In defence of the promotion of CA in Africa from a farming systems perspective

Justification for the promotion of Conservation Agriculture in Africa and the benefits of the practices remain a hotly contested topic within the scientific community. Among the sceptics it is suggested that CA is too costly for resource poor farmers to adopt; that the benefits take several seasons to emerge if indeed they exist; that CA is inflexible and promoted in a top-down manner; that more context specific research is required and that space should be provided for the inclusion of local knowledge.

The experience we have gained working with many thousands of farmers across East and Central Africa for over 20 years does not support these assumptions and in this paper we attempt to explain why.

1 The primacy of soils

The impetus driving the promotion of CA in the USA and Latin America over the past 5 decades focussed on evolving agricultural systems to replace extractive practices based on continuous overall soil disturbance and mono-culture that result in the inexorable deterioration of the natural resource base and develop alternatives aligned more closely to the regenerative ecological attributes of natural systems. Most authorities agree that the world's agricultural soils have lost 66 to 90 billion tons of Carbon due mostly to the effects of overall tillage through erosion and soil depletion which is particularly harmful in the tropics where high temperatures drive rapid oxidation of SOM.

Confronted by cumulative global evidence, nobody can disagree with the critical need to arrest the depletion of SOM and SOC and to go further by reversing this trend which commences immediately natural vegetation is removed to make way for agriculture and declines at varying rates depending on the topography, rainfall, soil types and farming systems applied to produce crops and livestock.

Among many others, the 2017 publication by FAO - ***Soil Organic Carbon, the Hidden Potential,*** reflects the work by many scientists to improve our understanding of the complex and interrelated natural processes that create and sustain healthy soils.

Alongside the need to regenerate soil health by replenishing SOC/SOM, a gradual process that can take many years or decades depending on local circumstances, is the widespread concern reflected in many publications including the **2011- GB *Global Food and Farming Futures Report*** warning that that the current status of global agriculture is incapable of responding to an increasing world population expected to plateau at 9 billion by 2050, - *'Farmers will have to grow substantially more food from more or less the same amount of land while simultaneously cutting greenhouse gases by up to 60 per cent by 2050'.*

At first sight these aims appear difficult if not impossible to reconcile due to the assumption among researchers particularly soil scientists investigating CF/CSA in the African context that there can be very limited productivity gains until soils are rehabilitated leading to the conclusion that the benefits of CA as defined by FAO even when fully applied, take years to emerge and are therefore unattractive to hard pressed food insecure farmers.

It is estimated that about 11% of arable farmland or 157 million hectares primarily in North and South America has been converted to No-till. Many enthusiasts including some academics classify this as CA. Proportions of this total may well qualify but as we highlight later, this misnomer has understandably led to much dissension in research circles.

Following from the above it must also be assumed that about 1.4 billion hectares is still tilled conventionally and despite the negative implications to soil health, crop yields and productivity with the exception of SSA in Africa continue to gradually increase driven by technical and scientific innovations, too numerous to repeat here, which have masked the accumulating depletion of soils.

What we maintain is that conversion to **Min-till** by small farmers, which is a fundamental element of CA, enables them to manage all crop production functions more efficiently and precisely and thereby minimize cumulative losses that are experienced by conventional practitioners and that these efficiencies produce immediate benefits that do not incur additional labour inputs or costs. Irrespective of the crucial aim in the medium and long term to reverse soil depletion it is these initial benefits which first persuade farmers to attempt alternative and more sustainable ways of establishing their crops.

2. The human element

It stands to reason that when urged by promoters to comply with the full CA package as a blueprint to improve the fertility of their soils, farmers in particular the impoverished, will prioritize those elements of 'CA' which in their circumstances are attainable, deliver rapid productivity gains and in doing so have a positive impact on their livelihoods i.e. those which address their most pressing needs but do not necessarily in the short term deliver the restoration of soil fertility.

As cited by CA purists – *'the ultimate purpose of conservation agriculture is maintenance and improvement of soil fertility for the improvement of food security, climate resilience and environmental sustainability'.*

There can be no argument with this overarching purpose however it suggests that neither 'CA' nor conventional farmers have other opportunities through the varied practices they apply from land preparation to harvest to improve their yields, food security and productivity other than the improvement of soil fertility. In doing so it diminishes the human element, the reality that the promoters of any specific set of agricultural practices in the domain of SSA in Africa are dealing not primarily with soils and the environment, but with farmers, as individuals and as families with all the social and economic challenges they are confronted by on a regular basis.

If small farmers are to be persuaded to take the first steps to abandon longstanding and destructive tillage practices they must experience tangible productivity benefits of some kind from the outset and in turn will be far more amenable to proceed to the following steps.

If on the other hand farmers are advised to abandon practices handed down through several generations, with the prospect that benefits will emerge several years in the future, the majority will persevere with the status quo.

Despite the many contradictory research publications on the benefits or otherwise of the interrelated components which in total comprise CA, the experiences of many thousands of farmers the CFU works with on a daily basis show that immediate productivity gains achieved through initial conversion to Min-till provide realistic opportunities to accelerate the path toward wider adoption of CA.

3 Min-till - CA: does any of it work? - Claims and counterclaims

Much of the published work on the subject of CA in Africa of which there is a huge and growing amount is contradictory with claims ranging from excessively positive to entirely negative and every step in between. For those less familiar with the detail of African farming systems, (and the devil and everything else lies in the detail), any number of conclusions can be drawn from these papers by advocates on either side of the debate.

As an introduction to this topic it is worth quoting from ***Landscapes Transformed, the History of Conservation Tillage and Direct Seeding edited by Wayne Lindwall and Bernie Sonntag*** whose efforts were instrumental in the transformation of much of Canadian Prairie agriculture to No-till:

'It is important to realize that the adoption of CA was met with a lot of opposition at the start in part because it meant radical changes in the way that land was managed and a lot of uncertainty. A number of myths infiltrated the movement in its early beginnings (the 70's and 80's) in part due to lack of knowledge and scientific speculation'.

The editors continue by describing and repudiating seven commonly held myths they encountered in the early years. Below is another pertinent conclusion from ***Science Direct, Soil and Tillage Research 137 – 2014 16 -22*** by author's recognised as authorities on Conservation Agriculture systems.

'No-tillage/conservation agriculture systems research has now been performed for more than half a century in many countries around the world, primarily for economic reasons, but also to reduce labour and energy consumption and improve environmental outcomes. However, an integrated approach to understanding this system requires standardized research methodology based on site-specific conditions. We contend that broad understanding is lacking of what conservation agriculture systems research means. This has led to a situation of conflicting research results because different technologies, methodologies, and definitions of conservation agriculture systems have been applied'.

3.1 The lack of clarity

Regarding the disquiet surrounding definitions, the CFU since 2001 has been quite clear regarding this issue when the three steps leading to full compliance were established as *Minimum Tillage **(MT)** – none or insufficient residue cover; Conservation Tillage **(CT) -** 30% or more residue cover; and Conservation Farming now defined as Conservation Agriculture **(CF/CA**) - 30% of cropped area occupied by legumes in rotation or as inter-crops.*

This was considered essential to enable us through adoption and impact surveys to establish who was doing what, how many farmers were doing it and to enable the disaggregation of results by gender and Min-till land prep practice i.e. Hoe, ADP owned or hired-in, or provided through Mechanised Min-till Service Provision (MTSP).

Understandably, the prevailing lack of clarity has fuelled much of the uncertainty in scientific circles regarding the benefits and adoption of CA among small-scale farmers in Africa while at the same time cyberspace is teeming with all manner of virtuous intentions and unverifiable claims by organisations remodelling their expertize to exploit the recent focus on African agriculture and the likely impacts of climate change.

3.2 A few examples of contradictory research findings

We are not qualified to comment on the validity of the complex statistical procedures applied by scientists to measure the performance and uptake of CA, but we highlight some contradictory findings to reflect the uncertainty that prevails. Researchers are naturally careful to qualify their findings which are often equivocal and usually culminate in a call for more research. However wider audiences without the necessary background to navigate the complex statistics and jargon contained in scientific publications draw their conclusions from summaries or abstracts and are likely to accept them as statements of fact.

The 2018 paper - ***Misunderstandings of Conservation Agriculture: Challenges in promoting, monitoring and evaluating sustainable farming, K.M. Findlater et.al,*** is relevant since it dwells on the issue of definitions. Investigating the practices of South African commercial grain farmers, the scientists discovered that only 14% of farmers adopted the full CA package whereas 47% of respondents practised 'No-Till' and 80% had eliminated burning residues.

The paper concludes among other observations that common survey methods used to track CA greatly overestimate beneficial adoption, thus suggesting that '*few or no benefits accrue unless the full package is adopted and that the farmers had little understanding of the FAO definition of CA and their interpretation of it differs significantly from the experts'.*

Farmers have to make a living and there is limited reference in the paper to the influence of market prices and for example, the financial implications of including leguminous or non-cash cover crops in rotation. Nevertheless the authors conclusions that the adoption of full CA is over reported is correct and is also reflected in the findings of CFU surveys which show that under very different circumstances full CF/CA adopters are in the minority relative to those who practise MT and CT.

Nevertheless, we disagree with the conclusion that no benefits emerge unless the full package is adopted because if this was the case there would little or no adoption of MT or CT among the farmers we work with in Central and East Africa.

Interestingly, the situation in parts of Kenya's highlands is the reverse where Maize/Bean intercrops are widespread because there is a vibrant market for Beans which can be intercropped successfully since the growth of Maize at altitude is less vigorous than in central Africa and Government input supply and marketing subsidies to promote Maize are applied on a limited scale to support the poorest families or when national food crises occur. With bimodal rainfall, residual biomass accumulation is also greater. Thus if widespread mechanised ploughing services and other overall tillage practices were replaced by Min-till and No-till alternatives and the burning of residues abandoned, many small farmers would be compliant with the FAO definition of CA.

The **CIMMYT/DfID** brief - ***Planting without ploughing: Zero till wheat takes root in the Indo-Gangetic Plains*** highlights the numerous benefits achieved by 620,000 farmers growing about 1.76 million hectares of Wheat. Although the benefits are highly significant, none of the farmers growing Wheat after Rice comply with the FAO definition of CA.

Among the list of benefits highlighted, the conclusion was that No-till increased Wheat yields by 6-10% and reduced costs by 5-10%.

On the contrary side of the discussion the paper – ***Productivity Limits and Potentials of the Principles of Conservation Agriculture C. Pittlecow et.al*** applied global Meta-analysis drawn from 610 studies with 6,005 paired observations representing 50 crops and 63 countries to compare No-till with conventional tillage practice. Overall, the authors conclude that the negative yield impacts of no-till were (-5.7%) but were smallest for wheat (−2.6%) and largest for rice (−7.5%) and maize (−7.6%), with the proviso that No-till performed best under rainfed conditions in dry climates, with yields often being equal to or higher than conventional tillage practices.

In a critique of the above paper ***- Does no-till agriculture limit crop yields, M. Tanadini and Zia Mehrabi,*** identified four fundamental issues with the meta-analysis based on standard statistical theory and best practice. The authors continue by showing how methodologically accounting for these issues produces results that strongly challenge the claims and conclusions of *Pittlekow.*

Meta-analysis intended to test broad hypotheses and arrive at unifying conclusions, extracts assembles and analyses large quantities of data from multiple publications to increase statistical power and uncover explanatory patterns has since 2006 fed into the debate regarding pros and cons of CA in Africa.

