AKTC
Zambian - German
Agricultural Knowledge & Training Centre

With support from

Federal Ministry of Food and Agriculture

by decision of the German Bundestag

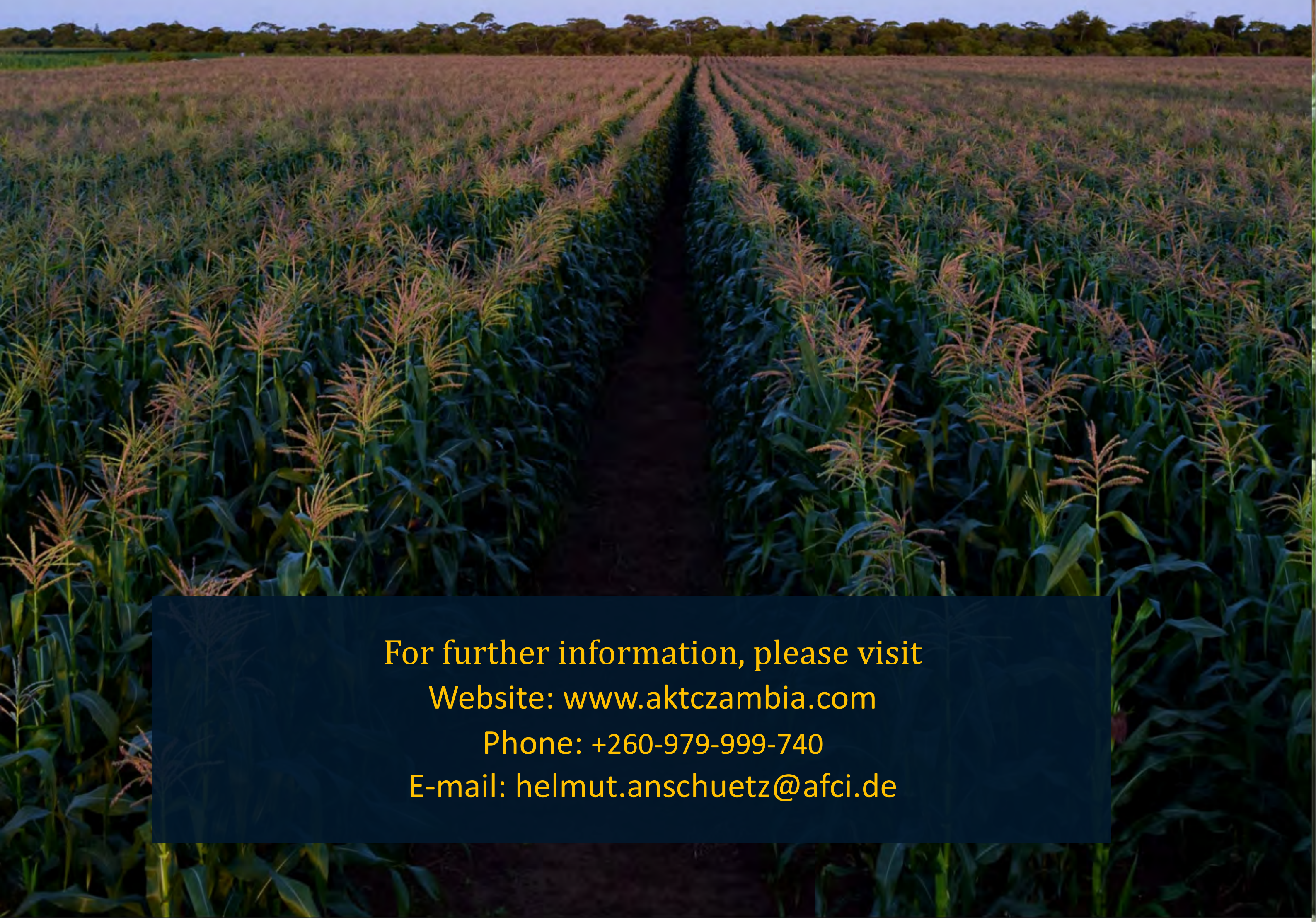
CLIMATE ADAPTED FARMING METHODS

Empowering Farmers to Adapt to Climate Change through Mechanized Conservation Agriculture

Agricultural Knowledge and Training Centre (AKTC)

Implementing the

Climate Adapted Farming Methods (CAFM) Project in Zambia



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LIST OF ABBREVIATIONS

1. **AKTC** Agricultural Knowledge and Training Centre
2. **BMEL** The German Federal Ministry of Food and Agriculture
3. **CA** Conservation Agriculture
4. **CAFM** Climate-Adapted Farming Methods
5. **GART** Golden Valley Agricultural Research Trust
6. **MoA** Ministry of Agriculture
7. **MCA** Mechanized Conservation Agriculture
8. **MCF** Mechanical Conventional Farming

1. INTRODUCTION

The effects of climate change have been experienced not only in Zambia but in neighbouring countries as well. Droughts have devastating consequences for both human beings and animals. Therefore, this calls for drought-prone sub-Sahara African (SSA) countries like Zambia to find a lasting solution to mitigate the negative climate change effects on farming. This has compelled the Agricultural Knowledge and Training Centre (AKTC) to go a gear up by implementing the Climate-Adapted Farming Methods (CAFM) project. The CAFM project seeks to address the effects of drought being experienced in Zambia through look-and-learn sessions. With the CAFM project, both the traditional mechanical conventional farming (MCF) and the mechanical conservation agriculture (MCA) are being practiced for the farmers to have a result-based comparison in order to make an informed decision on why AKTC thinks that farmers should adopt MCA practice.

The 2019/20 season was the first year when the CAFM project was launched at AKTC on 27ha of land, provided by our partner GART. Crops grown under different tillage methods on the project were maize – staple food, soya bean – a cash crop, and a cover crop for the much-needed residue for soil improvement. Farmers from all sectors, from emergent to commercial, were invited continuously to witness different field demonstrations. The demonstrations included land preparation, planting and weed control management. From the demonstrations, farmers were exposed to climate-adapted farming methods that can overcome the effects of drought by conserving the little rain received. Holding a field day at a time when all crops were fully grown gave the farmers an excellent opportunity to appreciate the products of the CAFM project. AKTC trusts that what the farmers saw from demonstrations up to the field day will spur their interest in MCA production.

"The CAFM project seeks to address the effects of drought being experienced in Zambia through look-and-learn sessions"

Why Climate Adapted Farming Methods (CAFM)

The CAFM project has come in as a mitigatory measure to one of the climate change calamities, in this instance -drought. CAFM aims to reduce the impact of climate-related revenue losses and ensure income for market-oriented farmers. This is achieved through the adaptation of climate-smart farming methods such as conservation agriculture (CA). Thus, the CAFM project aims to inform and teach farmers on the benefits of conservation farming techniques as opposed to the traditional conventional farming practices. The following benefits according to practicing CA come up:

a) Immediate benefits include: Increased soil water infiltration, reduced water run-off and soil erosion, reduced evaporation of moisture from the soil surface, less frequent and intense moisture stress on crops, reduced traction and labour requirements for land preparation, savings in fuel and labour costs among others.

b) Medium to longer-term benefits include: Increased soil organic matter, saves on inputs (nutrients, labour), better crop establishment, reduced crop production costs, increased biological activity, increased and more stable crop yields.

