BEST FIT PRACTICE MANUAL ON REDUCED TILLAGE FOR MAIZE PRODUCTION

Applicable for Mid-Altitude Areas Including Dera, South Achefer, Burie and Jabi Tehenan Districts of North-western Ethiopia

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Capacity building for scaling up
of evidence-based best practices
in agricultural production in Ethiopia

The CASCAPE project is designed to assist the activities deployed under the Agricultural Growth Programme (AGP) by further strengthening the capacity of AGP stakeholders in identifying, documenting and disseminating best practices in agricultural production. CASCAPE is jointly executed by Ethiopian researchers from Jimma University, Haramaya University, Bahir Dar University, Hawassa University, Mekelle University, Addis Ababa University and Dutch researchers from Wageningen University and Research Centre. In each site researchers from the universities and from the RARIs from different disciplines work on the CASCAPE project. The CASCAPE project is financed by the Dutch Ministry of Foreign Affairs through the Embassy of the Kingdom of The Netherlands.

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Acronyms/Abbreviations

ACSI	Amhara Credit and Saving Institute
AGP	Agricultural Growth Program
BoA	Bureau of Agriculture
CASCAPE	Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia
DAs	Development Agents
DoA	District office of Agriculture
FTC	Farmer Training Centre
NGOs	Non-Governmental Organizations
MoARD	Ministry of Agriculture and Rural Development
PRA	Participatory Rural Appraisal
TOT	Training of trainers
ZOA	Zone Office of Agriculture

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1. Introduction

This manual describes the tested and validated best practice that has been tested by CASCAPE project in South Achefer, Bure and Jabitehenan Districts. The practice described here are deemed proven enough to be handed over so it can be scaled out to many more farmers. This manual is written for staff of the BoA, SMS and DAs.

Minimum tillage is a relatively new concept for many farmers in Ethiopia and in Amhara region too. It involves minimizing the number of ploughs on a field to one time to place the fertilizer and seed. While, the common practice in many maize growing areas is to plough multiple times, which is labour intensive practice (ploughing and weeding) and also has detrimental effects on soil health because the soil surface is left largely exposed.

Soil degradation has been one of the main challenges to maintaining soil quality and ensuring high crop productivity and food security in Ethiopia. The primary causes of soil degradation including soil erosion and loss of soil organic matter are strongly associated with soil management and tillage systems in particular. Reduced tillage is a suitable practice to prevent soil degradation as compared to traditional practice (four to five times ploughing). Thus, reduced tillage practice is the best practice from an environmental point of view through reduced soil and nutrient loss from flash flooding that finally lead to reduction in crop production.

In addition to reduction of production costs advantage from reduced tillage. The practice is also beneficial for farmers who do not have draught animals that spent about 50 percent of their harvest for ox rent. Particularly, female-headed households will benefit a lot from the practice. Currently the use of animals for traction power is priority in the livestock sector than milk and meat production which is resulting in poor profitability of the farming system. A change in the composition of the livestock population towards milk and meat production will not occur unless the tillage system is modified. Thus, introduction/promotion of reduced tillage will enable farmers to replace animals for traction with animals for meat and milk production, which may increase the overall productivity of the livestock sector.

In addition to the above benefits, minimum tillage has great economic advantages over the traditional farming practice. The farmers' preference analysis also indicated that minimum tillage practice is chosen against the traditional practice for its labour saving for ploughing and weeding. It was also found more productive than the conventional ploughing. Besides, reduced tillage practice enables farmers to save time during planting. As per to their experience with reduced tillage one farmer can plant 0.75 ha of land per day while in the conventional practices it takes three days to plant 0.75 ha of land.

Generally, the best practice tested by the project was found very promising with respect to the environment, productivity, labour saving and profitability and is highly demanded by farmers. Writing of this best fit practice manual based on the project practical experiences is essential for wide spread dissemination of this best practice.

2. Testing of reduced tillage practice

Validation of reduced tillage practice in maize was carried out in 2013 and 2014 cropping seasons. In 2013, the practice was evaluated against the traditional tillage in south *Achefer* District on six farmers fields' on a plot size of 25 m by 25 m. In 2014, it was tested at three districts, on 10 farmers' fields and one FTC on a plot size of 50 m by 25 m. The altitude, rainfall and temperature of the intervention districts is given in Table 1.

Table 1: Altitude, mean annual rainfall and temperature of the study districts

Attributes	Districts		
	S/ *Achefer*	*Burie*	*Jabit*ehenan
Altitude(m)	1500 - 2500	700 - 2300	1500 - 2300
Rainfall (mm)	1450 - 1594	900 - 1400	1250
Temperature (^{o}C)	15 - 23	17 – 25	14 – 32

Source: District office of Agriculture

A combination of post-emergence herbicide (roundup) and pre-emergence herbicide (primagram) was applied on the reduced tillage plots to avoid weeds throughout the growing season (Figure 1) and compared against traditional farmers' practice. The post-emergence herbicide was applied at the rate of 4 liter/ha sprayed 6 days before planting while the pre-emergence herbicide was applied at the rate of 3 liter /ha 2 days after sowing.

For the reduced tillage practice, the soil was disturbed only to place the seed in the soil at the time of sowing (seed row formed using local plow). While, for traditional farmers' practice the soil was tilled five times using local plough, "maresha". Regarding to weeding, the plots with conventional practice were handed weeded three times. While, the reduced tillage plots sprayed with both pre and post emergence herbicides were not weeded at all. However, in some cases grassy weeds like cynodon dactylon emerged late (around September) and farmers used such grassy weeds as a source of feed through cut and carry system.