In the paper ***— Does Size Matter: A critical Review of Meta-Analysis in Agronomy, Cambridge Core,*** the authors hold that – '*meta-analysis is undermined by the large geographic scale at which results tend to be presented. The presentation of 'global' average results that are decoupled from the context-specific and diverse qualities of farming systems is unlikely to meaningfully inform policy and investment decisions, nor inform ways to improve farmer practice'.*

The 2018 paper - ***'Does conservation agriculture change labour requirements? Evidence of sustainable intensification in Sub-Saharan Africa, authored by G. Monnt and T. Luu*** in which the authors applied '*multinomial endogenous switching regression models (MESR), and counterfactual frameworks from longitudinal sample data'* gathered from Ethiopia, Kenya, Malawi, Mozambique and Tanzania arrived at the extraordinary conclusion that CA does not increase yields but increases labour input requirements driven by more work during harvesting and threshing stages.

In the 2015 paper - ***Critical Reflection on Knowledge and Narratives of Conservation Agriculture Whitfield et.al. University of Leeds***, the authors suggest an underlying a conspiracy in the promotion of CA in Zambia proposing that there is a '*knowledge politics'*, translating a weak evidence base into persuasive narratives and financial and political support, based on analysis through what they refer to as a '*political ecology lens'*. The authors continue by recommending that within this knowledge politics space should be opened to enable alternative narratives and the contestation of the pervasive CA scaling up agenda.

Alternative narratives may well be considered healthy within the scientific community but ultimately they must be translated into practical solutions that in some shape or form are of benefit to farmers and we hope that the many thousands of farmers who have adopted some or all of the practices that comprise CA in Zambia and East Africa where we operate are provided the opportunity to be included in these narratives so they can explain why they, with no incentives to do so, have abandoned the conventional systems they have practiced for generations, - systems based on the total inversion of soils to establish crops which were promoted and often enforced during the colonial era and which were previously entirely alien to them.

The author's conclusions are drawn from analysis of a history of the promotion of CA in Zambia and adjacent countries since 1994.

In an earlier paper ***Conservation Agriculture in Malawi: Networks, Knowledge Gaps and Research Planning**, **2014*** drawn from the outcomes of a series of stakeholder workshops in Malawi the authors note that the promotional landscape is complicated by numerous organisations advocating alternative versions of the technologies, transmitting confused messages and incentivising adoption through the provision of subsidised inputs including seed and fertilisers and conclude that, - *the establishment of the National Conservation Agriculture Task Force (NCATF) in 2007 in Malawi has not apparently improved the provision of consistent messages linked to context-specific advice for different agro-ecological zones.*

Our experience in Zambia has been unencumbered by the complex institutional and bureaucratic overlay experienced in Malawi. There are no task forces or coordinating bodies at the national level and irrespective of criticisms levelled against it, the governments Farmer Input Support Programme (FISP) has always been entirely disconnected from the promotion of CA.

The promotion of CA among many other initiatives is articulated in Zambia's National Agricultural Policy (NAP) which aims to -*'facilitate the development of a competitive, diversified, equitable and sustainable agriculture sector'.* However the absence of formalised structures to oversee and guide implementation, best described as a form of benign impartiality, has provided the CFU with unfettered freedom to operate effectively. This does not apply that we function in isolation. At the management, field and farmer level it has enabled the CFU to establish longstanding working relationships with numerous stakeholders in particular the Ministry of Agriculture, traditional leadership and private sector service providers.

Support for CA in Zambia which extends to the apex of political leadership has not arisen from the imposition of formal arrangements or pervasive narratives but has evolved from the experiences of farmers who have been provided with the opportunity to explain the benefits for themselves.

The principles of CA promoted through farmer to farmer training services described later, are not presented as a daunting and inviolable package of *'take or leave it'* practices with the exception of the first and most important step, conversion to alternative versions of Min-till which farmers can test and compare with the conventional methods they normally apply on whatever scale they prefer with whatever crops the grow, and resources they have and come to their own decisions regarding the merits or otherwise of the practices.

The paper ***- Beyond Conservation Agriculture K. E. Giller et. al; October 2015*** and earlier publications by the authors reinforce much of the scepticism regarding the promotion and benefits of CA. In brief:

- Objective measurement of CA adoption is challenging because none of the underlying principles is systematically captured—let alone the combination of the three principles. Studies have not used a correct definition of CA, that CA is a holistic approach and therefore cannot be analysed using the tools of reductionist science.

- Smallholders are inhibited from adopting key components of CA because they do not have access to the sophisticated technologies and tools of modern science applied by larger mechanised farmers.
- Failure to see yield improvements in the first 5–10 years of adoption *(Rusinamhodzi et al., 2011 meta-analysis*) was therefore commonly dismissed as a transition period.

- One problem is the increase in labour burden, when no-till is practiced without herbicides in manual low-input systems such as in large swathes of Africa (*Grabowski and Kerr, 2014*). Inversion ploughing is an effective means to control weeds. If herbicides are not available the labour burden for hand weeding under CA is strongly increased.

In *Section 3* above, we highlighted the need to disaggregate the definition of CA into its component parts so that the predicted benefits of each can be investigated and a clearer picture of the adoption patterns among farming communities can be established. We address the above issues later but first dwell on the conclusions of the publication which are presented below:

- The authors conclude by proposing a rigorous, context-sensitive approach based on Systems Agronomy to analyse and explore sustainable intensification options, including the potential of CA. There is an urgent need to move beyond dogma and prescriptive approaches to provide soil and crop management options for farmers to enable the Sustainable Intensification of agriculture'.

The view that the promotion of CA is dogmatic and prescriptive is alluring and resonates throughout many publications on the subject. The suggestion is that promoters are uninquisitive and unmindful of existing farming systems and the socio-economic impediments within the Agro-ecological domains where CA is promoted and that new avenues of research should be investigated offering a menu of options and choices for small farmers which are more amenable to their particular circumstances.

This premise leads to the notion that conventional agriculture as practiced today is subtle, diverse and informed by longstanding indigenous knowledge which is disregarded and disrupted by the imposition of alien CA practices.

This idea confuses ***conventional agriculture*** with ***traditional agriculture*** which over the past century has more or less been obliterated across much of Africa and replaced by practices which would be largely unrecognizable by the forefathers of contemporary farmers. What we see today is not diversity within specific agro-ecological domains but homogeneity in the manner in which the soil is manipulated to establish annual crops and excessive monoculture dominated by Maize.

Descriptions of the complex variants of traditional agricultural systems in Africa and the profound understanding of close knit communities of the possibilities offered by local ecologies to provide them with sustenance and opportunities for barter, together with the influences and pressures that extinguished these farming systems over the past century, have been the subject of numerous studies by anthropologists, social and political scientists, ecologists and agronomists.

Among these systems in communities occupying regions dominated by various forms of shifting cultivation and agro-pastoralism, ***Minimum Tillage*** was commonly applied to sow grains. Crop and weed residues were generally heaped and burnt (pyro-culture) and mixtures of cereals, Maize, Sorghum and Millet planted directly into the soil at wide spacing with a hole made by a stick or the strike of a hoe.

After the first shallow weeding during which uprooted weeds were left in situ, various crops were planted in the gaps, including Groundnuts, Bambara Nuts, Cowpeas, Pumpkins and Okra. Minimum Tillage and No-tillage are not alien to Africa and many other parts of the world, they have merely been largely if not entirely abandoned and existed in many countries across the world long before the words were invented.

4. Systems agronomy

Much of the research focussed on CA highlights the obstacles that apparently deter potential adopters, however the numerous difficulties experienced by conventional farmers to establish and tend their crops which all too often produce disappointing results is a subject that is generally overlooked by academics when comparisons are being made.

The conventional tillage systems described below may be considered subjective and even irrelevant as they are not well suited to reductionist analysis and immaterial to discussions focussed on the overarching policies and the strategies necessary to address stagnant agricultural productivity and the impacts of climate change in Africa.

However they show what millions of farmers actually do and shed light on several misconceptions that we find quoted and repeated in many publications.

In the brief **- Can we define the term farming systems? A question of scale, K.E. Giller 2013,** dwells on various attempts at defining Systems Agronomy over the past 30 years and concludes that an adequate definition is yet to be established.

Irrespective of this quandary we have spent many years observing conventional farming practices in the countries where the CFU operates, with some of us having the benefit of over 40 years of experience working in SSA across the African continent, in tropical, sub-tropical and semi-arid domains.

4.1 Conventional tillage systems (or systems of tillage)

Our observations relative to East and Central Africa (ECA) in regions where farmers rely on annual or bi-modal rainfall to produce grain crops are presented below.

Overall tillage is universally applied by an overwhelming majority of all arable farmers across ECA and elsewhere and the annual overall disturbance of soils by one form of tillage or another is omnipresent.

- Hoe farmers in Uganda dig over the whole field after the onset of early showers. In Kenya farmers do the same or rely on private tractor operators to plough their fields often before the onset of the rains. In both countries where cattle are prevalent animal draught power (ADP), is used for ploughing.

- In southern and central Tanzania hoe farmers construct ridges each year after the first early showers by splitting the previous season's ridges, or on softer loamy soils do this immediately before the rains. Some construct large ridges to accommodate two rows of crops and others smaller ridges into which a single row is planted. Mechanised ploughing and disking services are significant particularly in the eastern highlands. Ox ploughing is also commonplace in regions where cattle are raised.

- In Malawi the majority are hoe farmers. Each year they split ridges in the dry season scraping the top soil together to make new ridges in the previous seasons furrows. Ploughing with oxen is limited to about 13% of households.

- In east and central Zambia the majority of hoe farmers split ridges in the dry season, with a minority waiting for the rains to do this while even fewer dig over the whole field. On the plateaus of southern Zambia ox ploughing predominates and is also common on the central plateau.

In any domains where a particular tillage practice prevails the alternative versions described above can be found but the constant turning and churning of soil in one way or another links them all.

4.2 Burning of Crop and Weed Residues

The 2018 satellite fire detections from the Goddard Space Flight Centre, show that Africa is responsible for 70% of global burnt area. As Niels Andela a scientist who runs the Global Emissions Database *says 'in Africa something is always burning somewhere.'* Burning occurs every year and is another feature linked to conventional tillage practice. According to the World Bank 48% of global burning is associated with Maize residues.

This is no surprise because Maize and other cereals produce more residues than any other grain grown by upland smallholders, whereas in regions of mono-modal rainfall grain legume residues which are not fed to livestock rapidly dissipate in the dry season and provide little or no protection to the soil.

In Africa, pyro-culture is an ancient tradition and residues are burnt because they are considered a nuisance when the soil in entire fields are inverted with hoes or ploughs drawn by oxen or tractors. Restricting tillage to 12% of the surface area as described later alleviates this necessity.

The challenges associated with retaining residues in areas where communal grazing is prevalent are well known and reflected in many papers as an issue of resource competition. However, the magnitude of burning also reveals opportunities to reverse this practice because residues are obviously of no value to the countless farmers who set fire to them.