Proposed CAFM experimental farm outlook as in May 2019

Climate Change

Climate change refers to significant changes in global temperature, precipitation, wind patterns and other measures of climate that occur over several decades or longer. Evidence suggests that many of these extreme climate changes are connected to rising levels of carbon dioxide and other greenhouse gases in the earth's atmosphere. More often than not, the result of climate change are causes of human activities. The effects of climate change are being felt and experienced by nearly all countries in sub-Sahara Africa (SSA), mostly floods and persistent or reoccurring droughts. Lately, cyclones *(elnino, idai)* have been experienced in SSA, a phenomenon that had not been witnessed for centuries. In Southern Africa, there have been alternating seasons of floods and droughts, and these calamities have caused unwarranted food and fibre shortages to humans and animals, respectively. To brace up for these challenges, farming systems must be transformed to suit the prevailing climatic changes. Therefore, farmers must adopt some climate adopted farming techniques, which are of a potential benefit to the farmers and their nations at large.

Climate change adaptation refers to the adjustments societies or ecosystems make to limit the adverse effects of climate change or to take opportunities provided by a changing climate. Adaptation ranges from farmers planting more drought-resistant crops, taking up new farming methods, just to mention a few. As a result, farmers are now being encouraged to adopt the novel farming technologies capable of mitigating the climatic adversities. The technologies that conform to climate change to increase production and productivity is the way to go, and this is what the CAFM project is advocating for. For such an intervention, the CAFM project - to succeed the government interventions - farming stakeholders, and the farmers at large have to come and work together to achieve the intended objectives and ensure food security for the nation.

Climate Change in Zambia

Climate projections specific to Zambia for the period 2000-2050 indicate that the country will experience shifting rainfall patterns and rising temperatures. Different climate models produce varying results for rainfall. While climate models do not agree over the magnitude of changes in rainfall patterns over the coming decades, there is considerable consensus that the country will be hotter than it is nowadays. On a brighter side, climate projections results for the region show that Zambia will be the least affected country in the region. This provides an opportunity for Zambia to tap into export markets to supply various crops to deficit countries. However, this can only be realized if agricultural policies are right and predictable; policies that mitigate climate change effects such as conservation agriculture techniques.

Analysis of crop sensitivity to climate shocks shows that maize will be among the most negatively-affected crops with significant yield reductions due to anticipated future climate patterns. This has implications for policy and requires the country to implement policies and programs that support smallholder farmers to diversify in order to adapt to climate change. In terms of adaptation, smallholder farmers are likely to move away from the current cropping pattern of utilizing more land with low productivity output, to growing more hybrids and other drought-tolerant crop varieties with high yielding potential. However, these strategies will only partially mitigate the effects of climate variability and change. Therefore, this requires large-scale adaptation measures such as heat-tolerant seed varieties, agricultural investments in research and extension, and policies to reduce risks for smallholder farmers and enhance their adaptive capacities (e.g., weather index-based insurance, access to credit) (Omulo & Kumeh, 2020)[1].

[1]*Omulo, G. and Kumeh, E. M. (2020) 'Farmer-to-farmer digital network as a strategy to strengthen agricultural performance in Kenya: A research note on "Wefarm" platform', Technological Forecasting & Social Change, 158, pp. 120–120.*

BMEL Bilateral Cooperation Project

Through the bilateral cooperation project, the German Federal Ministry of Food and Agriculture (BMEL), in cooperation with the Zambian Ministry of Agriculture (MoA), has been supporting the development of the Zambian-German Agricultural Knowledge and Training Centre (AKTC) since 2014. Many Zambian farmers are currently unable to exploit their development potential due to inadequate technology and lack of technical and business knowledge. The AKTC addresses these potentials and challenges. It provides knowledge on the use of modern agricultural technology, inputs and good farm management practices for a sustainable increase in cereal (wheat), soya bean and potato production as well as protecting natural resources at the same time.

Thus, the activities of the AKTC are well linked to the objectives of the Zambian new national agricultural policy, increased agricultural production and productivity, strengthened capacities of agricultural training institutions and promotion of sustainable use of land and their natural resources.

In the second project phase, the project aims to create a broader impact (e.g. through national educational institutions and the national advisory service) through the intensive involvement of lectures, state agricultural advisors and other multipliers in the training activities. The centre offers a mix of theoretical, practical training and demonstrations on sustainable production methods and the professional use of agricultural machinery for agricultural specialist and agricultural service providers. Through these activities, the project aims to increase the technical and managerial skills of the target groups and contribute to the sustainable development and modernization of the Zambian agriculture. This foresaw the birth of the CAFM project in the 2019/20 season.

The Zambian Ministry of Agriculture emphasizes the importance of a competitive agricultural sector and increased yields through mechanization. Therefore, it has expressed interest to collaborate with the AKTC in the training of its agricultural advisors in agricultural technology. The government gives importance to knowledge transfer regarding soil conservation methods (conservation agriculture) through the AKTC. The activities of the project will be strictly linked to the plans and activities of Zambian agricultural development strategies in order to ensure a high degree of acceptance and support of the Zambian partners.

Cooperation with University of Hohenheim (UoH)

The overall objective of the collaboration between the AKTC and the German University of Hohenheim is to carry out an experiment on mechanized conservation agriculture (MCA) and further show through training and field demonstrations how this helps to reduce climate-related yield losses while ensuring good investment return among market-oriented farmers in Zambia. This is in line with the AKTC's project aim and goal to train market-oriented farmers and other target groups on climate-adapted farming systems as a measure against severe climate change effects. The proponents of the on-farm experiment are expected to find relevance among small-scale, market-oriented and large-scale farmers across Zambia and other Sub-Sahara African countries. The project's first year results, 2019/20 season, will be discussed in the following sections.

"The collaboration between the AKTC and the University of Hohenheim in Germany is to carry out an experiment on Mechanized Conservation Agriculture, MCA"

Under the afore-mentioned collaboration, the research team from the University of Hohenheim contributes expertise in agricultural engineering (Prof. Dr. Karlheinz Köller and Mr. Godfrey Omulo), agricultural economics and institutional development (Prof. Dr Regina Birner and Dr. Thomas Daum). Under the supervision of Prof. Dr. Karlheinz Köller and Prof. Dr. Regina Birner, the PhD Candidate, Mr. Godfrey Omulo, is the lead researcher of the CAFM project. Prof. Dr Köller and Prof. Dr. Birner visited the AKTC project and also had the opportunity to participate in the CAFM project field day on 25th February 2020, where they conducted a closed session on MCA with some stakeholders during the field day.

Prof. Dr. Karlheinz Köller *delivering a lecture in a closed session during the field day on 25th February 2020*

Prof. Dr. Regina Birner *delivering a lecture in a closed session during the field day on 25th February 2020*

***Mr.Godfrey Omulo** giving a presentation to the guest of honor and delegates during the CAFM project field day on 25th February 2020.*

2. Climate Adapted Farming Method-Project

Project Goal

The project's goal is to make sure that market-oriented farmers are capable of practicing climate-adapted conservation tillage methods in irrigation and in dryland farming on their own land.