Figure 1: maize field planted using minimum tillage practice

3. Best fit production practices

3.1 Development pathways

The promotion of best practices should be designed in the context of the broader development pathway for a selected location and the factors that shape the nature of particular development pathways. What are the comparative advantages for a specific geographic area and its household groups (target groups) and what best practices help develop such opportunities? What are the factors influencing the spread or inhibition of uptake of the best practices in each path? Farmers adopt best practices that help them exploit the comparative advantages provided by the development path and therefore transform their livelihoods.

Based on data collected from the base line survey of the project and current observation, the validation development pathway analysis result was summarised based on three main factors namely; agricultural potential, population pressure and market access. Validation of minimum tillage on maize production was introduced for the last two consecutive years at

South *Achefer*, *Burie* and *Jabitehenan* Districts. The result of minimum tillage development pathway analysis is presented in Table 2.

Table 2: Development pathway analysis for validation of minimum tillage for maize scaling out

Agricultural potential	Market and infrastructure access	Population pressure
High rain fall	Potential local and Regional markets	High population density(land shortage)
Availability of irrigation	Accessibility of high way and all weather roads	shortage of livestock feed(cattle and small ruminants)
Availability of well drained fertile soil	Accessibility of finance for input supply	Shortage of oxen for traction power
	Availability of grain transportation facilities like cart and others	Shortage of labour and time

As indicated in Table 2, the development pathway analysis revealed that the agricultural potential of the intervention areas are characterized by high rain fall, availability of irrigation and well drained and fertile soils. The presence of good road networks in these areas provided opportunities to have access to high local and regional market. The development pathways analysis had also showed that farmers having shortage of draft animals, labour and time for ploughing and weeding maize farm should be considered in scaling up of this practice. In these areas and areas with similar agro-ecologies and market infrastructure, therefore, the innovation would contribute to achieve sustainable production, productivity and food security.

3.3 Recommendation domains for specific practices

Recommendation domains are defined as a group of farmers whose circumstances are similar enough that the same recommendation can be given. In other words, places and sets of conditions for which a particular target technology is considered feasible and therefore good to promote. The specific conditions for minimum tillage technology adoption are given in Table 3. The specific particular information obtained in the recommendation domain analysis leads that areas in the mid to lowlands with reliable input supplier (chemicals), market access, local processors and traders (wholes sellers and retailers) located in a reasonable distance are preferable. The farmer should have access to capital or credit to purchase chemicals (premagram and roundup) and transportation means either by his own or by payment. Culturally, maize should be used for various forms of consumption and social services.

Table 3: Recommendation domain for reduced tillage in maize production

Identifier	Specific identifier	Remarks
Agro-ecology	**Midland to Low land**	
	High rainfall area	
Resource endowment	**Purchasing power or credit access for inputs (premagram and round up) purchase**	About Birr 2,360 is required for the purchase of chemicals only. When the costs of other inputs (fertilizer and labour) are added, the total cost might rise. But it is compensated by the reduction of number of ploughs and weeding frequency. Hence, any farmer can afford it both from his own or credit cash sources.
	Transportation facility such as cart, donkey or any other (own or pay)	
	Labour availability	It does not require much labour
Location	**Input suppliers (premagram, round up, fertilizer, improved seeds)**	Maximum 2 hour away by foot
	Market for maize	
	Local processors	Within 15 km distance
	Sufficient numbers of wholesalers and retailers	Within 10 km distance
Cultural	**Consumption pattern of the community**	
	Own food consumption (*Injera*, bread, and other forms)	
	Communities utilizing for local food and drink items preparation	

Note: Identifiers in **bold** are deemed more important

Recommendation domains are described interims of suitable agro ecologies, cropping compatibility, resource endowment, proximity, extension service, credit and market access and culture of community for reduced tillage on maize innovations. Therefore, any reduced tillage practices should target the above mentioned recommendation domain indicators.

3.3.1 Suitable agro-ecology

Maize can be grown in a wide range of agro-ecology; however, the optimum agro-ecological settings are presented below (MoA maize production manual, 2015)

- Altitude: 500 -2600 meter above sea level
- Minimum and maximum temperature, 10-35 ^{o}c, respectively
- Annual rainfall : 500 mm -1500mm
- Soil type: Fertile and drained soil within the range of 5-5-7.5 soil P^{H}, soil p^{H} outside this range usually makes certain elements more or less available which leads to the development of toxicity or deficiency. The ideal soil for corn is a deep, medium-textured, well-drained, fertile soil with a high water-holding capacity.

Maize is number one crop in terms of area coverage and productivity in these areas. Besides, this innovation can be practices anywhere in which maize is cultivated. Generally, the agro-ecology of the intervention areas is the best agro-ecology to cultivate maize and this best practice, reduced tillage can be practiced anywhere in which maize can be cultivated.

3.3.2 Compatibility to the cropping system

This practice will not hamper practicing of different cropping systems: intercropping, double cropping and relay cropping as long as the crops/forage species to be intercropped with maize does not need different tillage practices and will not be affected by the pre-emergence herbicide.

3.3.3 Resource endowment

Minimum tillage uses premagram and roundup chemicals. In the current market, the total cost of both herbicides is about Birr 2,360 per hectare. But minimum tillage reduces the frequency or number of ploughs. This means there is a reduction of the labour required to plough and to weed which makes the innovation very profitable and manageable among the resource poor farmers. Generally, this practice is very suitable for resource poor farmers, especially for farmers who have no oxen and labour to plough the land repeatedly

3.3.4 Location

Proximity to input suppliers: For the timely supply of chemical fertilizers, herbicides, fungicides and certified seed for farmers, input suppliers including cooperatives, private traders and seed enterprises should be available near to farmer’s village.

Extension services: Kebele DAs should be present near to farmers' village for effective and efficient supervision and implementation of minimum tillage on maize. Moreover higher level agricultural experts and other relevant stakeholders should support farmers with frequent supervisions.

Credit service: The cost of input for chemical fertilizers, herbicides and seeds for production of maize under minimum tillage is high. It is therefore recommended that credit service should be available at kebele level.