It is also a fact that cattle are selective grazers and consume the leaves of Maize residues leaving the stalks which from a reasonable crop (4 tons/ha +) can provide significant benefits by reducing the velocity of rain water and sheet erosion across fields.

4.3 The practical systems benefits of minimum tillage

It is understandable that without the endorsement of research, anybody informed that by just digging rectangular holes or by ripping furrows in lines across a field, in order to reduce soil disturbance to about 12% of the surface area, would be sceptical that crop yields can increase significantly in the first year of adoption.

Why for example should the experiences of many thousands of farmers (who have no pecuniary incentives whatsoever to make such claims) be believed when they declare that in the first year of converting to Min-till they have increased their yields by 20%, 50% or even more. How can this make sense without the sanction of elaborate statistical investigation?

To explain these claims it is necessary, as in any production system, to scrutinize in detail the sequence of activities undertaken by conventional farmers, (i.e. how they go about establishing and husbanding their crops), in order to expose how these practices can all too often disable them from achieving the results they hope for through the accumulation of losses from planting to harvest.

5 Conventional ADP tillage systems. The impediments from a farming perspective

The complex systems of sharing resources among traditional African communities have been described by many anthropologists. Below is a comment from a small farmer interviewed on the Tonga Plateau in Zambia in the 1950's several decades after the adoption of ox ploughing which led to the emergence of many wealthy Maize farmers – *'I must work on my neighbours field for one week while I can borrow oxen for only one day in return. This is a big loss of labour for my field'.*

Draft oxen are a scarce resource across many parts of East and Central Africa and are considered to be in decline due to; - periodic outbreaks of Tick borne diseases; the difficulties involved in developing effective prophylactic measures among pastoralists who migrate long distances with their animals; the scarcity of grazing and over grazing; recurring droughts; the cost of purchasing animals and the failure of past loan based oxenization schemes.

Although the scope of the 2015 study ***Moving to Mechanization in Maize Farming Systems in Ethiopia, Kenya and Tanzania, R. Bymolt et. al. KIT/CIMMYT/*CGIR** was limited to specific areas and cannot be applied to extrapolate national tillage patterns, the results showed that in Kenya, and Tanzania respectively 40% and 27% of farmers *hired-in* ox ploughing services in the areas investigated.

The 2015 study, ***Contribution of draft cattle to rural livelihoods in Tororo district of south eastern Uganda endemic for bovine parasitic diseases: an economic evaluation, Walter O. Okello et.al.,*** showed that, apart from being labour saving, the use of animal traction is highly profitable with the gross margin per year from the use of draft cattle amounting to $245 per work oxen owning household.

'The cash obtained from hiring out draft animals was equivalent to nearly a quarter of the average local household's monetary receipts'. The report also revealed that endemic bovine parasitic diseases such as trypanosomiasis and other tick-borne diseases reduced draft cattle output by 20.9 % and potential household income from the use of draft oxen by 32.2 %'.

The review - ***Animal Traction in Ghana Houssou et al;*** published by IFPRI in 2013 and undertaken in the north of the country over a 3 year study period showed that animal owners ploughed about 9.5 acres of their own land and about 7 acres for non-owners.

Clearly farmers who own oxen can cultivate larger areas than hoe farmers, are more food secure and have more produce to sell at harvest. However this generalization masks the consequences for farmers who *borrow or hire-in* oxen to plough, a subject seldom reflected in more recent research publications.

Also of interest are the papers by ***H. Dibbits and E. Mwena, Surveying Animal Traction Use in Zambia, and Animal Power for Weed Control: experiences in Zambia***, undertaken before the catastrophic 1992 regional drought. Between 1985 and 1990, Dibbits reports an increase of 45% to about 266,000 trained oxen ploughing 468,000 hectares with a severe decline in 1991 due to the outbreak of tick borne diseases.

'In areas where animal traction has been in use for a long time, some farmers use plows to remove weeds between rows, while others have used ox cultivators or ridgers. In all farming systems 70% of weeding is done by hand. In Southern Province, an animal traction area, only about 22% of weeding is done using draft animals (DoA, 1993), while in some parts of the same province about 90% of smallholder farmers use a plow to cultivate (till) their fields (Starkey, Dibbits and Mwenya, 1991)'.

'Surveys of Lusaka and Central Provinces revealed 16% and 3%, respectively, of weeding is done using animals (DoA, 1993). Comparing the use of animal traction for weed control to plowing in subsistence and emergent farming, oxen plow about 54% and 55% of cropped areas in Lusaka and Central Provinces, respectively (Dibbits and Mwenya, 1993). It is therefore clear that the use of animals for weeding is very low, compared to their use for plowing'.

The paper ***Conservation Farming in Zambia, S. Haggblade and G. Tembo IFPRI\FSRP, 2003*** showed that 64% of animal draught users do not own animals but borrow or hire.

The paper Animal draft power challenges in Zimbabwe J. Francis, B. Mudamburi et al; *reflected that 85% of the 1-1.2 million farming households use animal draft power but that the majority do not have adequate draft animals and that farmers who do not own animals hire them in, that access is untimely and associated with poor crop yields.*

These findings reflect the prevalence of the longstanding tradition of ADP borrow/hire and also suggest that significant fluctuations in the availability of draught power do not necessarily translate into a proportional decline in ploughing.

Farmers who have their holdings ploughed may weed by hand because they have planted some legumes, pumpkins or other crops into the field after the Maize has been established. These are generally smaller farmers who have never owned oxen, but the majority - Maize producers, subsequently weed by hand because they have lost their animals as a result of outbreaks of tick borne diseases or drought and cannot afford to replace them, have been obliged to sell them when confronted by severe or total crop failure, or have always been accustomed to ADP hire.

Wherever ploughing is an ingrained tradition, and this is not restricted to Zambia, farmers who have never had animals or those who have lost them continue to rely on more fortunate relatives or neighbours to plough their fields. In general they do not revert to the labour intensive and in their view the demeaning alternative of the hoe, with the exception of small 'home' plots which are traditionally the domain of women in which Maize, legumes and cucurbits are intercropped.

Close relatives may provide ox ploughing services free of charge after they have ploughed and planted their own fields, payment may be deferred in exchange for labour or a proportion of the crop after harvest. The hirers may still have implements but no animal**s.** The variants are innumerable but the consequences are dire:

5.1 The consequences of hiring draught animals to plough

Confirmed by numerous trials over many decades across ECA, there is no disagreement about the importance of early planting particularly for Maize, Cotton and late maturing legumes such as Groundnuts with losses accumulating on a daily basis and severe crop failure resulting when the rains terminate earlier than expected. In Zambia and Malawi the optimal planting window fluctuates from mid-November to mid-December or even later in poor years.

The onset of the rainy season is always unpredictable and is usually preceded by isolated showers and line-storms. The recurrence of rainfall is hard to foretell, precipitation may be prolonged or dry spells with limited or no rainfall may extend for several days or weeks and judgements about when to plant are always risky. Extended mid-term dry spells in January or February are also commonplace in central Africa.

Farmers who hire in animals have no choice about when to plough and plant. Close relatives will be at the front of the queue, whereas the less fortunate may have to wait until the owners have completed the cultivation of secondary weeds that have emerged in their crops. In Zambia we see ploughing to establish Maize and other crops continuing into mid and even late January.

- Farmers at the tail of the queue plough weeds 10cms to 20cms high immobilising any available N remaining in the soil, or fail to invert and eliminate them.
- The tradition of sowing seeds behind the plough (in each 3rd furrow) and covering them with the return pass leads to highly variable planting depths. Some seeds too close to the surface germinate and die if extended dry spells occur and seeds planted too deep fail to emerge at all. As a consequence plant populations suffer and reseeding extensive gaps after the emergence of the crop is commonplace.
- Because there is no guarantee of consistent crop emergence, Maize farmers who have fertiliser apply basal dressing on the surface rather than beneath the soil.
- Farmers who traditionally rely on hiring in ploughing service tend to have larger areas ploughed than they can weed by hand and portions of the crop become overwhelmed by weeds and are often abandoned. They do this because;- it is the area of land they were accustomed to cropping when they

had animals; or because they recognize the effect on late planting on yields and attempt to compensate by extending cropped area; or because of the hope for an extended rainy season. In these circumstances it is understandable that whole farm production to supply the family's needs and some surplus for sale rather than yield is foremost in their minds.

- Effective shallow ploughing with oxen requires moisture to a depth of about 15cms. When extended dry spells occur after the onset of the rains, ploughing is abandoned prolonging the delays for farmers waiting for the service.

- Between 2000 and 2008, 1,700,000 hectares of Maize planted in Zambia was abandoned according to analysis of national crop forecast surveys by *MACO/CSO/FSRP* over the period. Multiple causes will have contributed to these losses but late planting and the inability of farmers to control weeds were and continue to be significant factors.

- During the above period no extreme or severe droughts as classified by meteorologists occurred as they had in 1991/2, 2001/2, 2014/15 and 2018/19. In specific areas in some seasons farmers may have experienced extended dry spells, a later start or earlier termination to the rains than normal, but drought played no part in the losses experienced.

5.2 Ploughing by farmers who have oxen

- Defined in farmer's terms an ideal 'planting rain' is a heavy downpour (i.e. approaching field capacity) which provides sufficient moisture to guarantee germination and crop emergence without the need for further precipitation within 4 to 7 days. Disregarding Cotton which is dry planted sowing must ideally be completed within 1 to 2 days after the conclusion of the event depending on the characteristics of the soil.

- Farmers with oxen have a significant advantage over 'hirers', they plant earlier and invariably get better results. Nevertheless those who sow behind the plough cannot plant when soil moisture is optimal and reduce the risks of poor emergence because they have to wait until the soil is dry enough to plough. Ploughing one hectare with a pair of oxen takes 14 to 16 hours on average or 4 days and continues so long as adequate penetration can be achieved during which time the moisture content of the soil will be in decline. Once the seed is planted light showers may be adequate to germinate some seeds but may be insufficient to guarantee emergence.

- The above disadvantage should not be exaggerated but is highlighted because all ADP farmers who convert to dry season Min-till ripping minimize these risks as explained later.

- In general ox owners who plant behind the plough also suffer suboptimal emergence and top dress basal fertilizers on Maize limiting utilization efficiency.

- Farmyard manure is a scarce and extremely valuable resource. Farmers cart manure from kralls in scotch carts before the rains and dump heaps in different portions of their field each year, spread it out and plough it in. Needless to say much of the manure occupies the inter-rows and benefits weeds which rapidly proliferate rather than the crop.

5.3 Cultivation of weeds by ox owners

The manner in which ADP farmers cultivate weeds is seldom highlighted in research publications. The most comprehensive descriptions of the equipment used can be found in the 1989 publication - ***Farm Implements for Small-scale Farmers in Tanzania. B. Mothander et.al; or on the Zimplow Zimbabwe website.***

- Three implements are generally used. The most common is the *plough itself* followed by *ridging bodies* and lastly width-adjustable *3 tine cultivators* with or without a ridging body attached at the rear.