The planned results constitute:

- Climate adapted cultivation methods of conservation and conventional tillage have been developed and demonstrated.
- Interested farmers have expanded their knowledge of the use of climate-adapted conventional and conservation tillage techniques through demonstrations and training.
- The test results have been made available to a broad group of local farmers and policymakers.

Target Groups

The target group of the project are medium-sized market-oriented agricultural farmers, who already have a low degree of mechanization or intend to acquire simple equipment for agriculture. These market-oriented farmers are to be enabled by training measures and field demonstrations to apply climate-adapted conservation tillage methods on their own land.

Another target group is the professional and management personnel as well as scientific staff from educational institutions, which would like to develop their knowledge of climate-adapted conservation tillage methods, in order to pass it on to students and participants of training courses. This group plays an important role of multipliers.

In addition, political decision-makers are also a target group of the project. These have been invited to field demonstrations to learn about the benefits of climate-adapted conservation farming methods. This is to address a large, nationwide group of interested farmers. Through the buy-in of this influential group, policies to adopt conservation tillage methods can be drafted for adoption by farmers.

Conservation Agriculture (CA)

CA can be defined as an agronomic practice for growing crops without disturbing the soil through tillage. The objectives of CA includes conservation of soil, improvement of soil structure, organic matter, nutrients, water storing capacity, etc. but also savings in money, labour, time and inputs (e.g. fuel).

A. Manual System – for farmers without access to draught power

This is highly laborious as all operations are done manually. Although the benefits of CA can be achieved, the farmer is limited to cultivating a small area of land.

Planting basins

- Dig manually with a hoe during the winter period,
- Basins should be 15cm x 15cm and 15cm deep,
- In-row and inter-row spacing depends on the farm's agro-ecological region or natural region,
- Should be made in the same place each year,
- Enable farmers to plant the crop after the first effective rains when basins have captured rainwater and drained naturally,
- Enhance the capture of water from the first rains and enable the precise application of both organic and inorganic fertilizer as it is applied directly into the basin and not broadcasted.

B. Animal Draught Power (ADP)

Animal draught power is used for the farm operations ,mainly tilling the land.

i. Seeding behind ripper lines

- If the animals are not in good shape, this will affect the area of land to be cultivated,
- Ripping open furrows for moisture capture and break superficial compacted layers of soil,
- Rip lines are opened at a row spacing of 75 or 90 cm, for maize, and should be aligned along the contour.

ii. Animal drawn direct seeders

- Are designed to seed into mulched cultivated soil,
- Have separate seed and fertilizer bins and a cutting disc (coulter). The coulter cuts through the residue, a ripper tine opens a furrow, then fertilizer and seed are placed in the furrow – all in a single operation,
- Are manufactured for both oxen and donkeys,
- Provide fast and efficient operation – but not viable for commercial bigger land areas.

C. Mechanical – tractor-drawn system

This is when fuel-powered machines are used for tillage, and this is what the CAFM project is advocating for, and advising to farmers to use.

- Initial deep ploughing is often necessary to remove compacted zones,
- Ripper tines are used for this purpose as well as for opening furrows for planting into residues,
- Direct seeding planter can be used with a coulter in front to cut residue, ripper tine to open up the furrow and separate seed and fertilizer hoppers for placement of seed and fertilizer – all operations done at once.
- Direct seeders start from a single row planter to big planters depending on the farmers resource availability and the size of the arable land to be worked on.

Principles of CA

CA is a crop management system based on the following three principles:

A. Minimum soil disturbance

concentrates on the planting station only and leaves about 90% of the soil undisturbed.

Advantages of minimal soil disturbance:

- Less labour and time is demanded since only a small area must be tilled/worked on.
- Minimizes soil exposure to erosion.
- Soil microbial activity is not much interrupted.

B. Optimal crop cover

Cop residue consists of dead plant residues from the previous crops, including green manure and cover crops. Soil cover is one of the crucial factors ensuring conservation agriculture.

Benefits of soil surface residue cover

Usually, at least 30% of the cropped surface must be covered by residue.

- Less soil erosion,
- Improves soil structure, texture, and nutritional value of the soil,
- Improves water holding capacity and percolation,
- Reduces water evaporation,
- Weed suppression, therefore reducing crop-weed nutrient competition,
- More biological activity in the soil.

C. Crop Rotation

A crop rotation is a series of different crops planted in the same field following a defined order e.g. maize-cotton-sun hemp, soya bean-wheat or maize-soya bean.

Advantages of crop rotation:

- Different crops have different rooting/feeding systems. This enables deep rooted crops to benefit much from nutrients left by shallow rooted crops.
- Reduce pests and diseases in the cropping system,
- Increased crop production and yield potential
- Having a legume crop in the rotation will benefit the following crop to take up the nitrogen fixed by the legume crop.
- Since the legume fixes atmospheric nitrogen into the soil this then reduces input costs on the following crop on nitrogen demand.

Management Techniques

Farming involves a lot of factors that contribute to achieving the desired results at the end. Management is one of the factors of production; among them land, capital and labour.

3. Mechanized Conservation Agriculture (MCA)

Management involves the right choice of crops that a farmer wants to grow, the varieties, land preparation, plant spacing for optimum plant population and yield, planting time, weed and pest control and the methods used for plant protection, when to harvest and controlling post-harvest losses. It is advisable that, before embarking on any farming activity, field soil sampling be done first. This provides the nutrient status of the soil, giving the major nutrients inherent, vis, nitrogen (N), phosphorus (P) and potash (K) including other minor or trace elements like zinc, boron etc. The knowledge of the soil nutrient status will give information on the organic or inorganic fertilizer requirement per unit area; thereby saving on the input cost.

Mechanized Conservation Agriculture

As the name implies, this means the use of farming implements pulled by fuel driven engines.

Tractors

To achieve mechanized conservation agriculture (MCA), the use of tractors plays a pivotal role. The tractor does the pulling of different types of farm implements mainly during land clearing land preparation, planting, weed control and other farming operations. Tractors and tractor drawn implements ease the farming operations. Above all the use of tractors saves time of doing the farm work. With tractors farmers tend to farm commercially, as large areas of arable farmland can be easily cultivated. This will then result in high level production and productivity being achieved. The economies of scale will be enjoyed by farmers, as when production increases the cost of production decreases. Tractor owners can hire out their farm machinery to other neighbouring farmers. This, therefore, means that in that area more farmers will do their farm work with much ease and do not spend much of their time in the field. On labour saving – most field operations done by a tractor are usually done by one or two people the driver and an assistant. Tractors perform their work more effectively and efficiently as compared to jobs done by hand (manually) and or by animals.

There are many different makes and sizes of tractors found on the market in Zambia. Tractors can be from as small as 15 hp (horse powers) to as big as 8-wheeled high-horse powered types. What choice and size to buy depends on the availability of resources and the type of operations to be carried out at the farm. Tractors start from 2-wheel, 4 x 2 to 4 x 4-wheel tractors.