Market access: It is obvious that maize is a high yielding crop as a result most of the farmers in the project intervene are usually have surplus production of maize gran. Moreover, maize is one of the cash crop in these areas. Accordingly, creating market linkage at different levels (kebele, regional and nation) should be considered as one of the major problems to be solved. It will be very rewarding if market is accessible at kebele level.

3.3.5. Consumption and production culture

Communities are well aware of producing crops with the use of selective herbicide chemicals, particularly for broad leaved weeds. Hence, communities will adopted minimum tillage practice in maize production which needs through use of both post and pre-emergence herbicides. Besides, maize is one of the main staple crops in the area and is consumed in different forms including bread, *Nifero*, *Injera*, local beer. The excess produce of maize usually sold as source of cash.

3.4 Varieties

BH-540, BH-660 and BH-661 were used as test varieties in South *Achefer*, *Jabitehenan* and *Burie* Districts, respectively (Table 4).

Table 4: Improved maize varieties with their suitable agro-ecology and agronomic characteristics

Varieties	Year of release	Area of adaptation		Days to maturity	Productivity (quintal/ha)	
		Altitude (m)	Rainfall (mm)		On-research field	On-farm
BH-540	1995	1000-2000	1000-1200	145	80-100	50-65
BH-661	2011	1600-2400	100-1500	160	95-120	65-85
BH-660	1993	1600-2200	100-1500	160	90-120	60-80

Sources: Ministry of Agriculture, directory of released crop varieties

3.5 Land preparation

For reduced tillage practices, the soil should be disturbed only to place the seed and fertilizer in the soil at the time of sowing (seed row formed using local plow). In this practice, a combination of post-emergence herbicide (roundup) and pre-emergence herbicide (primagram) was applied to avoid weeds throughout the growing season. Thus, land preparation to suppress weed infestation is not a concern rather it is disturbed only to place the seed and fertilizer (Figure 2).

Figure 2: land preparation via frequent ploughing (left) and land ploughed only to place the seed and fertilizer in minimum tillage practice (right).

3.6 Planting time

Time of planting depends on the onset of the rainfall and also the type of varieties used. Early planting is recommended when there is enough moisture in the soil. During validation of the reduced tillage practice planting was done early June.

3.7 Seed rate and planting methods

Optimum plant density differs for different varieties depending on plant height, and maturity. For the late/medium maturing varieties used in the validation, row planting with 75 and 30 cm between rows and plants, respectively was employed with a seed rate of 25 kg/ha. Thus, 75 cm row spacing and 30 cm plant spacing is recommended for late/medium maturity varieties in practicing reduced tillage. Sowing should be done 3-5 cm deep in moist soil while under dry conditions it may be done a little deeper (5-7 cm). If the seed is planted too deep, the seedling depletes food reserves before it emerges out of the soil surface. On the other hand, leaving seeds on the surface or too shallow planting expose the seed to wild animals, damage and desiccation.

3.8 Fertilizer application

Fertilizer application varies from location to location (site specific recommendation). Based on the regional extension manual (2013) the rate of DAP and urea is 200 kg/ha for each of the commercial fertilizer for areas where site specific recommendation is not available. And time of application is all the DAP and half of urea at planting and the remaining half urea at knee height. However, for this practices, fertilizer was applied at 200 kg DAP and 250kg urea per ha. All the DAP was applied at planting while urea was applied in three splits viz 100 kg/ha

at planting; 100kg/ha at knee height following weeding; and 50 kg/ha at the initiation of tasselling (based on the experiences of the model farmer who owned the best practice).

Thus, concerning application rate and method of fertilizer it is promising to use 200 kg/ha DAP and 250 kg urea while all DAP and 100 kg of urea at planting, 100 kg urea at knee height and 50 kg urea at initiation of tasselling. But, it is advisable to use area specific fertilizer recommendation of the research institutes, if available for areas that will adopt this best practices.

3.9 Crop protection

Pest management refers to the management of a species defined as a pest, usually because it is perceived to be detrimental to crop production. Pest management is therefore a means to reduce pest numbers to an acceptable threshold. An acceptable threshold, in most cases, refers to an economically justifiable threshold where application of pest control measures reduces pest numbers to a level below which additional applications would not be profitable.

3.7.1 Weed control

In this practice, weed infestation is totally controlled by the application of both post-emergence herbicide (roundup) and pre-emergence herbicide (primagram). Thus, weeding is not practiced in reduced tillage system. However, in some cases grassy weeds like cynodon dactylon emerged late (around September) and farmers used such grassy weeds as a source of feed through cut and carry system.

Roundup application as a post-emergence herbicide

- In the plant, glyphosate is translocated via the phloem following absorption through the leaf tissues, and move to actively growing parts of the plant such as meristems and roots.
- Roundup is an herbicide which is sprayed on to green leaves where it is absorbed and drawn into the plants vascular system. It then stops the production of the amino acids which build the protein the plant needs to grow and survive. The plant effectively starves to death.
- Glyphosate's herbicidal mode of action is to inhibit a plant enzyme involved in the synthesis of three aromatic amino acids: tyrosine, tryptophan, and phenylalanine. It is absorbed through foliage, and minimally through roots, and transported to growing points. Because of this mode of action, it is only effective on actively growing plants and not effective as a pre-emergence herbicide.
- The ideal time to spray is when it is dry, mild and humid. In these conditions plant surfaces are soft and the plant is circulating nutrients quickly. Avoid spraying if plants are frost covered, or dried out by drought conditions.