- After seeding on the flat, ploughs and ridgers are used for cultivation to cast soil, any remaining residues and weeds from the inter-row into the crop row forming a succession of bare ridges and furrows. Contour ploughing is non-existent and during heavy downpours ridges are eroded and the furrows concentrate rainfall which flows down the prevailing slope carrying top soil and nutrients with it.

- Ploughs are not designed for cultivation but are the most common implements used since they can be used to both till and cultivate. Plants are dislodged and side roots exposed exacerbating wilting in dry spells.

- The width adjusters on cultivators are cumbersome and cannot be modified during use. Row spacing varies, oxen are often poorly trained or mismatched due to losses of prime animals and as a result plants are disturbed or uprooted.

- A smaller number of ADP farmers particularly in eastern Zambia do not plough but ridge up soil after the rains and plant seeds on the top by hand.

- Maize is a spreading shallow rooting plant. Tap roots may extend to a depth of a metre or more but 70% of the moisture is drawn from the top 50cms of soil with 50% extracted from the top 30cms. During extended dry spells ridges dry out more rapidly increasing the likelihood of crop stress and wilting. Ridges are split each season in a similar fashion to hoe farmers with top soil moved laterally to make ridges in the previous season's furrows.

- Farmers' who rely on ploughing to establish later planted crops, often an opportunistic activity if the rains appear positive, also invert excessively tall weeds in portions allocated for these crops because the cultivation of emerging weeds in the main crop generally Maize, takes precedence.

- Shallow ploughing encourages the spread of Couch grass (*Cynodon dactylon*), a rhizomatous weed that is almost impossible to eradicate without the use of herbicides, thrives on depleted soils and there are many examples in southern and central Zambia where plough farmers have abandoned fields as a result.

The numerous effects of ploughing on soil health have been exhaustively documented and need no repetition here other than to say that the continuous movement of top soil pulverises structure, oxidises organic matter and beneath the shallow layer of soil that is constantly disturbed, compaction inhibits the infiltration of rainwater.

The challenges that confront all ADP farmers compelled to wait for the rains to trigger activity are underestimated. Nature rapidly changes gear, weeds proliferate immediately and families can soon become overwhelmed by the choices they have to make to establish their crops and undertake critical tasks on time.

6. The alternative of ADP min-till

6.1 The Magoye ripper

The *Magoye ripper* designed to rip planting furrows through dry soils was developed in 1987 in Zambia at Magoye research station Southern Province by the Ministry of Agriculture in collaboration with IMAG of the Netherlands government. Basic improvements to the design were later made by the CFU including a narrower case hardened reversible tip to improve penetration and reduce drag.

The ripper bodies designed to be attached to a standard plough beam is manufactured by Zimplow Zimbabwe and also now in India, are imported and sold through apex agro-dealers rural stockists. After the two recent dry seasons there has been a surge in interest and it is estimated that about 14,000 to 15,000 rippers are now in use in Zambia. The device is also promoted by the CFU in Kenya, Uganda and Tanzania but usage is unknown.

6.2 The farming systems benefits of ADP min-till

- The effective ploughing window to achieve timely planting is two to three weeks. The window for ripping extends through the dry season i.e. over 3 months in regions of mono-modal rainfall. This advantage makes far better use of scarce animal draught power.

- Farmers who own oxen have perceived the business opportunities afforded by providing ripping services to clients with some now providing services to 10 farmers or more.

- Dry ripping 1 hectare takes one pair of oxen 4 hours compared to 14 hours for ploughing. The cost of ripping is currently about $15/ha whereas the cost of ploughing is $26/ha. The cost of a Magoye ripper is $30-$33 and the investment can be recovered well within one season.

- Setting up and using a Magoye ripper correctly requires skill but with demonstration and practice it can soon be learned and more uniform depths can be achieved.

- Farmers who receive the service can choose when to plant i.e. after an effective planting rain which is an extremely important advantage. They band any basal fertiliser they have acquired along rip lines in advance or during planting, sow by hand, cover with hoes and achieve more accurate planting depths and more rapid and even emergence.

- Ripping is a misnomer since penetration in dry soils will not exceed 12cm to 14cm however the shallow furrows concentrate early rainfall from the inter-rows extending the survival of the crop during early dry spells.

- Manure for those who have it is banded along the rip lines before planting extending its value to plants over much larger areas.

- Agricultural lime can also be applied and concentrated in the ripped furrows at a rate of 200kg/ha on an annual or biennial basis to amend acidity rather than the standard rule of thumb recommendation of spreading 1 ton or more every 4 to five seasons which is impossible for small farmers to achieve.

- Another significant advantage of dry season ripping is that critical tasks are separated out and can be effectively sequenced. Plough farmers who own oxen are often confronted with the choice of cultivating weeds in early planted fields usually closer to the homestead or continuing to plough and plant 'away' fields.

- Owners or hirers who dry rip, or re-shape them after first showers soften the soil can apply basal nutrients to Maize, plant all their crops earlier and thereafter focus on the task of early weeding either by hoe or using herbicides as explained later.

- Each season farmers are encouraged to open up, plant and cover the same rip lines as previously, a form of *controlled traffic* farming popular with commercial farmers. The idea is to concentrate and to the extent possible, accumulate nutrients in the cropped rows particular P which is relatively immobile and lime if applied in previous seasons.

7 Conventional hoe tillage systems. The impediments from a farming perspective

Among hoe farmers as described earlier the annual construction of ridges on which crops are planted each season is almost universal in Malawi, and common in southern Tanzania east and central Zambia. The disadvantages of ridge culture have already been highlighted in relation to ADP tillage systems.

Furthermore there is no scientific evidence which shows that this practice, which was first enforced by the British administration in Malawi in the 1930's to eliminate erosion brought about by the expropriation of land and the consequent congestion in reserves allocated to African farmers, provides any benefits whatsoever.

7.1 Ridge Culture

- **Labour Inputs – tillage**

The soil movement involved in this practice which the majority of farmers undertake before the onset of the rains after the heaping and burning of residues is enormous. In Malawi for example about 2 million families cultivate about 4.5 million hectares of land and it can be safely assumed that about 3.5 million hectares is ridged up annually, involving the construction of at least 35 million kilometres of ridges.

The labour input varies between *25 to 35 days/ha* depending on the characteristics of the soil, the size of ridges and the age and health of the members of the family involved, during which time about 250 to 300 tons of soil/ha is moved. Some farmers construct small ridges, plant seeds in them when the rains arrive and build them up during the first weeding round. Continuous movement of the top soil oxidises SOM and pulverises structure making it friable and easy to manipulate by farmers with generations of experience.

- **Weed Control**

As reflected on *page 6* above, research publications regularly dwell on the disadvantages of min-till relative to the control of weeds, the opinion being that conventional tillage practices remove the first flush of weeds in advance whereas hoe Min-till does not, so the weeds emerge with or before the crop and in order to eliminate them herbicides are essential and for most smallholders unaffordable.

This generalization is misleading because any forms of *dry tillage* do not eliminate weeds - the seeds of which occupy the entire profile that is manipulated each season and proliferate immediately the rains commence, in the case of ridges, mostly on the softer soil along either side of the planted crop.

These farmers of whom there are millions, are accustomed to eliminating weeds that grow alongside or even before the emergence of the crop and the assumption that conversion to hoe Min-till alternatives requires investment in chemical weed control is mistaken. Applied correctly herbicides offer numerous important advantages but they are a choice and not essential.

It is also evident to anybody who observes how hoe ridge farmers weed i.e. by first scraping weeds off the ridge and then pulling the soil back from the furrows to reconstruct them, that it takes more effort and time than weeding crops planted on the flat.

However despite the many disadvantages of ridge culture these farmers have a significant advantage over ADP farmers because they are prepared before the onset of the rains and can choose the optimal time to plant. Depending on the season 2 to 3 weeding rounds will be required and will take about *45 to 60 days/ha* in total.

7.2 Flat Culture

- **Labour Inputs – tillage**

In Uganda, Kenya and northern Tanzania the majority of hoe farmers do not make ridges, they wait for early showers, dig over the whole field and make rows of planting holes into which they sow seeds immediately or as a separate exercise later. In effect they combine the first weeding round with planting. This task takes about *40 to 50 person days/ha* in regions of mono-modal rainfall and considerably more where rainfall is bimodal and two crops are grown annually. In effect this activity mimics ADP ploughing.

- **Weed Control**

For all farmers including these, secondary weeds proliferate rapidly irrespective of the tillage practices applied. Farmers who dig over the field to eliminate primary weeds before planting still have to remove weeds which emerge later in the crop and over a growing season will in total spend no less time weeding than hoe farmers who ridge their fields before the onset of the rains, and no less time than farmers who convert to hoe Minimum Tillage in advance of the rains.

Here, it is worth speculating how the opinion that Basin Min-till involves additional labour for hoe farmers arose? Efforts to extend the promotion of this practice in Zambia and Zimbabwe commenced 3 to 4 years after the 1992 drought. In Zimbabwe it has been estimated that over 1 million cattle perished or were lost due to disease or distressed sales with proportional losses no less significant in Zambia. With limited opportunities to hire ploughing services the alternative of Hoe Min-till promoted in these areas involved a reversion to manual labour and was bound to elicit negative reactions from farmers regarding the effort involved. Investigations of the pros and cons of CA tillage practices must compare *like with like* tillage systems.

It is also possible that if residues are not burnt and remain on the surface as recommended, they may interfere with hoe weeding tasks. Nevertheless, there is scant evidence to verify this assumption which is primarily based on data extrapolated from comparative plot trials into which heavy residues are introduced and has not been expressed as a deterrent by many thousands of farmers who have adopted CT.

It is also worth recalling that the early promotion of CA in Zimbabwe by NGO's required farmers to *mulch* their demonstration plots by removing biomass from surrounding areas and placing it in thick layers in the crop rows. This exercise, appropriate for small horticultural plots, is extremely labour intensive, was unpopular with farmers and may also have contributed to the view that conversion to Conservation Tillage (CT) requires overwhelming labour inputs and that heavy mulch cover can restrict crop growth by reducing soil temperatures during extended periods of overcast weather.

The description mulching is still referred to in many research publications on CA and is often not distinguished from residue retention which is an entirely different practice.

8 The alternative of Hoe min-till

8.1 The Basin System

Oblong holes about 20cms in length are dug in the dry season at 70cm spacing in the row and 90cm between rows. At the correct spacing there are about 15,800 permanent planting positions per hectare and no special equipment is required.

All that farmers need to convert to Min-till is a strong narrow bladed hoe, two 90cm sticks, a length of twine with bottle tops squeezed onto it at 70cm intervals and two pegs to hold the rope. Once the positions are marked out, holes the width of a hoe blade and about 15cm to 20cm in length, and 20cms deep are dug out.

In the first year digging will take between *20 to 40 days/ha* depending on the soil type and its condition. Although only about 12% of the surface area is disturbed, the task can take more time than expected due to compaction beneath the shallow layer of depleted top soil that is repeatedly disturbed by conventional tillage. In the first year of conversion, farmers who have ridged previously generally dig out the planting stations in the furrows between the remnants of old ridges and during weeding draw soil toward the crop rows producing a flat surface.

The aim is to provide a layer of soft soil under the planted seeds into which the young roots can establish and through which rainfall can percolate. Once established, the Basins are re-opened in the same positions each season the soil becomes easier to work and labour inputs decline.