Advantages of tractors

Although tractors are expensive to acquire and run, they save on labour and time. The following are other advantages of a tractor.

i. Versatility

Modern tractors are designed and manufactured to offer versatility in performing a wide range of tasks. Compact tractors can accomplish tasks ranging from gardening to simple farming jobs, with the ability to do more by attaching various implements such as front loaders or back hoes.

ii. Power and durability

Tractors are typically designed with powerful engines to run over rough terrain and pull extremely heavy loads, making them effective in tough farming or landscape tasks. Modern tractors also come with cast iron front axles for extra strength and durability.

iii. Ease of transmission and operation

Modern tractors feature power shift transmission and hydrostatic transmission to simplify operation. While these tractors are also provided with power steering to make turning much easier, advanced models help reduce operator fatigue with exclusive shift controls and an automatically responsive transmission.

Tillage Methods

Tillage refers to cultivation of the soil to improve production of crops. A farmer can choose from a wide range of tillage methods when practicing MCA depending on what suits the farmer. The commonly used MCA tillage methods are:

i. No-tillage (slot planting)

No-tillage, direct drilling or direct seeding are all terms describing the sowing of seeds into soil that has not been previously tilled in any way to form a seedbed. Direct drilling was the first term used, the term 'no-tillage' began in North America, but there has been recent support for the term 'direct seeding' because of the apparent ambiguity that a negative word like 'no' causes when it is used to describe a positive process.

ii. Strip till or zonal tillage

Strip tillage, or zone tillage refers to the practice of tilling a narrow strip ahead of (or with) the drill openers, so the seed is sown into a strip of tilled soil but the soil between the sown rows remains undisturbed. Strip tillage also refers to the general tilling of much wider strips of land along the contour, separated by wide fallowed strips, as an erosion control measure.

iii. Reduced or minimum tillage

Minimum tillage, min-till and reduced tillage all describe the practice of restricting the amount of general tillage of the soil to the minimum possible to establish a new crop and/or effect weed control or fertilization. The practice lies somewhere between no-tillage and conventional tillage. Modern practice emphasizes the amount of surface residue retention as an important aim of minimum or reduced tillage.

4. CAFM PROJECT FIELD LAYOUT

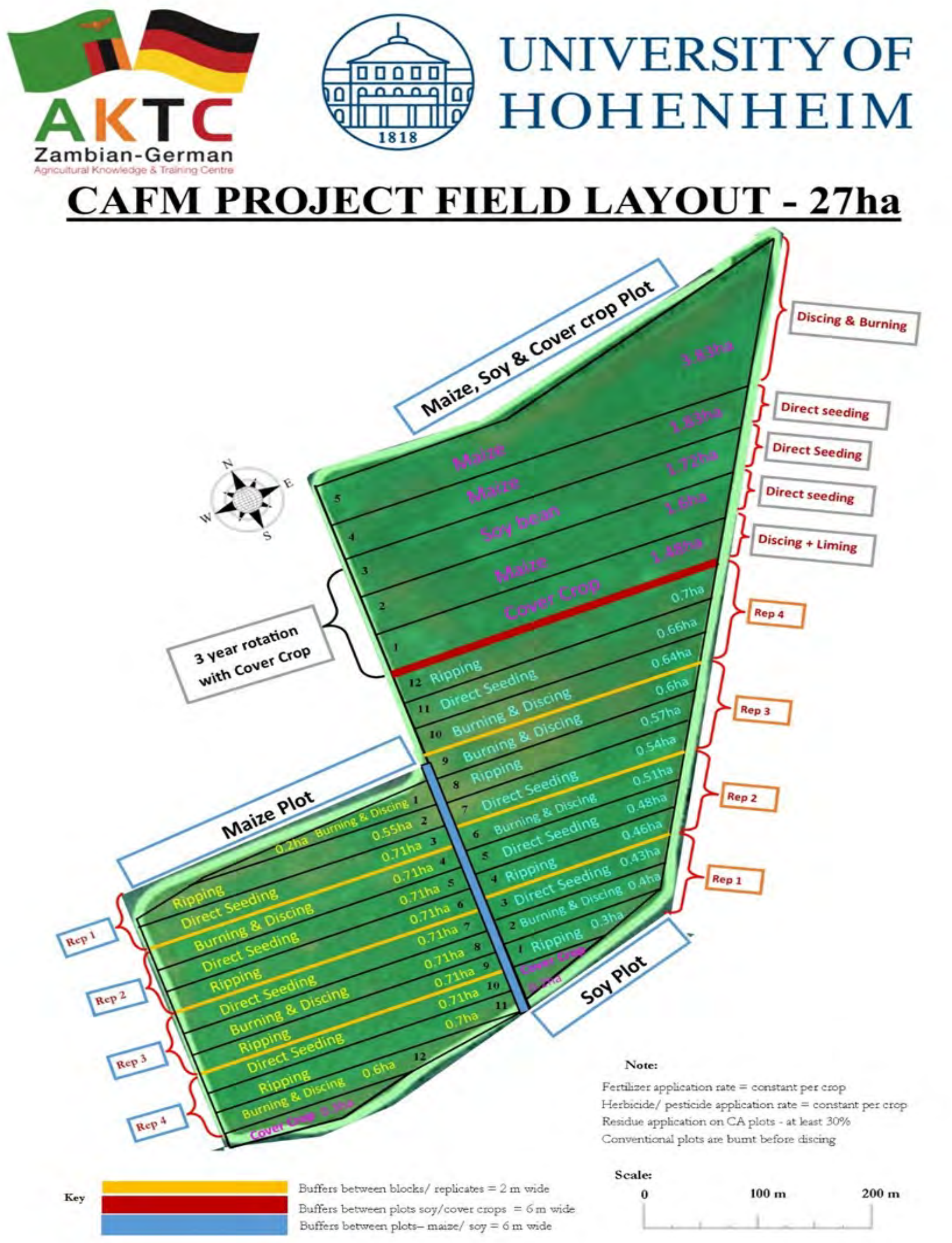

Figure 1: CAFM/UoH experimental plots design - 2019/2020 season.

Maize Plot

Treatments: Conventional vs CA tillage

- Burning + disc harrowing
- Ripping tillage
- Direct seeding

Replicates: Three

Total replications: 12

Average plot area: 0.64 ha (24 x 267) m

Rotation crop: Soya bean

Soya bean Plot

Treatments: Conventional vs CA tillage

- Burning + disc harrowing
- Ripping tillage
- Direct seeding

Replicates: Three

Total replications: 12

Average plot area: 0.53 ha (24 x 221)m

Rotation crop: Maize

Maize soya bean & cover crops Plot

Treatments

- Continuous Burning + disc harrowing - Maize
- Continuous direct seeding - Maize
- Continuous direct seeding - Maize, Soya bean & Cover crop

  3 year Cover crop rotation with Maize & Soya bean

Cover crops: Sun hemp, Millet, Sorghum & Sunflower

FIELD SET UP - Step by step process

The following are the tillage methods used in the Climate Adaptive Farming Method (CAFM) research project.

