats</td>
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<td>Non-uniform sowing density and depth</td>
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<td>Too many seeds per pocket</td>
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Integrated pest management (IPM): an essential component of sustainable intensification of agriculture

Here the term pest includes insects, mites, nematodes, weeds, bacteria, fungi, oomycete, viruses, phytoplasm, vertebrates, as well as other organisms that interfere with food, feed and fiber productions. Pests are one of the greatest threats to food supply as they compete with crops for essential nutrients and reduce both the quantity and quality of the crop product. The global yield losses due to pests were calculated for the most important food and cash crops by Oerke et al. (1994), and they range from 29-51% (Fig. 4). To benefit from all other yield enhancing technologies, these high crop losses due to pests have to be counteracted by any methods. Pesticides are fast and effective pest control options, however, the adverse effects of pesticides, such as environmental pollution, killing of beneficial organisms, promotion of genetic resistance and outbreaks of secondary pests, and toxicity to workers, traders and consumers have sparked a renewed interest in the use of alternative pest control methods such as integrated pest management (IPM). In this context, it is worth mentioning EU’s Directive on sustainable use of pesticides (2009/128/EC) that sets rules for the sustainable use of pesticides to reduce their negative impacts on people, beneficial organisms and the environment.

Fig. 4. Total yield losses caused by pests (disease, insects and weeds) in different crops. Data Source Oerke et al. 1994
Components of IPM

IPM is a multifaceted and sustainable approach to manage pests without harming the environment. It is a holistic, interdisciplinary approach that considers the ecological and socio-economic conditions of the growers and strives to maintain the agro-ecosystem on a sustainable level by giving preference on the use of non-chemical methods while maintaining the pest below the economic damage level. The major components of IPM are:

Cultural practices:-pest management practices that reduce the survival or dissemination of the pest such as crop rotation, sanitation, cultivar mixture, mixed cropping, use of trap plant, time of planting, and tillage practices.

Biological control: use or introduction of natural enemies such as predators, parasitoids, and other insects and pathogens that suppress or kill the target pest.

Genetic control: use of plant varieties that have resistance to the target pest.

Biopesticides and alternative natural products such as oils, plant extracts, use of pheromones to lure pests, provide habitat for the natural enemies, and use hormones to disrupt the life cycle. Chemicals control is the use of selected least toxic pesticides as a last resort only when necessary. The key idea of IPM is to use multiple pest control tactics that can mutually strengthen each other and fit to the overall crop management practice. IPM is part of the overall crop production system rather than a separate well-defined activity.

IPM program in Sudan

In Sudan, the Food and Agricultural Organization (FAO) has implemented, since 1979, an effective integrated pest management recommendation for cotton when the problem of insects become out of control with the conventional pesticides. The first IPM phase was from 1979-1983, where resistance cultivars to white fly (Bemisia tabaci) and identification of natural enemies were implemented. In the second phase, 1985-1989, demonstration trials and introduction of the natural enemies of different pests were implemented. During the demonstration phase of the biocontrol, farmers were guaranteed compensation for any yield loss as 320 hectares of the cotton crop were left unsprayed to investigate the potential of the natural enemies in the absence of pesticides (Peshin and Dhawan 2009). The IPM program, which consists of cultural practice (timely sowing and removing egg masses of insects), biological, chemical and regulatory measures, resulted in more than 50% reduction in insecticide use (Peshin and Dhawan 2009). The Farmers Field School (FFS) IPM program was
implemented in Sudan from 1993-1996 under the FAO Vegetable IPM project. The impact
evaluation showed that farmers trained on IPM on average applied 3.3 applications of pesticide
whereas the non-IPM trained farmers applied on average 12.5. This reduced the pesticide use
by about 75%. Comparing the pesticide spray frequency from 1995 to 2001, the pesticide use
decreased from 4.3 to 3.3 applications (reduced by 23%) by IPM trained farmers, this in contrast
to the fact that the spray frequency increased from 9.6 to 12.5 applications (increase by 31%)
in case of non-IPM farmers (Khalid 2002).

**IPM Program in Mali**

The IPM practice decreased production costs and reduced the negative impact of pesticide on
human health and the environment. In Mali, 24 000 ha of cotton crops are managed by IPM
practices and growers save more than 60% on pesticides by conducting just one or two spray
treatments instead of four to six as recommended in conventional pest control strategy
(http://www.cirad.fr/en/research-operations/research-results/2007/cotton-pests-in-mali-
making-pesticide-management-more-sustainable). A recent study by FAO reported that Cotton
farmers in Mali use biopesticides like neem tree extract and have eliminated 92% of their
These cotton farmers saved then about €400,000 by not applying 47,000 litres of pesticides
(http://www.irishexaminer.com/farming/news/un-applauds-natural-pest-controls-used-by-
farmers-in-mali-260597.html). "Pragmatic, field-based and farmer-centric education can and
must play a key role in making agriculture stronger and more sustainable," said FAO Director-
General José Graziano da Silva. "At the end of the day, sustainable intensification will be the
result of the collective action of millions of small farmers, who through their daily decisions
determine the trajectory of agricultural ecosystems across the world". More than 20,000 cotton
farmers have been through field schools in Mali. An ecologically based IPM program on
selected horticultural crops has resulted in substantial reductions in pesticide use. A tomato IPM
package, which includes disease free planting material and sanitation, allowed the recovery of
tomato production in areas where whitefly-transmitted gemini viruses had eliminated crop
production (http://www.oired.vt.edu/ipmil/wp-content/uploads/2013/04/Mali-fact-sheet-
FINAL.pdf).
Drivers for IPM/Intensification

There are several reasons for the implementation of IPM in crop pest control. Several case studies concluded that IPM provides green and ecofriendly alternative for environmental and agricultural pest management. The main drivers are:

- Reduced exposure to pesticides
- Reduced crop loss
- Minimize environmental pollution
- Reduced chemical contamination of agricultural products
- Maintain ecological balance with minimum effect on environment
- Reduced production cost (pesticide cost)
- Maximum labour and land productivity
- Climate change
- Increased farmers’ income
- High demand for safe and quality agricultural produce/food
- Increased population

“An intensification of crop production without an adequate protection from pests damage is economically not justified and ecologically harmful because the amount of production necessary has to be produced on a larger area which otherwise could be handed over to nature” (Oerke and Dehne 2004).

Conclusion

In Africa, socially acceptable, technically and economically feasible agricultural technologies are required to feed the ever-increasing population. Mechanization of agriculture has improved labor efficiency; improved production input efficiency; improved timeliness of operations and enabled sustainable production systems to be implemented. This case study shows the yield and labour saving benefits of introducing mechanization in combination with seed priming, seed treatment and microdosing of mineral fertilizer. These technologies will, in addition, secure optimal sowing, improved crop establishment and earlier harvest. Motorized mechanization appears to be a feasible option for farmers that are cultivating more than 5 hectares. Access to credit will be required for rapid upscaling of motorized mechanization. These results suggest that the impact of animal traction, motorized sowing and integrated pest management practices on intensification of agricultural production varies by region, crop type, and depends on a broad set of agro-ecological and economic conditions. Furthermore, capacity
building and awareness creation and farmers training are crucial for the adoption and sustainable use of agricultural technologies. Any technology that does not adequately take the local situation and farmers’ knowledge into account, and does not build-in sustainability, will result in the failure of the intensification pathway.

References