The description Min-till **Basins** used by the CFU may have mislead some to assume that seed is planted in depressions similar to the ancestral **Zai-Pit** farming system that evolved in the western Sahel and has captured the interest of agencies working in arid zones as a method to concentrate rainfall and scarce nutrients.

The principles are similar but once Basins have been dug, basal fertiliser, manure if available, or combinations of both and lime if necessary can be applied before the onset of the rains. Once this task is accomplished the Basins are *backfilled to within 5cms of ground level* and when adequate rains occur seeds are planted and the soils is covered level with the surrounding field.

The name derives from a halo of moisture observed for several days after a rainfall event which results from the shallow slumping of softer soil surrounding each planting station into which rainfall from the more compact inter-rows percolates.

8.2 The farming systems benefits of hoe Min-till

As outlined in *Section 6.2* above the benefits are similar to ADP Min-till but are more pronounced particularly in drier seasons and many farmers who have advanced to versions of ADP Min-till still continue with Basins on portions of their fields because they know from experience that despite the initial labour inputs required, the practice invariably outperforms ripping furrows in drier seasons.

Perhaps an alternative if over simplified explanation of a fundamental aim of Min-till relative to annual row crop farming is that the inter-rows are the domain of weeds so what is the point of expending labour, draft power and in the case of mechanised tillage fuel to provide an ideal seedbed on 88% of the field unoccupied by crops in which weeds can flourish?

With regard to weeds and hoe weeding, the task is onerous for all farmers but as we have highlighted it takes no longer to eliminate weeds that proliferate alongside crops emerging in Basins than it does to remove them in advance by hoe-ploughing the whole field. And as explained earlier, the millions of hoe farmers who complete ridge tillage in the dry season also weed after crop emergence.

9 Precision and efficiency

In addition to the promotion of CA principles, the CFU extends practical advice to adopters on all crucial aspects of establishing and husbanding many different crops. All versions of Min-till provide a permanent in-field layout that improves the efficient use of whatever resources farmers have and whichever annual crops they grow by simplifying the provision of crucial agronomic recommendations by trainers and their application by farmers.

Attempts to desegregate the contributory benefits of the elements of CA are extremely difficult to isolate due to the interplay of innumerable external factors. Rudimentary examples of the complications that arise include the benefits of more efficient resource utilisation which are significant but extend beyond core CA principles. Investigations can also be confounded by the tendency of farmers to concentrate more of their labour and purchased inputs on converted fields because they have discovered the returns to their investments produce superior results.

10. Alternative CA tillage practice for hoe farmers

In Malawi Total Land Care (TLC) developed a less intrusive alternative where hoe farmers converting to CA apply *No-till.* The remnants of old ridges and residues are left undisturbed and seeds are accurately spaced and planted on top together with measured doses of fertiliser applied in the case of Maize. This practice has the significant advantage of reducing labour inputs for land preparation to almost zero and leaving the soil entirely undisturbed and overtime the fields transform to flat culture as the ridges decompose.

The technology evolved from earlier efforts by *Sasakawa Global 2000* across many countries in Africa which in Malawi focussed on the intensification of agricultural production through the demonstration of yield benefits which involved the provision of input support and the application of improved agronomic practices based on conventional ridge tillage including more optimal plant populations, herbicides for weed control and adequate fertilization of Maize.

Malawi in particular has benefitted considerably from long term farmer managed and carefully supervised trials the results of which are reflected in several publications including the paper- ***Evidence and Lessons Learned from Long-Term On-Farm Research on Conservation Agriculture Systems in Communities in Malawi and Zimbabwe - 2015, Thierfelder et.al.*** The results of this study clearly showed that Maize grain yields increase significantly (across a diverse range of soil types and rainfall patterns), - with the retention of crop residues on the surface compared with the conventional ridge and furrow system. The decision to use herbicides on the CA plots in some of these trials to investigate the cost/benefits may have contributed to the view among some peers that herbicides are an essential components of CA practice but can be discounted in respect of the results of these experiments since all treatments including conventional plots which were hoed manually, were kept weed free.

Of particular interest were the comparative results from *Zidyana* in northern Malawi an area with particularly fertile soils and high rainfall (well over 1000mm/pa) during the 9 year study period with the exception of one year, and *Zimuto* in Zimbabwe with poorer infertile soils and erratic rainfall of under 550mm/pa in 6 of the study years. The results showed benefits arising after 5 years in *Zidyana* and from the second year in *Zimuto* although Maize yields at this site were consistently low.

These results may have contributed to the assumption that the benefits of CA take time to emerge and are more suited to regions of low rainfall. This may well be true however agro-ecological domains are seldom predictive of rainfall patterns which can vary significantly within areas of 10kms or less. It also does not explain adoption in Uganda by 62,000 families applying elements of CA including the full package many of whom cultivate soils that are more fertile than those found in central Africa and in general benefit from more consistent rainfall. Under these circumstances, one would not expect adoption of the alternative tillage systems promoted by the CFU to be persuasive but farmers have noticed the benefits that arise from timeliness and precision.

Among alternative CA tillage systems there are always trade-offs. The Basin alternative promoted in Zambia described above is labour intensive particularly on heavily compacted soils in the first year but little more so than the effort involved in annual ridge culture. Is the *No-till* option sufficiently transformative in the minds of industrious Malawian farmers occupying regions of lower rainfall to persuade them to change and do the yield benefits take longer to emerge than via the more intrusive version practiced in Zambia? We avoid speculation but both systems have also been promoted in Malawi and should provide opportunities for some useful comparisons if not already investigated.

11. Mechanisation

In Section 3.2 page 5, we referred to the view reflected in many scientific papers, *'that incentives to adopt CA by households in the context of small-scale agriculture is constrained by the need for mechanisation'.*

11.1 Some background

It is unnecessary to dwell in detail on the early efforts to transform the manner in which soil is manipulated to establish field crops which was first attempted by a handful of commercial farmers in the US and South America in the 1960's in their attempts to minimize soil disturbance to mechanically plant seeds.

Suffice it to say this required abandoning ploughs and disk harrows and planting Maize and other wide spaced row crops with conventional seed drills into furrows opened up using modified cultivators or chisel ploughs while leaving the inter-rows undisturbed.

Clearly the early trailblazers were large scale farmers who had the opportunity to improvise and experiment with alternative tillage systems on small areas while continuing with conventional tillage practices to earn a living.

Ultimately close collaboration between farmers, scientists, agricultural engineers and manufacturers coupled with the parallel evolution of a wider range of herbicides gradually overcame many of the problems confronted by the pioneers and **Min-till** evolved into **No-till**, with one of the first seed drills manufactured in 1981 by *Roy Appelquist* of Great Plains Mfg.

Since then advances in design have continued and single, double or multiple row No-till planters suited to drill a wide range of seeds and fertilizer through crop residues into different soil types and drawn by animal power or tractors have become widely available.

11.2 No-till promotion in Zambia

In 2008, the CFU imported and tested various mechanised and ADP drawn 'No-till' planters and the agency for the latter equipment was taken on by a local agro-dealer. However utilisation by adopters is less than 1% since ADP versions cost in the region of $1,200 and micro-finance institutions were uninterested in offering loans. Various imported and locally manufactured hand held Jab No-till planters were also tested but were found to be impractical and unreliable.

Expensive No-till equipment is beyond the reach of the vast majority of small-scale farmers. However mechanised versions of Min-till service provision (MTSP), much like the ADP version is gradually expanding and becoming popular among small farmers particularly in Zambia and Tanzania and has now gained a foothold in Kenya, Uganda and Ghana.

A visit by the CFU to Kenya in 2007 where many hundreds of small commercial tractor operators migrate across the country each year and plough fields, (often before the onset of the rains), for small and medium scale farmers, raising dust, damaging soils and burning excessive amounts of fuel with the costs passed on to their clients, prompted the launch in 2011 of MTSP in Zambia in association with John Deere agents AFGRI with loans now provided by local Banks. The CFU worked with NDUME Ltd in Kenya to design tractor drawn Min-till rippers able operate effectively through trash and these implements are now manufactured locally.

11.3 Mechanised Min-till Service Provision (MTSP)

From zero less than a decade ago there are presently 220 operators in Zambia and an additional 70 or so in the above countries providing MT services to small and medium scale clients. MTSP is still in its infancy and progress is constrained by fluctuating exchange rates; the cost of finance; the requirements of banks to securitize loans; variations in seasonal liquidity in rural areas resulting from adverse seasons and in Zambia's case the late delivery of inputs and payments for Maize by the government's Farmer Input Support Programme (FISP) and the Food Reserve Agency (FRA).

The convention held for eons that 'ploughing is farming' is difficult to overcome. In 2017 the world ploughing competition was held at Egerton University in Kenya of all places and won by an Irish team and ploughing is still promoted by many manufacturers, development agencies and NGO's.

11.4 MTSP – equipment and support

From our experience the most appropriate equipment for MTSP service providers is a 65 to 70 HP 4wd tractor linked to a ripper with adjustable depth wheels, 2 parallel or offset tines with cutting discs set in front of the shanks and crumbles to the rear. Alternatively, a hydraulically operated 3 tine configuration set on a v shaped tool bar with adequate distance between the front central tine and the rear tines to allow the flow of residues through the unit.

Preferred width of the reversible points is 5.5 to 6.5cm and depth achieved 25cm and no less than 20cm. Operator training is essential and is provided in Zambia by

Through the CFU's lead farmer networks, potential customers are identified in advance so operators have sufficient work in any locality to make the distance travelled worthwhile. Farmers are also provided with practical guidelines to ensure the services provided are of the standard required to achieve good results.

11.5 Comparative costs of ripping and ploughing

- Ripping at customary 0.9m spacing takes 1.0 to 1.25hrs/ha and fuel consumption is 5.0 to 7.0lt/ha. Ploughing takes 3.5 to 4.5hrs/ha and fuel consumption is 13.0 to 15lt/ha.

- The cost of ripping to the client is $40 to $45/ha. The cost of ploughing is $95 to $105/ha. The depth of ripping is 20cm to 30cm and the depth of ploughing is 10cm to 15cms and in east Africa much of this work is done before the onset of the rains and the advantage of eliminating early weeds is not achieved.

- Typically experienced operators dry rip for 80 to 100 customers in a season with the most proficient servicing over 300 farmers and one operator this season ripping 617 hectares. The average area of land tilled per farmer ranges from 0.9 to 2.5 hectares and shows that the majority are small farmers.

After two successive dry seasons in Zambia, MTSP operators this years have in several areas failed to meet demand and paradoxically there is a risk that farmers expecting to receive the service will not have undertaken alternative Min-till options to be ready for the rains. The introduction of any novel technology involves risks, in this case particularly for the service providers who have to satisfy equity positions required by banks and interest based entirely on commercial rates. The careful screening of suitable applicants is essential and scheduling of loan repayments is structured to account for the seasonality of operations.

Nevertheless, it is interesting to note that in the UK in 2018, landowners received £3.5 billion of financial support from the EU's Common Agricultural Policy whereas novel ventures such as the above undertaken to enhance the productivity and climate resilience of small African farmers have to survive the test of outright commercial principles.