1. Burning and Discing

Step 1: Land Clearing

The plots were first cleared of shrubs and tree stamps. This was followed by burning of any plant residues within the plot.

Step 2: Land Preparation

The land preparation was by discing using a Lemken compact disc harrow at a depth of 15-20cm and a 130Hp tractor was used to pull the disc harrow.

Step 3: Planting

Planting of both maize and soya beans was done using a no till Massey Ferguson Planter (MF L45). For maize, the inter row spacing was 75cm x 25cm per plant space, the seeding rate was 25kg/ha. For Soya beans, the inter row spacing was 75cm x 5cm per plant space, the seeding rate for was 80kg/ha.

Burnt & disc harrowed plot

2. Ripping

Step 1: Land Clearing

The plots were first cleared of shrubs and tree stamps. This was followed by rolling down any grass to act as a soil cover

Step 2: Land Preparation

In the land preparation stage, ripping was done using a ripper at a depth of 15-20cm

Step 3: Planting

Planting of both maize and soya beans was done using a no-till Massey Ferguson Planter (MF L45). For maize, the inter row spacing was 75cm x 25cm per plant space, the seeding rate was 25kg/ha. For Soya beans, the inter row spacing was 75cm x 5cm per plant space, the seeding rate for was 80kg/ha.

Ripped Plot

3. Direct Seeding

Step 1: Land Clearing

The plots were first cleared of shrubs and tree stamps. This was followed by rolling down any grass to act as a soil cover

Step 2: Planting

Planting of both maize and soya beans was done using a no-till Massey Ferguson Planter (MF L45). For maize, the inter row spacing was 75cm x 25cm per plant space, the seeding rate was 25kg/ha. For Soya beans, the inter row spacing was 75cm x 5cm per plant space, the seeding rate for was 80kg/ha.

Direct seeded plot

5. MACHINERY & IMPLEMENTS USED

In order to carry out the CAMF project successfully, the following machinery and implements were used in the project. This section outlines the machinery used and its specifications. However, due to soil conditions, a few modifications were made on the implements as explained in details below.

TRACTOR

Name: *Massey Ferguson (MF)*

Model Number: *MF 360*

SPECIFICATIONS

- Engine Power: 60HP
- 2 Wheel Drive

DISC HARROW

Name: *Lemken Compact Disc Harrow*

Model Type: *Rubin 9*

SPECIFICATIONS

- Number of Discs - 20
- Working width - 2.5m
- Horse Power requirement 130hp

Note: To meet the HP requirement of the Disc harrow, a 130 HP tractor was used.

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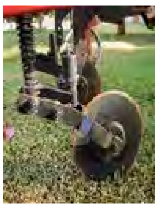

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RIPPER

Name: MF Ripper

SPECIFICATIONS

- Two row rip lines
- Required Horse Power – 60 HP (see tractor above)

MODIFICATIONS

The following were added:

1. Trash wheels - to remove trash and break big soil clots in the rip lines
2. Depth control wheels – to ensure that the ripping depth is maintained.
3. Shear bolt and leaf spring - to provide some shock absorption for the ripper

5. MACHINERY & IMPLEMENTS USED

BOOM SPRAYER

Name: *Agrional*

Model Number: Beta *SP 800*

SPECIFICATIONS

- Capacity: - 600 Litres
- Spraying Width: - 12 Meters
- Anti-drip Nozzle

FERTILIZER SPREADER

Model Name: *Rauch*

Type: *MDS 17.1*

SPECIFICATIONS

- Hopper Size:- 190cm x 120cm
- Holding Capacity: - 1800kg
- Spreading Capacity:-10-18 m

PLANTER

Name: *Massey Ferguson-* No till planter

Model Number: MF 104 *L 45*

SPECIFICATIONS

- Two-Row planter
- Row Spacing - 40-135 cm
- Seed Hopper - 50kg
- Fertilizer Hopper - 160 kg

MODIFICATIONS

- Trash Wheels- These were added to remove trash from the rows.

* **Note:** These modifications were necessary because of the soil type that we have in our fields

6. FIRST SEASON'S RESULTS

Ecological Considerations

Upon successful implementation of the first growing season, results regarding rainfall, soil moisture conservation and soil temperature are explained below.

i. Rainfall data

The rainfall pattern in the central region of Zambia has rapidly changed in the past few years majorly due to the effects of climate change. The previous season 2018/2019 recorded the lowest rainfall amount (561.5 mm) ever experienced in a span of a decade (Figure 2). Nevertheless, even though this current season 2019/20 recorded a slight rainfall improvement, the amounts are generally lower compared to other regions or provinces that receive over 1200 mm of rainfall annually like in Northern and North-Western provinces.

Figure 2*: Annual rainfall outlook for the last ten years: from 2009-2019.*

ii. Daily Temperature & Rainfall data

From the AKTC weather station, daily data regarding rainfall, temperature, relative humidity and solar radiation were monitored throughout the season. The highest average monthly temperature was recorded in October 2019 - 28°C, while the lowest was recorded in April 2020 - 21.5°C. The first rainfall was received in late November (30 mm), however, subsequent months experienced evenly distributed rainfall amounts. January and February received the highest rainfall, 221 mm and 218 mm respectively. A two weeks dry spell was experienced in mid-December 2019. The amount of rainfall, relative humidity, temperature and solar radiation affected crop growth and soil moisture availability throughout the season (Figure 3). This was reflected by the variation in soil moisture contents, and soil temperature between the direct-seeded plots and disc harrowed plots (as outlined in Table 1 on page 19).