- Applied the post-emergence herbicide at the rate of 4 liter/ha sprayed 5-7 days before planting
- Do not spray if it is raining or if rain is expected, or the herbicide will be washed off the leaves before it has had time to penetrate the leaf surfaces. Do not spray when it is windy as you risk damage to other vegetation caused by drift. Choose a calm day when you can direct your spray output accurately.
- When applying roundup you have to have protective clothing to protect yourself from exposure. Minimally, protective gear should include rubber gloves, eye/face protection, a long-sleeved shirt and closed shoes.
- The spray volume for roundup is 200 liter/ha.

Primagram application as a pre-emergence herbicide

- Pre-emergent herbicide: herbicide applied to the soil directly after sowing and prior to weed and crop emergence.
- Apply the pre-emergence herbicide at the rate of 3 liter /ha 2 days after sowing of maize before weeds and crop emergence
- Primagram is mainly taken through the shoots of germinating plants and seedlings. Weeds are therefore killed before emergence or shortly after emergence.
- The spray volume for primagram is 200/ha.

3.7.2 Insect pest control

Stalk borer, termites and weevils are the major insect pests hindering maize cultivation.

Stalk Borer of maize

Damage caused by stem borers is one of the main causes of low maize yields. Female stem borer moths lay eggs on maize leaves. The newly emerged larvae enter into the whorls of young maize plants and feed actively on the tender leaves (Figure 3).

Figure 3: Maize stem borer damage on leaves and stems

Management options to tackle stalk borer

- Cultural practice (crop rotation, intercropping, remove residue, early planting)
- Plant resistance (moderate tolerance)
- Insecticides - to kill young larvae before they enter the stems like Diazinol 60% EC (1-2 l/ha)

Termites on maize

Termites pose a serious threat to maize production in many parts of Ethiopia. The problem is particularly prevalent in the Western part of the country where it has been well known for many years and received wide publicity (Figure 4).

Figure 4: Termites damage on roots of maize

Management Options to tackle termites

- Mulching (corn stover and other grasses);
- Spread of wood ash around the base of the crop;
- Use of lodging resistant and early maturing corn varieties;
- Diazinon, 60% EC at 2.5 l/ha;

Maize weevil

The most important primary pests of cereals in the humid tropics, attacks undamaged grain; often infests before harvest. The larvae develop within the grain, leaving a characteristic round hole on emergence.

Management options to tackle maize weevil

- Proper and careful drying of grains to safe moisture level after shelling (12.5%)
- Maintenance of sanitation and hygiene of store as well as grains 4 to 6 weeks prior to placing new harvest for storage.
- Use of both preventive and protective chemicals: Actellic 2% D and Malathion 5% D

3.7.3 Disease control

Turcicum leaf blight, common leaf rust and giberrella stalk and ear rot diseases are among the major maize disease hindering maize cultivation.

Turcicum maize leaf blight

An early symptom is the easily recognized, slightly oval, water-soaked, small spots produced on the leaves. These grow into elongated, spindle-shaped necrotic lesions (Figure 5). They may appear first on lower leaves and increase in number as the plant develops, and can lead to complete burning of the foliage. It is widely distributed, abundantly prevalent and is consistently found especially in wet and humid areas.

Figure 5: Symptoms of maize leaf blight

Management options to tackle turcicum maize leaf blight

- Cultural control: use of adequate inorganic fertilizer in combination with farm yard manure, intercropping with legumes and crop rotation, use of optimum seeding rate, spacing and early planting of corn are recommended.
- Resistant/tolerant varieties: using varieties relatively resistant/tolerant to the disease. Examples: BH-670, BH-660 and others.
- Chemical control: use of combination of mancozeb and propoconazole at the rate of 2 kg active ingredient per ha of maize (2-3 times of application at ten days interval) is recommended.

Common maize leaf rust

Maize leaf rust is most visible when plants approach tasseling. It may be recognized by small, elongate, powdery pustules over both surfaces of the leaves. Pustules are dark brown in early stages of infection; later, the lesions turn black as the plant matures (Figure 6).

Figure 6: Symptoms of common maize leaf rust

Management options to tackle common maize leaf rust

- Cultural control: timely planting, intercropping corn with legume and crop rotation reduces the level of infestation.
- Resistant/tolerant varieties: using varieties relatively resistant/tolerant to the disease. Example. BH-670, BH-660 and others.
- Chemicals control: combination of mancozeb and propoconazole at the rate of 2 kg active ingredient per ha of corn (2-3 times of application at ten days interval) are recommended.

Giberrella stalk and ear rot, Giberella zeae

Plants wilting and leaves changing colour from light to dull green; lower stalk turns straw yellow; internal stalk tissue breaks down; interior of stalk has a red discoloration; black fungal fruiting bodies may be visible on the stalk, often at internodes, and can be easily scraped off; if fungal infection affects the ears, it produces a red mold at the tips of the ear which spreads down; early infection may result in the ear being covered in pink mycelium which causes the corn husk to adhere to the ear (Figure 7). Fungus can enter through wounds to stalk or ear; ear rot is caused by the fungus infecting silks and moving down through the ear; fungus survives on corn debris in soil and on debris of other host plants such as wheat.

Figure 7: Symptoms of maize ear and kernel rot

Management options to tackle maize giberrella stalk and ear rot

- Stressed plants are more susceptible, providing adequate fertilization and irrigation can help reduce incidence of disease; control insects, especially stem and ear borers; hybrids differ in their susceptibility to the disease and further information is required in order to develop specific control measures.
- Seed dressing with fungicide Luxan TMTD at 200-500 g/quintal of seed is recommended.

3.10 Harvesting, threshing and post-harvest handling

- Harvest at about 12-14% grain moisture content
- Cobs should be:
  - Picked
  - Sorted (remove rotten cobs)
  - Dried (either in sun or in drier at low air temperature)
  - Shelled (usually by hand, or gentle machine)
- Harvesting fully mature seed will result in
  - Maximum yield
  - Improved appearance of grain
  - Greater resistance to mechanical injury

3.11 Productivity

During the validation process, reduced tillage practice via the combine application of both premagram and roundup together gave 29% (in 2013) and 13% (in 2014) grain yield advantage over traditional farming system and reduced tillage using only post-emergence herbicide, respectively (Table 5).