11.6 Other appropriate equipment

Fragile equipment such as zero-till planters and boom sprayers are not suitable for the provision of services to smallholders which involves travelling considerable distances on potholed and rutted tracks and operating in fields that may not be entirely clear of roots and other obstacles.

Trailers are essential to extend tractor usage throughout the dry season and PTO driven Maize and Groundnut shellers would also offer sound business opportunities by obviating the labour required to shell these crops for market which is commonly done by hand and in the case of Groundnuts particularly time consuming.

The principle stressed here is that the benefits of providing a loan to a single carefully identified, thoroughly trained and business savvy service provider to acquire an appropriate set of equipment can in different ways benefit hundreds of smallholders downstream.

Too often, the potential benefits of mechanization are considered inappropriate for small-scale agriculture because it is perceived in the narrow context of private ownership for use on individual holdings as is the case in commercial agriculture.

11.7 The benefits

The benefits are no different than those described in the above sections relating to Min-till other than the advantage of deeper penetration into undisturbed sub-soil thereby improving early root development and rainwater percolation, the elimination of labour for land preparation and the opportunity of farmers to graduate from hoe and ADP versions which have enabled them to increase their yields and afforded them sufficient disposable income to hire the services.

12 Herbicides

12.1 The weed problem

The negative social and economic consequences of weed competition for small farming households across sub-Saharan Africa has been the subject of research for over 50 years, and cannot be overemphasized. The struggle to control weeds in a timely fashion is the most significant on-farm challenge smallholders face and frequently results in severely depressed yields, crop abandonment and wastage of the resources they invest.

The failure to keep abreast of the proliferation of weeds is a universal problem for small farmers and pre-dates the promotion of CA by many generations and the suggestion that –*'If herbicides are not available the labour burden for hand weeding under CA is strongly increased,* is misleading.

There is no doubt that the rapid growth of extensive Maize production on the Tonga plateau in Zambia between the 1930's and 1950's and elsewhere resulted from the expansion of ADP plough farming because they could till much larger areas, had the advantage of inverting the first flush of weeds which provided a window of 3 to 4 weeks before cultivation was necessary either by ox drawn implements or labour provided by less fortunate neighbours.

However compared with the combination of farmers today who rely on hiring in oxen, who make ridges manually or dig over their fields across central and east Africa and all weed by hoe, ox owners are a minority, - according to most calculations representing only 14% to 16% of the total.

12.2 The promotion of herbicides

In 2008, the CFU first incorporated training on the use of herbicides to control weeds through its farmer to farmer training services. Before this the number of small farmers using them effectively was negligible although many thousands of farmers producing Cotton for ginning companies were familiar with the use of knapsacks to spray insecticides on their crop.

The promotion and use of herbicides by smallholders is frowned upon in some quarters but the critics have yet to come up with viable alternatives that would reduce the burden of hoe weeding by men and in particular women and children. In Zambia the first school term commences on the 14th/15th of February and coincides with peak labour demand for weeding. The task often starts at dawn and children arrive tired and inattentive or miss classes altogether.

Hiring labour to control weeds is still common in Africa and has its roots in traditional agriculture when relatives and neighbours would gather in groups and weed holdings often in exchange for beer brewed by the farmer's wife – a cooperative social event to get the job done!

Today hired labour is generally paid in cash or kind. Labour is generally scarce and often drawn from families who have insufficient Maize or other staples from the previous season to see them through to the next harvest and are compelled by circumstance to abandon tending their own crops resulting in failure to provide for the basic needs of their families.

12.3 Progress

During the 2018/19 season in Zambia statistical surveys undertaken by the CFU indicated that over 60,000 farmers were using herbicides to control weeds in areas covered by the current programme financed by UK-DfID. Adoption is not restricted to larger producers with farmers cultivating between 1 to 3 hectares comprising the majority because it is this segment of households upon which the CFU focuses its training services.

Most commercial farmers will acknowledge that the detail required to apply herbicides of the correct type in the correct quantities at the correct time is one of the most challenging tasks they face perhaps simplified these days by advances in computerisation that automate some of the more precise calibrations required.

Smallholders on the other hand are lumbered with the hydraulic knapsack sprayer a device invented by Paul Berthoud in 1895 and apart from various improvements to enhance its flexibility and efficiency remains more or less unchanged since then.

Using herbicides is a choice for small farmers, some with sufficient labour may not wish or need to use them others whose yields are poor with insufficient disposable income may not be able to afford them while others who can afford herbicides may be put off by the commonly held belief that they kill crops and poison soils. This is no surprise, the technology is outdated, difficult to use, prone to error and requires detailed training and support which the purveyors of equipment and chemicals are unable to deliver on the scale required. It is not merely the costs involved that are a hurdle to adoption.

12.4 The Obstacles

▪ **Using hydraulic knapsack sprayers**

- To spray 1ha of row crops planted at 1m spacing the farmer will walk 10kms carrying 15 to 20kg of water on his back. He has to continue pumping to maintain the correct pressure through the nozzle and walk at the correct pace to disperse the correct amount of product over the target. He has to refill the sprayer 7 to 15 times to complete the task and have 100 to 200 litres of clean water on hand to avoid blocked nozzles.
- Because it has moving parts the sprayer has to be in good condition and spares have to be available locally. The farmer must use the correct nozzle for the purpose required to achieve the application rate/ha recommended by the manufacturer of the product and the pattern of spray required to cover the target.
- The farmers need to know the most reliable and robust sprayers on the market for which spares are available at local agro-dealer outlets.
- The farmers have to be able to interpret the recommendations on product labels which are normally presented as the quantity to be applied per ha and calculate the correct quantity to mix in each tankful.
- Farmers have to understand the difference between pre-emergent and post-emergent, non-selective and selective herbicides and know when each should be applied to achieve good results, to which crops they are suited and when and in what conditions they should be applied and products that are not purchased and exceed their shelf life have to be safely disposed of.
- The farmers have to understand and comply with safety recommendations during use and ensure the safe disposal of empty product containers.

▪ **The products**

Since the CFU commenced training farmers there has been a huge increase in the number of products available on the market. For example there are 22 brands of glyphosate containing 360g/l or 480g/l active which require different application rates while others are labelled as salts.

There are 32 brands on the market which farmers are advised to avoid either because they are hazardous such as Paraquat or in the case of pre/post emergent herbicides used for Maize are unsuitable because they have extended residual effects which can damage legumes or other crops planted in the following season.

- **Health and safety**

- Exposure of farmers to hazardous chemicals from spillage during mixing and leakage from poorly maintained sprayers during use.
- Environmental pollution arising from spray drift and run off from plants.
- Inadequate protective clothing because farmers cannot afford the attire or it is too uncomfortable to wear in hot conditions.

12.5 Electrodynamic spray technology – a potentially superior alternative

In the early 1980's Ron Coffee a scientist working for ICI's Plant Protection Division developed the alternative of electrodynamic spraying based on the principle of electrostatic forces to create mutually repellent positively charged droplets of spray that attract to the negatively charged target plants.

The device called the *Electrodyn* was originally designed specifically for small-scale farmers producing Cotton who were exposed to the hazards of spraying insecticides on the crop with knapsack sprayers. Cotton suffers more pest pressure than any other major cash crop and it is estimated that globally 16% of all insecticides are applied to Cotton which occupies about 3% of the total area planted to commercial crops.

After further development and extensive field testing in many countries the Electrodyn was promoted and sold among Cotton producers in India, the Cameroon, Angola, Mozambique, Zambia and Brazil and proved highly effective in the control of target pests.

For users the device had many advantages over hydraulically operated knapsack sprayers including:

- Pre-formulated oil based chemicals contained in a sealed screw-on 'Bozzle', no mixing of chemicals, no guesswork and no spillage.
- Nozzle restrictors fixed during manufacture governed sprayer output.
- Application rate determined by walking speed only. No variation in flow rate due to fatigue from constant knapsack pumping.
- No moving parts. Low power requirement. 4 x D-R20 quality cell batteries last 40 to 60 hours, potentially a whole season for small farmers.
- Charged spray droplets attracted to both sides of foliage no spray drift into adjacent crops.
- Reduction in insecticide active ingredient by up to 50%.
- Weight of Electrodyn with full bozzle 2.5kgs. Ideally suited to use by both men and women.
- 5 to 6 hours to spray 1 hectare compared with 15 to 18 hours with knapsacks.
- Application rate of oil based chemicals 0.5 to 1.5 litre/ha.

In the early 1990's ICI shelved further development and promotion of the Electodyn. The supply of Bozzles restricted to a sole supplier led to issues regarding lack of competition. The active ingredients were limited to ICI patented synthetic pyrethroids with an inadequate range of alternative insecticides to avoid the build-up of pest resistance. Also, insufficient focus on intercompany negotiations to acquire products necessary to expand the product range, the success of the prevailing business model focussed on selling high volume products worldwide suited for use through knapsack sprayers and the breakup of ICI.

For the benefit of smallholders worldwide the technology should revisited. To compete with the flexibility of knapsacks the device must be capable of delivering a range of both herbicides and insecticides to control weeds and insect pests.

The proposed pathway envisaged would involve close collaboration between a University with proven expertise in electronic and mechanical engineering and an agro-chemical company with expertise in the formulation of bio-chemical products followed by rigorous field testing and ultimately commercialization.

The risks should not be underemphasised; multinational corporates have a vested interest in the volume sales of pesticides delivered at high dosage rates irrespective of the downstream ramifications. Similarly, corporates who sell knapsack sprayers worldwide have a vested interest in protecting the status quo.

The efforts of stewardship organisations and regulatory bodies concerned with limiting the social and environmental hazards of pesticide use by small farmers are hindered by outdated spray technology that is unsuited to their aims and should be interested in contributing to the R&D costs necessary to revitalise the technology.

13 The promotion of CA in Africa – what is the future?

13.1 Uncertainty

Among the growing volume of scientific publications on CA in Africa there are many which irrespective of the challenges shed a positive light on the benefits of the practices from social, economic and soils perspectives. Nevertheless, the signals emanating from research institutions are mixed and from the viewpoint of donors the benefits remain clouded with uncertainty.

With a highly experienced team, uninterrupted support from Norway for over 20 years and from the British DfID since 2016, the CFU has been in a position to focus almost exclusively on the promotion of CA and the supportive initiatives and technologies necessary to eliminate some of the barriers to adoption. We started small learned on the job, made mistakes, followed some blind alleys but in doing so learned from farmers themselves what was of value to them irrespective of numerous external factors that lie beyond their control.

Breaking through the inertia arising from longstanding traditions, peer pressure, misunderstandings and the fear of novel ideas is not a characteristic limited to small farmers, but for them it is amplified by the anxieties and pressures of transitory food insecurity, climatic uncertainty and poverty,- of existing on the edge.

Adoption of the various elements that comprise CA in Zambia and East Africa, where the CFU operates may be considered limited set against the backdrop of many millions of farming households who experience low yields, stagnant productivity, declining soil fertility and the consequences of climate change. Nevertheless it continues to be the largest endeavour of its kind and the indications signalled by farmers themselves are promising.