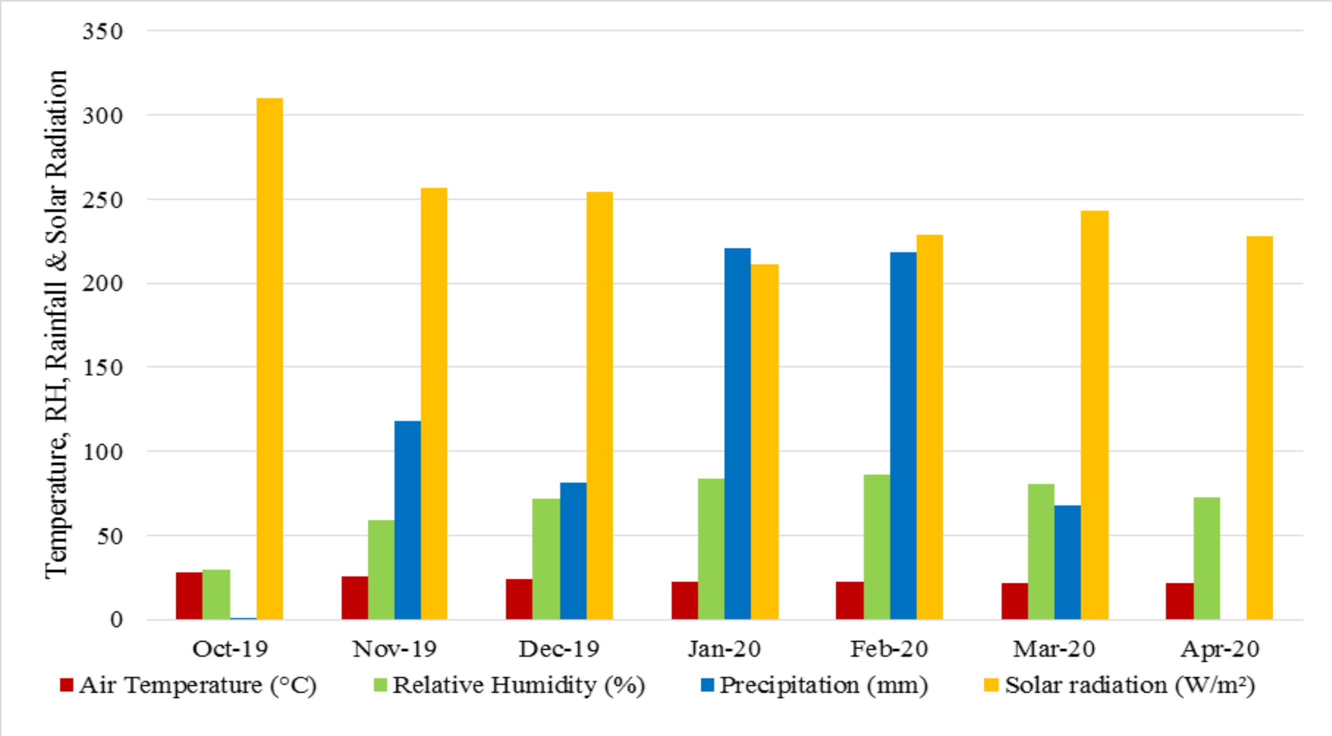


Figure 3: *Temperature, relative humidity, rainfall and solar radiation variations throughout the season 2019/20.*

iii. Soil moisture and temperature conservation

A high amount of soil moisture was retained in direct seeded plots compared to conventional disc harrowed plots (see Table 1). Water available at the topsoil for plant germination was higher in no-till plots (11.51 mm) compared to disc harrowed plots (3.97 mm). Similarly, the amount of water available at mature plants root zone was higher in no-till plots (37.69 mm) than disc harrowed plots (14.81 mm). The amount of moisture retained in the soil influenced the overall crop growth and heat stress during dry spells. There was better water infiltration in direct seeded plots than disc harrowed plots. This was due to good soil structure as well as improved microbial activities since the soil remained undisturbed. Direct seeded plots at 15 cm and 45 cm registered low soil temperatures compared to disc harrowed plots. The residue cover on direct seeded plots cushioned the soil from the direct impact of solar radiation compared the bare disc harrowed plots. The high temperatures greatly influence soil moisture loss via evaporation and can lead to heat stress and wilting during the dry spell.

Water logging in disc-harrowed plot

No water logging in direct seeded plot

Tables 1*: Soil moisture content and temperature at varying depths for different tillage methods practiced during the 2019/20 season*

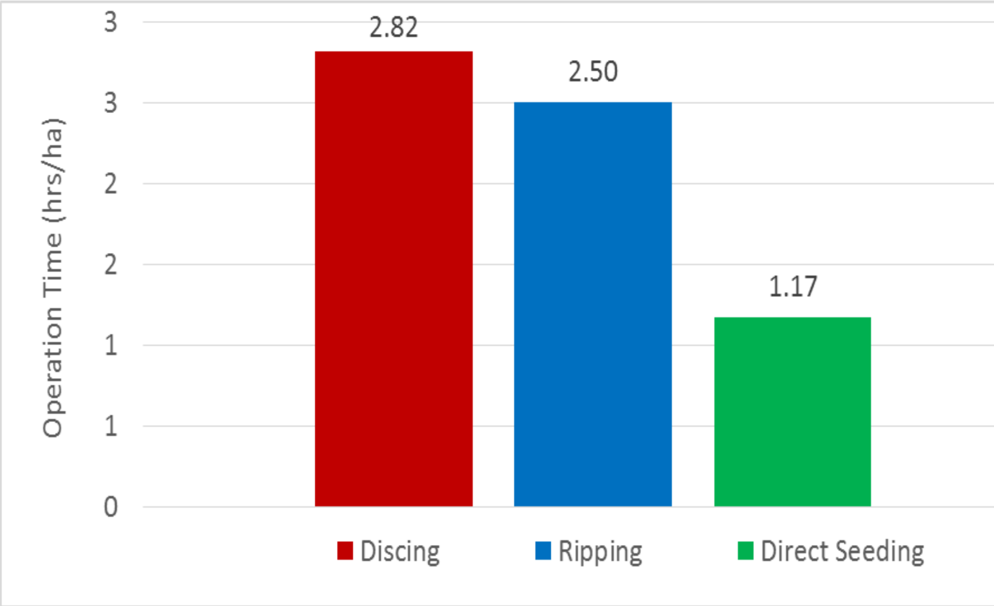
Depth (cm)	Tillage type	Mean soil moisture content (mm water)	Depth (cm)	Mean soil temperature (°C)
0-10	Discing	3.97		
	No-Till	11.51		
10-20	Discing	8.54	0-15	24.30
	No-Till	7.72		23.33
20-30	Discing	3.19		
	No-Till	7.43		
30-40	Discing	4.18		
	No-Till	2.44		
40-50	Discing	18.09	15-45	24.40
	No-Till	11.72		23.54
50-60	Discing	14.81		
	No-Till	37.69		

Soya bean plot under burnt & disc-harrowing tillage treatment, 6 weeks after planting

Economic Considerations

i. Time

The time taken to accomplish every tillage operation per hectare was recorded. Thus, the cumulative time taken from land preparation to planting in ripping (2.50 hrs/ha) and disc harrowed (2.82 hrs/ha) plots was more than double the time taken to perform direct seeding (1.17 hrs/ha). The time for herbicides application (pre-emergent and post-emergent), top dressing fertilizer application, pesticides, fungicides and insecticides applications were not significantly different.



The difference in operation time implies that the saved time while doing direct seeding can be used either to do more farm work or to engage in other economic viable activities by farmers such as tractor hiring service, transportation, irrigation among others.

Figure 4*: Cumulative time (hrs/ha) comparison between various tillage systems, in maize and soya bean plots*

ii. Fuel consumption

Fuel consumption per hectare from land preparation to top dressing fertilizer application were also recorded (see Figure 5). Fuel consumption was highest in disc-harrowed plots (22.50 lts/ha), followed by ripped (13.86 lts/ha) and direct seeded (6.46 lts/ha) plots respectively. This difference in fuel consumption was significant, implying that using direct seeding and ripping tillage practices can save almost four and two times fuel consumed per hectare respectively. More fuel consumed in the disc-harrowed plots was recorded mostly during land preparation.