Table 5: Productivity of reduced tillage practice and traditional tillage practice (quintal/ha)

Practices	2013 cropping season		2014 cropping season	
	Grain yield (quintal/ha)	Advantage (%) over traditional practices	Grain yield (quintal/ha)	Advantage (%) over traditional practices
Roundup + Premagram	76	29	62	13
Roundup only	63	7	55	--
Traditional (ploughing five times)	59		--	

3.12 Profitability

Profitability analysis was done by considering only the costs that vary among treatments. For this purpose treatments are listed in the order of increasing costs that vary. The details are presented in Tables 6-9.

Table 6: List of treatments

Treatment	Number of tillage	Chemical used
1. Reduced tillage with round up only	1 times	4L roundup
2. Farmers practice	5 times	No
3. Reduced tillage with round up and Premagram	1 times	4L roundup 3L Primagram

Data

To spray roundup for one hectare it takes 4 hrs or Birr 25

To spray primagram for one hectare it takes 3 hrs or Birr 20

Rent of spraying machine = Birr 60/day or Birr 30 for the round up and Birr 20 for the premagram

Field price of one liter of primagram = Birr 600

Field price of one liter of roundup = Birr 140

Field price of one pair of oxen with the farmer/day = Birr 160

One hectare can be ploughed in 4 days by one pair of oxen

Farmers practice and round up plots need two times of weeding

First weeding needs 4 pair of oxen with the farmer and 4 man days of labour/hectare

Second weeding needs 8 man days/hectare

Field price of labour/day = Birr 45

Total costs that vary

Here treatments are put in columns and the cost items in rows and then calculates the total costs which vary from treatment to treatment in each of the treatments.

Table 7: Total costs that vary

Costs	Treatments		
	Reduced tillage with roundup only	Farmers practice	Reduced tillage with roundup and Primagram
Cost of roundup (Birr)	560	0	560
Cost of primagram (Birr)	0	0	1800
Cost of ploughing (Birr)	640	3200	640
Cost of labour for spraying roundup (Birr)	25	0	25
Cost of labour for spraying primagram (Birr)	0	0	20
Cost of labour for weeding (Birr)	1180	1180	0
Rent of spraying machine (Birr)	30	0	50
Total costs that vary (Birr)	2435	4380	3095

Table 8: the partial budget

Items	Treatments		
	Reduced tillage with roundup only	Farmers practice	Reduced tillage with roundup and primagram
Average yield (kg/ha)	6268	5898	7610
Adjusted yield (kg/ha)	5641	5308	6849
Residues (carts/ha)	3	2.9	3.2
Gross field benefits (Birr/ha)	25565	24061	31013
Cost of roundup (Birr/ha)	560	0	560
Cost of primagram (Birr/ha)	0	0	1800
Cost of ploughing (Birr/ha)	640	3200	640
Cost of labour for spraying roundup (Birr/ha)	25	0	25
Cost of labour for spraying primagram (Birr/ha)	0	0	20
Cost of labour for weeding (Birr/ha)	1180	1180	0
Rent of spraying machine (Birr/ha)	30	0	50
Total costs that vary (Birr/ha)	2435	4380	3095
Net benefits (Birr/ha)	23130	19681	27918

Marginal analysis

Table 9: Marginal analysis

No	Treatment	Total costs that vary (Birr/ha)	Net benefits (Birr/ha)	Marginal rate of return (%)
1	Reduced tillage with roundup only	2435	23130	
3	Reduced tillage with roundup and primagram	3095	27918	725

The minimum rate of return = 100%

As indicated in the Table 9, the marginal rate of return (725%) is well above the minimum acceptable rate of return (100%). Hence, the farmer is willing to shift his activities from

treatment 1 (using roundup only) to treatment 3 (using round up and primagram together). By adopting the combined use of primagram and round up chemicals, the farmer will get additional benefits of Birr 7.25 for each additional one Birr invested in this technology.

3.13 Farmers preferences

Farmers preferences on minimum tillage technologies in maize production was assessed using CIAT manual (1993). Farmers preferred minimum tillage practice that uses both roundup and primagram compared to the roundup only and the control/conventional methods due to increment of yield, less cost of production, minimized soil erosion and uniformity of maize seed germination. The general preference analysis matrix table result is shown below in Table 10.

Table 10: Validation of minimum tillage on maize production farmer's preference analysis

Criteria	Treatments		
	Roundup and primagram herbicide	Roundup only	Control/conventional method
Cost of production	1	2	3
Soil erosion	2	1	3
Grain yield	1	2	3
Labour demand	1	2	3
Uniformity of seed germination	1	2	3
Change in soil texture(soil dry)	3	2	1
Total score	9	11	16
Rank	1	2	3

Note: the highest the score the least the rank and vice versa

3.14 Sustainability assessment

Sustainability of a technology can be favoured or constrained by many factors among others the economic, social and environmental (people, profit and planet) are the main ones. Thus, it will be important to examine the sustainability of a technology by setting indicator for the three parameter and analyse the short term and long-term effects of the technology.

The sustainability indicators for the three parameters were selected with the farmers and development agents for the systemic comparison of the framers' practice (benchmark) that allows ploughing of maize field 4-5 times with reduced tillage that has the following elements. Combination of post-emergence herbicide (roundup) and pre-emergence herbicide (primagram) and reduced tillage or ripping of the land at the time planting only (Table 11 and Figure 8).