13.2 The CFU's operations

It is not necessary in this paper to detail the many supportive activities undertaken by the CFU required to facilitate the adoption of CA which include the expansion of rural agro-dealer networks stocking appropriate hardware, herbicides, legume seeds, lime, fuel efficient stoves, solar devices, etc., so prospective adopters can access the items they need to convert and those who have generated surplus income through productivity gains can purchase items that may not have been affordable previously. And more recently the facilitation of input supply, crop aggregation and marketing services centred on progressive lead farmers.

Gains in agricultural productivity unlock numerous opportunities and there is no doubt that private sector engagement in the delivery of input supply and marketing services to the small-scale sector has increased considerably over the past decade.

Nevertheless, the engine room driving progress is anchored is the training and advisory services provided by lead farmers (experienced practitioners) of whom in Zambia there are presently 2,700 each providing 3 to 4 discrete and voluntary training sessions on different CA topics before the onset of each planting season to groups of 25 to 30 farmers men and women alike. Prior to the 2018/19 season 269,000 farmers of whom 45% were women attended training, some new to CA and some already adopters wishing to enhance their knowledge on specific aspects.

Toward the end of each season field days are held on adopter's fields and last year 255,380 farmers of whom 46% were female attended. At larger venues traditional and administrative leadership, agricultural ministry staff, agro-dealers, seed companies and NGO's are also represented. We believe these numbers alone reflect a genuine interest in CA.

Field surveys undertaken by the CFU's ME section showed an increase of 61,900 new adopters in 2018/19 and a surge in MT land preparation between August and November this year suggests this number may increase by a significant amount in 2019/20. Cumulative adoption of MT, CT and CA in Zambia, and in the east African countries - Uganda, Kenya and Tanzania where the CFU operates through In-country partners is estimated to be approaching 400,000 farm families.

13.3 Promotion and Adoption

The consensus among many scientists that despite the extensive scaling up agenda 'CA' adoption is sporadic and limited is undoubtedly correct when it is considered that in East and Southern Africa alone Maize mixed farming systems comprise 32 million hectares of cultivated land, (FAO).

Disregarding the imponderables surrounding terminology, recent data on adoption shows 65% to 70% of farmers in South America now apply CA, whereas in the USA less than 15% fully comply with the FAO definition with 35% converting to No-till and among these 27% advancing to Conservation Tillage (CT).

In the UK No-till is applied on 3.2% of arable land and to what extent this relates to compliance is unknown. This data reflects that adoption is moving in a positive direction but also that it is a stepwise process not only for small farmers in Africa but also for mechanised farmers with access to sophisticated scientific and technological innovations.

Set beside the overwhelming numbers involved, the need to transform the manner in which farmers in Africa establish their crops toward more productive, sustainable and climate resilient alternatives, is a daunting challenge.

However, to what extent the heated debate regarding the merits of the promoting CA in Africa is matched by effective investments that drive down to the farm gate and deliver face to face practical knowledge to farming communities by organisations with the necessary experience, is questionable.

There are many agencies doing good work, but the promotion of CA is often comingled with all manner of community based social welfare initiatives that complicate management and divert attention from the delivery of the knowledge intensive technical detail required to achieve positive results.

Implementation by NGO's who do not have the necessary background and expertize is often weak. Poor results feed scepticism among farmers and offer researchers, who seldom appreciate the broader contextual background, a wealth of information that casts uncertainty on the benefits of the practices.

Food relief and other unnecessary incentives have been and are still offered by NGO's to entice farmers to adopt CA with disastrous effects when they are abruptly removed.

The institutional landscape relative to support for African agriculture and many other development sectors is extremely complex and more politicized than previously. The commitment by the UK and other countries to spend 0.7% of GDP on foreign aid annually is a noble objective but places significant pressures on institutions to meet arbitrarily set political targets while at the same time identifying investments that have a genuine impact and deliver value for money.

Donor priorities, policies, investment frameworks and strategies are subject to constant review and change, and in an era of mass communication, institutions responsible to politicians for the utilization of public resources have to take account of the concerns of numerous influential lobby groups.

At national and institutional levels platforms exist to improve the coordination of aid delivery in different sectors including agriculture however this aim is less evident on the ground. The direction and formulation of investment programmes are driven by predefined policies and the need to publicize the virtuous intentions of the institutions involved to audiences that are detached from the intended beneficiaries and their most pressing needs. Constrained by these barriers, consultants charged with the responsibility to identify potential investments seldom take account of existing initiatives that show promising results. This leads to a lack of lateral integration between discrete programmes with contrasting expertise but similar objectives which would amplify impact and avoid fragmentation, confusing signals to farmers and unnecessary wastage of resources. The question by itinerant consultants seeking investment opportunities 'what are you doing' is often raised but the more important question 'what could be done to leverage the impact of your efforts' is seldom if ever posed.

With the exception in our case of Norway's enduring support to the CFU, CA is promoted through discrete projects with lifetimes of 4 to 5 years, whereas it should be perceived as an endeavour and supported for as long as it takes to have a meaningful impact on a scale demanded by the present and future challenges confronting African farmers.

The recent paper ***Conservation Agriculture Systems, JP Mitchell, DC Reikosky et.al;*** proposes that the core principles of CA provide a unifying framework for sustainable food production systems options variously portrayed as Good Agricultural Practice (GAP), Sustainable Agriculture and Rural Development (SARD), Sustainable Intensification (SI), Ecological Intensification (EI), Climate Smart Agriculture (CSA) and more recently Climate Resilient Agriculture (CRA) etc. We agree wholeheartedly with the author's conclusions but the meaningful transformation of small-scale agriculture in Africa will take decades to achieve and has limited traction among politicians and development institutions constantly seeking modish alternatives to a challenge that from past experience appears intractable.

This is not surprising, from the 70's to the mid 80's, huge resources were invested in Agricultural Development Programmes (ADP's) and Integrated Rural Development Programmes (IRDP's) in Africa. The construction of feeder roads, the provision of seasonal loans, the distribution of improved seeds and fertilizer, train and visit extension services, efforts to diversify cropping patterns and to organize farmers into self-managed associations to inculcate business acumen and enable more efficient marketing of commodities were in varying degrees all part of the development mix. These efforts delivered some important infrastructural benefits to rural communities but by and large they failed to increase agricultural productivity and the expected social benefits because they were superimposed on farming systems that were inefficient, unnecessarily wasteful and unproductive.

In some countries nationally driven cooperative movements were perceived as the most appropriate route to achieve rural development. However the institutionalization of hierarchies to manage their affairs became politicized and the productivity required to generate meaningful surpluses by individual members was insufficient to provide the collective bond required to hold them together.

13.4 Research and Development

Nobody can deny the crucial importance of research but science is never settled and it can become a self-perpetuating activity with researchers dialoguing and competing among their peers for recognition, influence and status, with the complexities involved providing a bounteous scientific arena for proponents and critics to dispute their claims.

Farmers are oblivious of these debates and from the CFU's perspective we would argue that the drivers of CA in the ECA areas where we and other experienced promoters operate are the practitioners themselves and what better advocates are there than farmers prepared to invest their time and resources in methods that were previously entirely foreign to them.

There are many avenues or research that must be pursued but these should include investigations to resolve the difficulties confronted by farmers who have converted to MT and CT but in the circumstances in which they operate are inhibited from advancing to the final step. Furthermore, research and promotion of systems which may have been shown to provide agronomic benefits but for various reasons have no utility for farmers as expressed by themselves, should be avoided.

- **Measuring the potential of CA – broad based surveys**

Sampling techniques and statistical procedures to eliminate bias in the implementation of broad based agricultural surveys investigating various perspectives are thoroughly developed and widely applied. If enumerators identified for the purpose are conversant in the skills required to glean accurate information from farmers which is not always the case, the data generated captures the entire range of performance, - those who are thoroughly conversant with the practices, those who are new to them and those who apply them defectively.

This information is valuable as it reveals trends that can guide implementation and the direction of research. However it says little about the performance of the technologies in the hands of top operators who apply best practice and from whom much could be learnt regarding the potential of CA.

- **Build-up of soil organic carbon**

The results of studies on the build-up of SOC and soil fertility under CA are inconclusive. Research by ***Cornelissen and Martinsen et. al; - NGI;*** undertaken over 7 years at a site in Zambia with MT basins receiving lime and fertiliser each year under strict management showed significant improvement in soil quality inside the basins as compared with outside. Whether or not these benefits extend to farmers in less controlled conditions including those who apply different forms of hoe ADP and mechanised MT is uncertain but deserves further investigation over the long term.

- **Legumes and diversification**

- **Availability of improved varieties**

The common standard applied for full compliance with CA requires 30% of cropped area to be occupied by legumes either in rotation or as intercrops is the most daunting challenge faced by promoters in Central Africa. The combined proportion of legumes grown in Zambia primarily Groundnuts, Field Beans, and more recently Soya Beans occupy less than 10% of cultivated area overall with the former two concentrated in Eastern and Northern Zambia. Numerous value chain studies more recently by the **Indaba Agricultural Policy research (IAPRI)** and the **Pan Bean Research Alliance (PABRA),** reflect the challenges and potential opportunities to expand and integrate the production of traditional legumes in Zambia into cropping systems.

A frequent theme reflected in these papers is the lack of availability of improved varieties of both crops developed through collaborative research between local and regional institutes, leading to the continuous re-cycling of inferior varieties. If at considerable cost public resources are applied to develop and release elite varieties is there not a case to commercialize multiplication and subsidise prices at the point of sale (agro-dealerships) to provide the quantities required at affordable prices to accelerate diversification? The preferred alternative of identifying farmers to multiply seed is slow and subject to contamination and varietal degeneration through insufficient isolation and cross pollination with unimproved varieties.

- **Intercropping – a contextual challenge**

As noted earlier, Maize/Legume intercrops are common in the plateaus of east Africa, usually planted as alternative rows of each. The *Mbili* system developed by researchers in Kenya where the configuration was changed to two rows of each crop increased crop yields and economic returns by reducing competition for light and nutrients. Further essential details are presented in papers by ***Mucheru-Muna,Woomer et.al;*** and others. The 2:4:2 Maize/Cowpea /Maize configuration promoted by IITA in west Africa has also been shown to be best suited to areas where the return from the legume justifies devoting less land area to a cereal crop.

In regions where severe population pressures restrict cultivation to 1ha or less, small farmers concentrate on Maize to ensure basic food security and intercrop configurations involving the replacement of Maize with Legumes is extremely challenging particularly in central Africa where the growth of mono cropped Maize at lower altitudes with higher temperatures is rapid and aggressive. Determination of Land Equivalent Rations (LERS), generally show that the combined production of cereal legume intercrops is more productive than monocrop alternatives. However where staple yields are low and land is restricted farmers are often unprepared to exploit this advantage.

The release of hybrids and to a lesser extent OPV dent and flint varieties that are disease resistant, drought tolerant, bio-fortified, and tailored to perform in a wide range of agro-ecological zones, continues to accelerate with significant benefits to farmers who have access to them as reflected in the gradual increase in national Maize yields over the past two decades in ECA. Nevertheless few farmers manage to exploit the anywhere near the commercial potential offered by the most recent releases of 7 to 11 tons/ha, or even half the potential yield of the earlier hybrids released in the mid 60's and 70's.