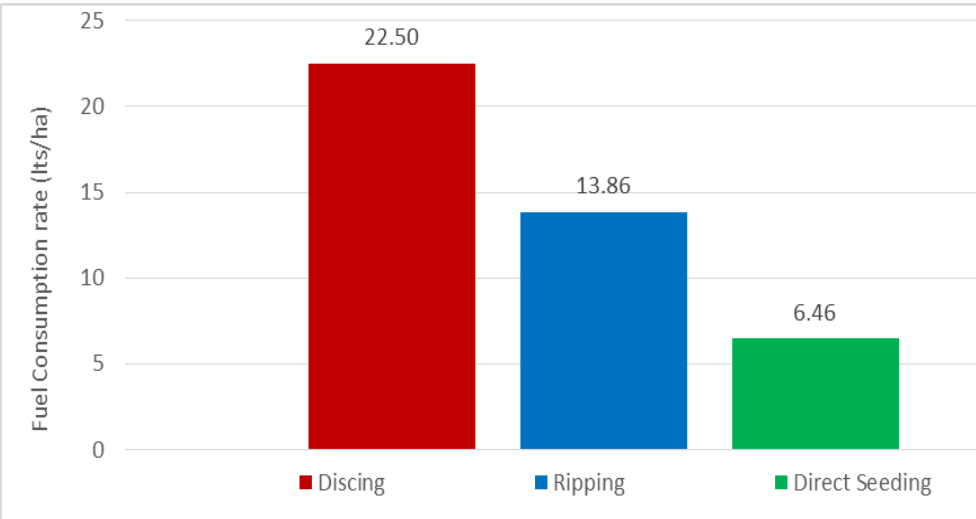


Figure 5*: Fuel consumption between conservational and conservation tillage systems*

Yield Comparisons

i. Soya Bean

Generally, crops from the conservation tillage systems yielded a higher amount of grains per hectare compared to conventional burning and discing (see Figure 6). Direct seeding, ripping and burning and discing yields were 3120 kg/ha, 2997 kg/ha and 2843 kg/ha respectively. However, based on the first season's data, the yields were not significantly different. Soya bean variety Safari (2997 kg/ha) yielded better than the Spike (2581 kg/ha) variety under direct seeding treatments.

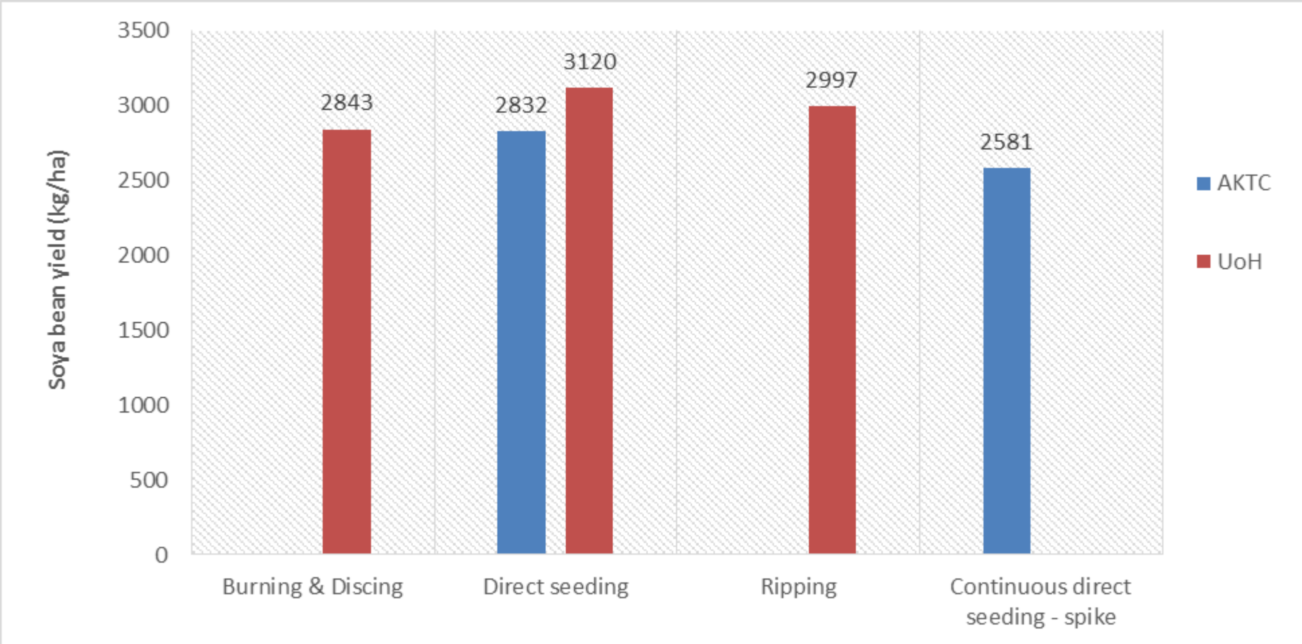


Figure 6*: Soya bean yield comparisons between conservation and conventional tillage practices. Season: 2019/2020, Soya varieties: Safari and spike.*

ii. Maize

Maize yield varied considerably between conventional and conservation tillage systems (Figure 7). Ripping tillage recorded higher yields (6,910 kg/ha) in the UoH experimental plots compared to disc harrowing (6,781 kg/ha) and direct seeding (6,349 kg/ha). There was no significant difference in yield between conventional burning and discing (7,071 kg/ha) and direct seeding for cover crop rotation (6,900 kg/ha) for the CAFM plots. Overall, there was no significant yield difference between the different tillage systems recorded in the first season (2019/2020).