Once the indicators are set and their relative magnitude is evaluated then spider graph will simplify the comparison of indicator through visualization Figure 2. Where most of the agricultural activities of small-scale farmers are implemented manually, the labour demanding nature of a technology has a lot for its sustainability. Reduced tillage on maize has resulted higher advantage over the convectional in terms of labour requirement. It only involves ripping of land at the time of planting while the conventional tillage involves 4-5 times ploughing. This huge difference in labour requirement has implication on the advantage of the reduced tillage for all farming community with minimum number ox. Thus, it didn't discriminate farmers with high or minimum number of oxen for traction. However, the spraying of the herbicides (roundup and primagram) could affect the health of the people.

The main inputs for reduced tillage technology are post-emergence herbicide (roundup) and pre-emergence herbicide (primagram) and their market accessibility and affordability is good. However, it incurs additional cost compared to the conventional.

Reduced tillage didn't disturb the soil, thus it prevents soil degradation by reducing enormous amount of soil and nutrient loss from flash flooding. The soil erosion from reduced tillage is smaller compared to the conventional. However, in terms of soil nutrient depletion the two methods showed similarity. Though the nutrient depletion by flash erosion is minimum for reduced tillage, there is additional loss of nutrient from higher harvested product which at the ends balanced the two systems. For the conventional tillage the nutrient depletion from soil erosion is high whereas nutrient mining from crop product harvest is minimal because of lesser yield,

As the reduced tillage uses pre and post emerging herbicides to suppress weeds, there would be associated biodiversity loss for reduced tillage.

Table 11: Summary of sustainability indicators for reduced tillage practices

Sustainability parameters/indicators	Conventional method	Reduced tillage innovation	Remarks
People			
Labour demanding	-	++	Reduced tillage highly minimize the labour requirement of ploughing
People safety	±	-	The spraying of the herbicides (roundup and primagram) could affect the health of the people.
Discrimination of people on the presence of draught animals	-	±	The traditional tillage that involves five times ploughing is in favour of people with oxen for traction, whereas reduced tillage avoid this discrimination
Profit			
Revenue	±	+	The overall productivity biomass (maize grain and residue) of reduced tillage gives better result than the traditional tillage
Resource efficiency	±	+	Minimum tillage gives 20-29 % yield advantage over the traditional tillage. Thus, its land use efficiency is higher
Input supply	±	-	Compared to the traditional tillage practice the affordability of inputs mainly herbicides would slightly
Planet (Environment)			
Soil erosion	-	+	Reduced tillage minimize soil erosion and maintain the soil structure because there are many undisturbed area by ploughing.
Soil nutrient	±	±	Higher biomass harvest from reduced tillage contribute to higher nutrient depletion through harvest, however, this is compensated form highly conserved soil and nutre4in from minimum tillage
Biodiversity	±	-	The Herbicides might have negative impact on the life of other beneficial organisms

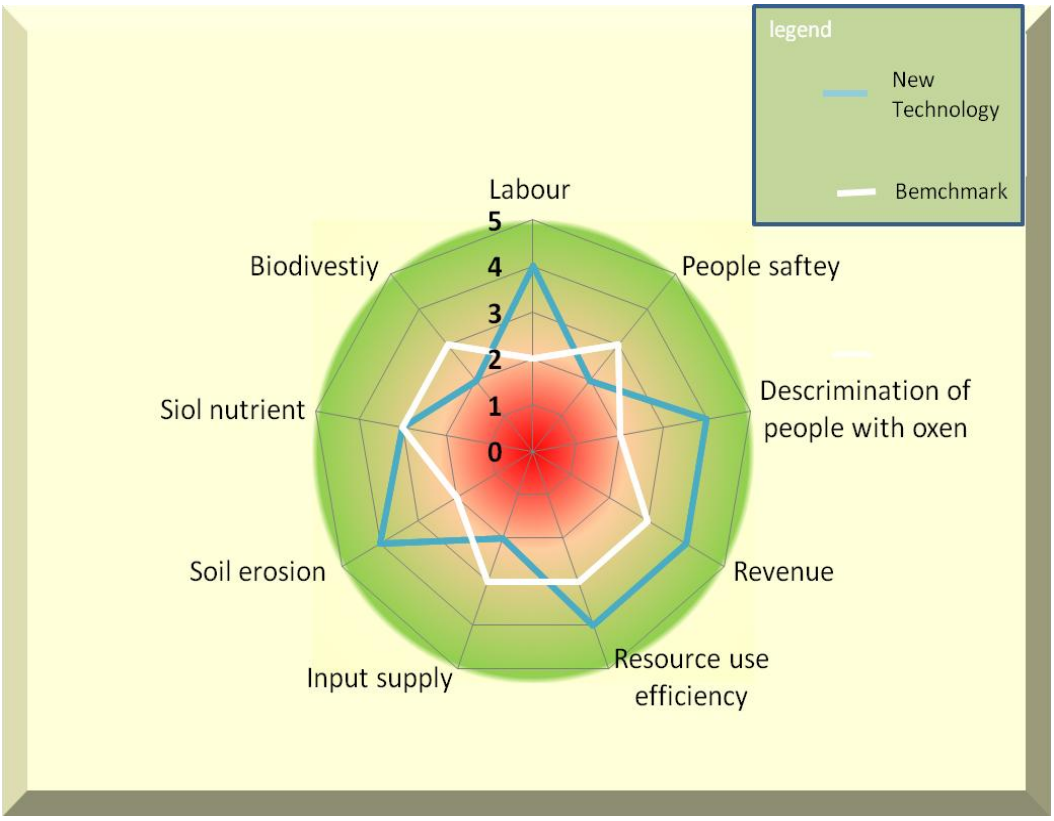

Figure 8: Spider graph of reduced tillage on maize versus farmers' practice (benchmark)

3.15 Contribution of the best fit practice to nutrition and gender aspects

With regard to nutrition, reduced tillage has no direct effect on nutrition. However, indirectly it has a positive effect through economical empowering of the household. Maize has a great role for the household consumption and especially for children's complementary food preparation. The different recipes indicated below demonstrate how maize is blended with other food types to prepare various quality foods.