We have no expertize in the area of Maize breeding but much of the dramatic progress in achieving the full expression of Maize yield potential has arisen through the genetic manipulation of plant architecture to achieve increased tolerance to high plant densities when grown as a monocrop.

Some research investigating the performance of Maize varieties at low plant densities have been undertaken in Kenya , Australia and elsewhere. The evidence is unsettled but suggests that older synthetic and hybrid varieties with multi-cobbing or prolific characteristics may be better suited to intercropping.

With average smallholder Maize yields in ECA fluctuating between 1.5 to 2.5 tons/ha there should be room to reduce Maize populations and arrange intercropping geometry to enable farmers limited to small areas of land to increase Maize yields to 3.5 or 4 tons/ha, produce reasonable legume yields and benefit from the synergies that arise. This may involve increasing fertiliser application rates on Maize rows but may also reduce total requirement compared with the monocrop alternative. Whether farmers would be attracted to this variant would of course also depend on the scope of government input and marketing interventions to encourage the production of Maize.

The challenges are complex, experiments undertaken in Malawi reported by ***Thierfelder et.al;*** and many other scientists have demonstrated the agronomic benefits of under-sowing Velvet Beans, Jack Beans Tephrosia and other non-edible legumes to Maize. However, research has also indicated that edible alternatives that are marketable are preferred.

Perennial Pigeon pea is widely cultivated in semi-arid regions of Kenya, Tanzania and particularly southern Malawi where there is a robust local market for the crop. Pigeon pea is deep rooting, drought tolerant, provides leaf litter, improves soil structure, fixes N and also has numerous benefits including the consumption of immature seeds and pods as green vegetables, with leaves and stems used for fodder and dry stems for fuel wood.

The paper ***Assessment of the Current Situation and Future Outlooks for the Pigeon pea Sub-sector in Malawi F. Simutowe et.al, -*** among other reports details collaboration between researchers, seed companies, government institutions and development agencies to promote the adoption of the crop and the ongoing challenges Malawi faces to retain its position as hitherto, the largest exporter in ESA of the crop.

Among edible grain legumes that can be successfully intercropped with Maize in densely populated semi-arid zones Pigeon-pea stands out as a prime contender. However, the challenges confronting wider utilisation of this highly beneficial crop highlight the hurdles confronting the pathways to full compliance with CA in context specific circumstances.

- **Legume fallows**

In situations where farmers had access to more land than they commonly cultivated or where portions of land have been abandoned due to excessive soil depletion the CFU attempted to encourage reoccupation through the planting of fallows particularly Velvet Bean (*Mucuna pruriens*) and Red Sunhemp (*Crotalaria ochroleuca*). These efforts failed to take hold because the crops had no market value.

- **Agro-forestry**

- **Alley farming**

Alley farming conceived in the late 1970s by researchers at the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria, involving the combination of deeper rooting leguminous trees and crops to replenish soil fertility. Despite the investment of significant resources in research and promotion in ECA this promising technology has failed to be widely adopted due to the excessive labour requirements involved and various other limiting factors summarised in the paper ***Alley farming: have resource-poor farmers benefitted, J Carter ODI.***

- **Faidherbia albida**

The numerous benefits of *Faidherbia albida,* a deep rooting leguminous tree, widely distributed across the Sahel and east and central Africa in regions of mono-modal rainfall with the unique characteristic of reverse phrenology, (sheds its foliage in the rainy season), have been established since the 1950's.

Analysis of four years of trials by the CFU involving Maize, Cotton, Groundnuts and Soya beans grow in CF Basins under and outside the canopy of mature trees without fertilize showed average Maize yields of 4.0 tons/ha under the canopy and 2.4 tons/ha outside. As expected there were no additive benefits for the legumes while Cotton yields were depressed by fungal diseases and increased shading effects toward the end of the rains.

A sustained effort by the CFU over 8 years involving the provision of seed, sleeves and training in the construction of small air pruned trellises and seed clipping to enhance germination perfected by Total Land Care Malawi (TLC) to avoid the costs involved in the transport of seedlings was technically successful. However since the benefits take 15 or more years to materialize farmers were more concerned with their immediate needs. Nurseries were neglected seedlings were often not planted out, were weeded by mistake or damaged by uncontrolled bush fires.

Incentives for farmers to establish and protect these highly beneficial trees including the provision of Carbon credits despite the daunting complexities, or other potential alternatives should be considered.

- **BioChar**

Over the past 7 years the CFU has collaborated with scientists of the Norwegian Geotechnical Institute (NGI) who are also involved in initiatives in Indonesia/Malaysia, Nepal, Tanzania and Brazil, aimed at investigating the potential of Biochar produced from organic waste to sequester carbon and improve soil quality. The promising results of these experiments on acidified sandy soils in particular, and progress relating to practical approaches to enable small farmers to benefit from the manufacture of Biochar and can be accessed from NGI's website. Suffice it to say that Min-till alternatives involving the establishment of crops in relatively permanent planting positions are well suited to targeted application.

- **Micro-biological Agronomy**

Are there opportunities for small farmers to benefit from the recent advances in micro-biological agronomy involving the manufacture of inoculants of microbes that have numerous beneficial effects on plant growth and which are being increasingly exploited by commercial farmers?

- **Equipment**

Can further improvements be made to ADP and mechanised rippers, can the Chaka hoe designed by the CFU for digging Basins be lightened; could electrodynamic sprayer technology replace hydraulic knapsacks; could the improved weed-wipe device (the Zamwipe) developed by the CFU be revisited and improved and could drones be used to augment field surveys designed to measure adoption?

11 Conclusions

The CFU takes no credit for the development of Conservation Agriculture which has evolved over many decades through the work of famers, scientists, enthusiasts and numerous organisations. Perhaps we can take some credit for is evolving practices that are simple for farmers to understand and adopt and despite the ongoing debate regarding the pros and cons of CA the results achieved by adopters speak for themselves. Our interest in writing this paper was prompted by the need to reach beyond the abstract theories and debates that are clouding the horizon and to advocate on behalf of African farmers for the effective promotion Conservation Agriculture, (call it what you like), - for the millions who have never heard of it or may have but have never benefitted from sound practical advice.

It may be considered heretical, but over the past 25 years we have seldom been enlightened by academic publications on CA and only delve into them when we are challenged to do so, because they have no content that we can grasp that offer viable innovations for farmers. The technologies we have evolved have arisen from experience from working alongside farming families on a daily basis, understanding their perspectives and what is practicable in their circumstances and what is not.

In Zambia there are farmers who have applied some or all of the elements of CA for over 15 seasons continuously; farmers who can for the first time afford to send their children to school; families who can go about their farming activities and no longer have to supplement their food reserves or cater for unforeseen demands for cash by hiring out their labour; families who have produced yields in adverse seasons when their neighbours have failed; womenfolk and children liberated from the ardours of weeding their crops by hand; families who have invested in improving their houses, purchased livestock, bicycles solar equipment, TV's and other items. The descriptions are not virtuous signals or aspirations that may accrue in the future, they are facts. In Uganda, Tanzania and Kenya where the CFU operates through partners albeit on a smaller scale, adopters are equally positive about the opportunities offered by the simple technologies to improve their livelihoods.

There is a wealth of diverse information that can be gathered from adopters and we would welcome any scientists, individuals or organisations interested in CA to come and interact with those who do all or bits of it – the farmers themselves.

We conclude by highlighting the perspectives reflected in the ***International journal of agricultural sustainability, Ndah, Schuler, Diehl et.al.***

'We assessed the reasons behind positive CA adaptation and adoption trends in Zambia. Main reasons behind Zambia's emerging success are (1) a positive institutional influence, (2) a systematic approach towards CA promotion – encouraging a stepwise adaptation and adoption, and (3) mobilization of strong marketing dynamics around CA. These findings could help to eventually adjust or redesign CA promotion activities. We argue for a careful shift from the 'dogmatic view' on adoption of CA as a packaged technology, towards adapting its principles to the small-scale farming context of SSA'.

Peter J. Aagaard Co-founder CFU.

Ps. On the following pages we have included a few photos to highlight some of the points we have made in this paper. More detail can be accessed from the *'CFU Reference Manual for Field Managers, Agronomists and Promoters'* on the website *conservationagriculture.org*

Conventional ADP Tillage:

Seeding behind the plough

Poor emergence

Ridge weeding with plough

Exposed Maize roots after ridging up

Late ploughing

Ploughed field weed infested, abandoned

Manure dumped before spreading and ploughing

Degraded land infested with Cooch grass and abandoned

Conventional Hoe Tillage:

Dry ridge splitting - Zambia

Ridges prepared for rains - Malawi

Large ridges prepared for rains - Tanzania

Weed emergence after onset of rains

Dry hoe dug hillside fields - Kenya

Wet hoe dug fields - Uganda

Wet hoe digging weeding and planting - Zambia

Sheet erosion ridged field

Conventional Mechanised Tillage:

Dry ploughing – Kenya. Weeds will emerge with first rains

Many small farmers rely on disc ploughing

Dry ploughing – Tanzania

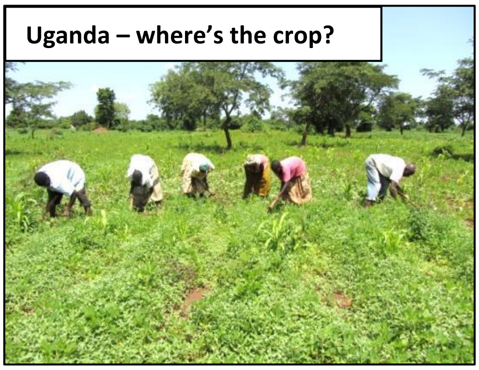
Late wet ploughing – Zambia

Weeds – a problem for all farmers:

Weed emergence in poor crop after dry ploughing – Kenya

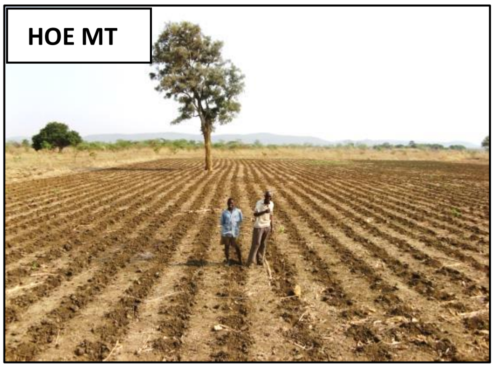
Late hoe weeding after ADP plough hire - Zambia

Kenya



Uganda – where's the crop?

A few examples of MT – CT and CF/CA



Early rainwater harvesting around Basin

ADP ripping through light Maize residue after communal grazing

ADP ripping through heavy Cotton residue

Mech. CT service provision Kenya through heavy Maize residues

Mech. MT service provision Zambia through light residues

Applying manure, seeding and covering – targeted nutrients, timeliness and precision application

With sufficient examples of what farmers could achieve the CFU abandoned demonstrations in 2002.

Simple, practical and efficient

Faidherbia albida **trials – Zero fertilises**

Maize performance under and outside canopy of mature trees

Given sound practical advice small farmers can achieve excellent results and progress using whatever resources they can muster

Spraying Cotton with the Electrodyn circa 1985