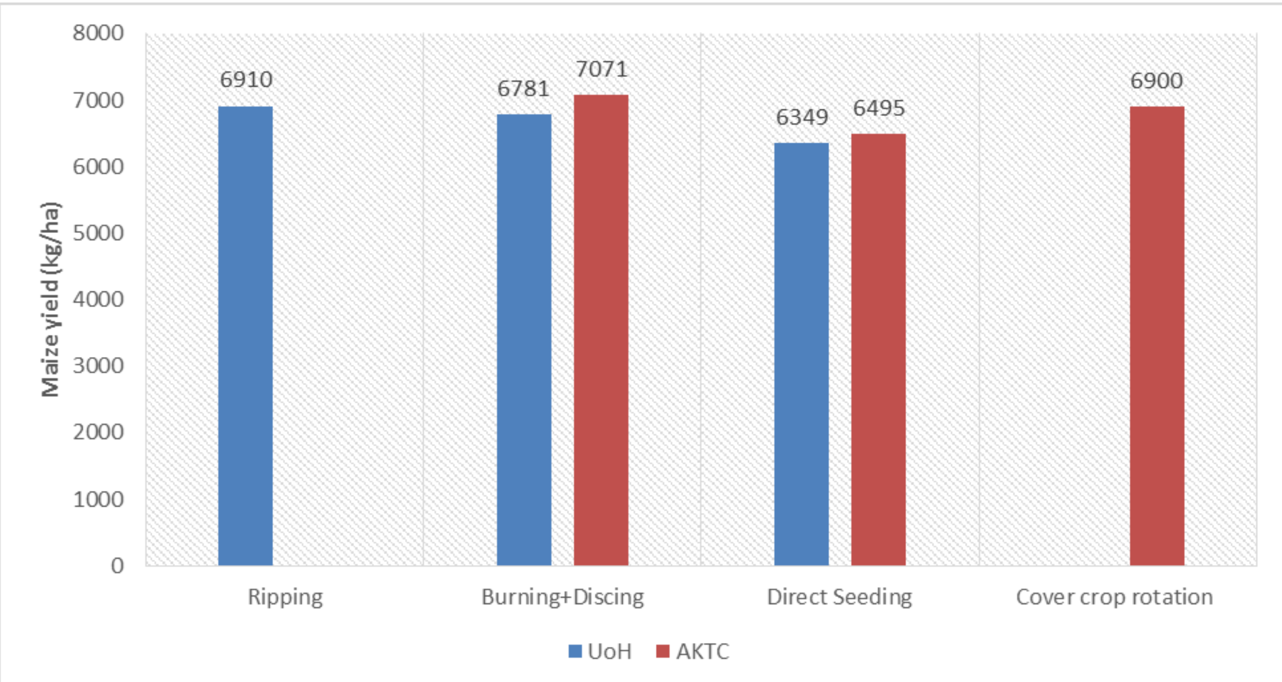


Figure 7*: Maize yield comparisons between conservation and conventional tillage practices. Season: 2019/20, variety: SC 633.*

Profit Analysis

To examine profit comparison between the three tillage systems, a gross margin analysis was conducted for both the maize and soya bean crops. Total revenue from the crops yield was based on the Zambian government Food Reserve Agency maize (K2.25) and soya bean (K6.36) prices per kilogram for 2020. The total variable costs of inputs and labour were calculated based on the unit price per item and daily casual labour charges were estimated based on the local rates. Labour cost approximations from land development, planting, chemicals, fertilizer including machine harvesting were based on the local hiring rates of a tractor and combine harvester. Thus, the gross margin was determined by getting the difference between the total revenue and the total variable costs. From the first seasons' yield, direct seeding and ripping tillage were slightly profitable for maize production. However, the gross profit was no significant difference between the conventional and conservation tillage systems. On the other hand, conservation tillage systems for soya bean (direct seeding and ripping) recorded significantly higher profit margins compared to the conventional burning and discing. This findings will be compared with the subsequent seasons (2020/21) after soya bean, maize and cover crop rotations, as a necessary requirement in CA principle.

Table 8: *Gross Margin Analysis (profit analysis) for Maize production under various tillage systems, 2019/20 season.*

Season	**UoH - 2019/20**			**AKTC - 2019/20**		
Tillage systems	Burning+ Discing	Ripping	Direct seeding	Continuous Burning+Discing	Continuous direct seeding 1	Continuous direct seeding 2
Yield (kg/ha)	6,781.	6,910	6,349	7,071	6,900	6,495
Total Revenue (ZMW/ha)	14,918.00	15,202.00	13,968.00	15,556.00	15,180.00	14,289.00
Variable costs (VC)						
Seeds (ZMW/ha)	296.00	296.00	296.00	296.00	296.00	296.00
Fertilizer (ZMW/ha)	2,516.00	2,516.00	2,516.00	2,516.00	2,516.00	2,516.00
Herbicides & pesticides (ZMW/ha)	504.00	504.00	504.00	504.00	500.00	501.00
Labour (ZMW/ha)	2,986.00	3,353.00	2,844.00	3,146.00	1,617.00	1,982.00
Total Variable Costs	8,818.00	9,185.00	8,676.00	8,978.00	7,445.00	7,810.00
Gross Margin (ZMW/ha)	6,100.00	6,017.00	5,292.00	6,578.00	7,735.00	6,479.00

Table 9: *Gross Margin Analysis (profit analysis) for Soya Bean production under various tillage systems, 2019/20 season.*

Season	**UoH - 2019/20**			**AKTC - 2019/20**
Tillage systems	Burning+ Discing	Ripping	Direct seeding	Continuous, direct seeding
Yield (kg/ha)	2,843	2,997	3,120	2,743
Total Revenue (ZMW/ha)	18,081.00	19,061.00	19,843.00	17,445.00
Variable costs (VC)				
Seeds (ZMW/ha)	539.00	539.00	539.00	449.00
Fertilizer (ZMW/ha)	1,205.00	1,205.00	1,205.00	1,003.00
Herbicides & pesticides (ZMW/ha)	704.00	704.00	704.00	560.00
Labour (ZMW/ha)	2,583.00	2,236.00	1,738.00	1,399.00
Total Variable Costs	6,235.00	5,888.00	5,390.00	4,415.00
Gross Margin (ZMW/ha)	11,847.00	13,173.00	14,453.00	13,031.00

7. CONCLUSION

The look-and-learn farmer demonstration sessions conducted during the entire production season cannot be over emphasized. The demonstrations showed the exact production practices that needed to be done by every concerned farmer during these erratic rainfall seasons. For instance, the direct seeding tillage method, which drew much interest to most participants showed how economic it is in reducing costs and time as all operations were done in a single run. To add to this, the direct seeded crops could not be differentiated from other crops where ripping and discing was done prior to planting. Considering that equal treatment was given to all crops under different tillage methods and the crops did not show any significant yield differences, makes it easy for farmers to choose which tillage method to adopt.

Bearing in mind that most farmers have been/are practicing CA either manually or using animal power, CAFM is demonstrating that it can further be done through the use of a tractor. The tractors being used at the project are not the big, sophisticated and inaccessible ones. The CAFM project tractors are small and simple. Most interestingly, some farmers own bigger tractors that those used by the CAFM project. The only challenge being posed to farmers who own tractors is to acquire the appropriate MCA implements. With what has been portrayed at the project fields, the message to farmers is being loud and clear: *start practicing MCA at a larger scale.* Climate change effects are being felt severely in Zambia, therefore in order for the country to be more food secure, climate smart agriculture is the way to go.

Despite fact that the CAFM project is in its infant stage it has been received with an overwhelming response from the farmers and stakeholders. A lot of activities were done on the CAMF project fields and the attendance was very resounding. Teachings and demonstrations were carried out and this included land preparation, planting and weed / pest control management. Above all, post-emergence and pre-harvesting look-and-learn field days were also carried out with farmers and other concerned stakeholders in attendance. All the machinery that was used for production was also displayed and seen doing their work in the field. It is from this usage of machinery that most farmers were very much interested in the direct seeding. This resonated well with the project's mechanized conservation agriculture call.

From what was observed last season and considering the farmers' active participation in all the demonstrations done, AKTC is being challenged to continue with the CAFM project. Both the ecological and economic preliminary results have shown that CA plots conserve more soil moisture, improve good water infiltration besides yielding similar or even more grains and a better profit margins. In order to fulfil the project's goal, the project has to be carried out to cover more farmers in different districts and provinces of Zambia. This can be achieved by training more farmers and extension staff and also having some demonstration plots in different provinces. Also working with other stakeholders such as FAO, SASSCAL, CFU, local Universities and Agriculture training colleges will improve the quality of CAFM project intervention mandate to increase production and productivity. Ultimately, this will improve the food security status not of the farmers alone but the country at large. It is hoped that AKTC will continue with the CAFM's good work and can spread the Mechanized Conservation Agriculture (MCA) techniques to many other farmers in Zambia.

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