Complementary food production using quality protein maize

Recipe 1: Porridge enriched with maize, kidney beans, tomato and oil (Table 12).

Table 12: Ingredients

Ingredients	Amount	Weight gram
Maize flour	Over half a coffee cup	53 gm
Oil	1.5 teaspoon	7 ml
Kidney beans	1.5 teaspoon	7 gm
Tomato	1 tomato	30 gm
Water	5.5 coffee cups	385 ml
Iodized salt	For taste	-
Ripe avocado	1/2 medium sized	50 gm

Procedure

- Soak kidney beans overnight in water.
- Boil beans in water, remove skin and mash
- Boil, peel off skin and chop tomato
- Mix maize flour in water, bring to boil and iodized salt
- Mix in tomato, butter/oil and mashed beans then stir until cooked enough.
- Cool porridge and consume.

Recipe 2: Porridge enriched with maize, milk, tomato and oil (Table 13).

Table 13: Ingredients

Ingredients	Amount	Weight gram
QPM flour	More than half coffee cup	55 gm
Tomato	1small size	20 gm
Milk	More than half coffee cup	50 ml
Oil	1 teaspoon	5 ml
Iodized salt	For taste	-
Water	4 coffee cup	280 ml
Banana	1 medium sized	50 gm

Procedure

- Mix the maize flour with water and milk and put it on the heat
- Add iodized salt.
- Boil, peel and chop the tomato
- Add the tomato, oil and stir until cooked properly
- Allow the porridge to cool and feed the baby with spoon with encouragement

Preparation and cooking time: 30 min.

Recipe 3: Maize porridge enriched with pumpkin, milk and oil (Table 14)

Table 14: Ingredients

Ingredients	Amount	Weight gram
Maize flour	One coffee cup	60 gm
Pumpkin	1.5 slice	15 gm
Milk	More than half coffee cup	50 ml
Butter/oil	1.5 teaspoon	15 ml
Water	4.5 coffee cups	315 ml
Iodized salt	For taste	-
Orange	1 medium size	50 gm

Procedure

- Mix maize flour with milk and water
- Put it on fire, add iodized salt and heat.
- peel, remove seed, chop and boil the pumpkin in water
- Take off heat and mashed pumpkin
- To the pumpkin mixture, add the oil and stir until cooked
- Allow to cool and feed the baby

Recipe 4: Maize porridge enriched with pea flour, carrot and oil (Table 14).

Table 15: Ingredients

Ingredients	Amount	Weight gram
maize flour	More than one coffee cups	80gm
Pea or bean flour	1 teaspoon	5 gm
Carrot	1 small size	20 gm
Oil	3 teaspoon	15 ml
Water	7 coffee cups	490 ml
Iodized salt	For taste	-
Milk	1 coffee cup	70 ml
Ripe avocado	1 medium size	100 gm

Procedure

- Mix the maize flour with water and milk
- Add iodized salt and put it on the fire
- Peel, wash and boil the carrot
- Take off the fire and mash it
- Add the carrot and oil and cook by stirring.
- Allow cooling and fed to children.

Maize minimum tillage is labor reducing farming practice both for women and men. According to farmer's opinion it reduces weeding and frequency of tillage - oxen. Women were more engaged in weeding and tillage - hand farming practice, but due to maize minimum tillage technology, women are getting relief to spend their time for household activity and other social issues.

4. Suggestions for points of attention for extension agents and other development actors

4.1. Identification and involvement of relevant stakeholders

Identifying and participating the key stakeholders is the prior task to share responsibility and mitigate the effort of each stakeholder, for the successful scaling up of minimum tillage on maize. The key stakeholders and their role are listed down in Table 16.

4.2 Joint planning

Joint planning, monitoring and evaluation, should be done by the cooperation of the relevant stakeholders based on their specified role listed in Table 16.

Table 16: Key stakeholders and their roles

Identified stakeholders	Stakeholders' role
Model farmers	• Joint planning and execution of scaling up • Seed multiplication • Share their best experience on maize production
Kebele office of agriculture	• Assist farmers in site selection • Provide training and technical backstopping to farmers
Kebele Administration	• Mass mobilization • Facilitate inputs supply to farmers
District office of agriculture	• Participate in joint planning • Provide training and technical backstopping to farmers and DAs • Facilitate timely availability of input • Arranging market availability to farmers
District office of administration	• .Participate in joint planning and mobilizing the community
BoA	• Provide training and technical backstopping to ZoA and DoA • Facilitate timely availability of inputs
Quarantine Agency	• Seed quality inspection, control and certification
Seed enterprises	• Multiply and supply certified seed of maize seed to farmers
Research institution and centers	• Provide training to BoA, DoA, ZoA and DAs

	• Technology demonstration and evaluation • Supply basic and pre-basic seeds for seed enterprises
Cooperatives	• Organized local seed producer cooperative and provide training at different levels • Supplying chemical fertilizers and herbicides to farmers
Traders	• Supply herbicides to farmers • Buying the maize produce
Universities	• Provide training and advisory services • Technology demonstration and evaluation
Credit institutions	• Provide credit to farmers for purchasing input
Projects and NGOs	• Support logistics and participating in capacity building • Participate in input supply and technology transfer

4.3 Training at different levels

Experts from BoA, research centres, universities and NGOs should provide both theoretical and practical training of trainees (ToT) for ZoA and DoA. Similarly, ZoA and DoA should train development agents. Finally, development agents should provide training to target farmers.

4.4 Availability of inputs

The main inputs for minimum tillage are fertilizer, premagram, roundup and seed. Fertilizer and improved seed are found in sufficient amounts and timely by their respective primary farmers' cooperatives. But the supply of round up and premagram chemicals are not reliable. In rare cases, cooperatives provide them in limited quantities which are not sufficient to do fully fledged scale out activities. In other cases some private traders do some business in trading them. Hence, the input supplies department of the bureau of agriculture is expected to do some arrangements to avoid shortages in the supplies of these chemical inputs.

4.5 Market access

Maize is a major crop in Jabitehenan, Bure Zuria, South Achefer, Mecha and Dera Districts as well as at regional and national level. So there are already established regional and national market systems such as farmers' cooperatives, unions and exchanges between producers and traders. In addition, the AGP AMDe is doing intensive works in maize value chain in Amhara Region which can be taken as an opportunity for maize grower farmers. Most woredas have all weathered road access to transport their surplus maize products to the markets. Regardless

of all of these efforts and opportunities, the price of maize grain sometimes gets lower, especially during harvest seasons. But this is seasonal which stays for a short period and not even lower than the costs of production plus some marginal benefits for producers.

Unless farmers are forced by immediate cash needs, they need to keep the grain until the price rises to comfortable level. They can also build modern storage facilities like air tight metal silos or buy insect proof bags to protect the grain from damages by insects and rodents during storage.

4.6 Joint monitoring and evaluation

A. Definition

Monitoring is a management process that systematically seeks to supply to the stakeholders information on the progress of implementation of a program/project in order to facilitate timely decision making. Monitoring means keeping track of where you are with a project in relation to where you planned to be. Evaluation is a periodical review of the status of implementation and of achievement of a project or program.

Joint monitoring and evaluation is where all stakeholders involve in the monitoring and evaluation process either alone or together. Each stakeholder has a role to play in the process and need to participate to make the process effective by creating sense of ownership in the whole process of production, harvesting, processing, utilization and marketing. Farmers need to follow the day to day events of the production process because they are the nearest stakeholders for each activity than anyone in the system. They can know what is happening in the planted maize crop, in the status of weeds, in the emergence of diseases, in the process of harvesting and marketing on a daily bases. They can also evaluate the efficiency and effectiveness of the system better periodically. In so doing farmers can deliver correct and fresh information for other stakeholders who are located relatively in far areas from the field, for instance for Kebele and woreda stakeholders and subject matter specialists.

The other stakeholders can follow up the process as timely as possible and can support technically as well as with resources. For instance, the technical people at woreda or region can advise on the technique of planting, weed and disease control, harvesting processing, marketing and utilization based on their periodic follow up or information obtained from farmers.

B. Data collection

Qualitative and quantitative data should be collected regularly by stakeholders and should be centrally organized, analysed and communicated again to stakeholders. The tools used to collect qualitative data are focus group discussion, key informant interview, storytelling, attitude and perception measures. Similarly, there are a number of tools which we can use to

collect quantitative data. To mention some, structured formats developed and agreed up on by stakeholders, reports, surveys, transect walks, field visits, etc.

C. Data analysis

All the data collected by different stakeholders should be brought into experts/department of the respective organization for reorganization and analysis. Some of the parameters considered during the analysis include yield, productivity, environmental impact, profitability, income, land requirement, labour demand and so on. Summary tables can be produced focusing on:

- Different attributes/indicators;
- Comparison between planned and actual;
- Comparison between different areas (*kebeles*, *woredas*, zones and regions) ;
- Comparison between years;
- Compare the performance of different interventions; and
- The average performance at *kebele*, woreda, zone, region and at country level.

In most cases the above analysis relate to the quantitative data. However, if this is complemented with the qualitative data which will be generated by the qualitative surveys it will help to answer why the interventions are performing as observed in the quantitative data. For example, the quantitative data about training can be complemented with the trainee's feedback result on the same issue. This type of information can explain why things are happening (or not happening) in a particular manner and provide significant insights for decision making purposes.

D. Communication

The M&E information collected through the established M&E process can only be used for accountability, learning and decision making, as well as input for re-planning of program/project if there is a clear plan for appropriately communicating it to the stakeholders of the programme. Communication can be done through periodical reports, stakeholders meetings and critical reflections, broachers, leaflets, using electronic means (telephone, e-mail, etc), vocal, workshop, field days, seminar, training and so many other means. Communication should be done timely.

E. Capacity building for M&E

For the joint monitoring and evaluation process to be effective, capacity building need to be given intensively. Farmers should be given appropriate training on how to record information and on how to communicate it. They need also be supported by necessary materials. The other stakeholders in the process need to get the capacities which enable them to discharge the monitoring and evaluation process effectively. Moreover, need based training have to be given on data collection analysis and communication for other stakeholders.

In general, the monitoring and evaluation activities must be done jointly and in participatory ways. Otherwise, lack of sense of ownership and carelessness may appear in some stakeholders and will lead to total failure in implementing the innovation as a whole. This is usually appearing in most projects and programs.

4.7 Lessons learned and challenges faced

Lessons learnt

- Reduced tillage minimizes soil erosion through soil cover and less soil disturbance so that the farming system will be more sustainable than under traditional system (five times ploughing).
- Benefit resource poor female-headed households and male headed households who do not have draught power as this practice enable them to manage their own land instead of renting out and sharing out.
- In addition to the above advantages, minimum tillage, as indicated in the economic analysis part, has great economic advantages over the traditional farming practice (five times ploughing). The farmers' preference analysis also indicated that minimum tillage practice is chosen against the traditional practice for its labour saving for ploughing and weeding and productivity.

Challenges faced

- Herbicide availability and affordability, thus creating access to inputs and credit should be considered
- Lack of awareness on how to use the herbicides, thus training farmers and development agents on safely application of herbicides is important.
- Safety may be a problem during spraying, thus train farmers and development agents how to spray safely.
- Farmers fear that their land might be affected by chemicals. Awareness creations and trainings is needed.

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