

# Status and Impact of Different Levels of Agricultural Mechanisation on the Smallholder System in Ethiopia

Master-Thesis

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## Glossary

Arashogel	Oxen implement for tillage (extension to maresha)
Aybar	Small-scale mechanisation enterprise
Derdero	Means “planting bed” and is the name of RCA practise
Enset	<i>Ensete ventricosum</i> (also: false banana)
Maresha	Traditional oxen-tillage implement
Mekenajo	Practice of two farmers joining their single oxen to a pair for ploughing
Kebele	Smallest administration unit
Quintal	Unit of weight (1 quintal = 100 kg)
Teff	<i>Eragrostis tef</i>
Terwah	Means “furrow” and is the name of a RCA practise
Woreda	Administration unit below regions

## List of abbreviations

ADLI	Agricultural Development Led Industrialization Strategy
AGP	Agriculture Growth Programme
ASSAP	Sustainable Agricultural Productivity
BBM	Broad bed maker
CA	Conservational agriculture
CT	Conservational tillage
Cimmyt	International maize and wheat improvement centre
EIAR	Ethiopian Institute of Agricultural Research
FGD	Focus Group Discussion
GIZ	German Agency for Development Cooperation
ha	Hectare
MoA	Ministry of Agriculture Ethiopia
METEC	Adama Agricultural Machinery Industry - state-owned industrial company also (also importing and/or assembling agricultural machinery)
PTO	Power-take-off (attachment for rotary devices)
RCA	Resource conservation agriculture
SSA	Sub-Saharan Africa
2WT	Two-wheel-tractor

## Acknowledgement

My sincere thanks to my supervisors Bernhard Freyer and Gerold Rahmann for their continuous support.

Above all I want to express my gratitude to the farmers from Arsi for sharing their experiences and knowledge and their participation in the focus group discussion and all the key informant interviewees for their detailed explanations and insights. Also, many thanks to the GIZ and IP-consult employees and the local extension workers for supporting me with organising the interviewees and the focus group discussion.

Furthermore, I want to thank GIZ and Gerold Rahmann for the opportunity to conduct my research during the internship in GIZ Ethiopia.

## 1. Introduction and problem statement

Ethiopia's agricultural system has a century-long tradition in arable and livestock farming and is characterized by its diversity, which is determined by several climate zones, agro-ecologies, topographies and a multitude of agricultural crops and livestock. The highlands provide favourable climatic conditions for crop production with overall adequate rainfalls and temperatures and relatively fertile soils. In spite of these positive prerequisites for the countries food production, Ethiopia faces huge challenges in terms of food security. The yield status of the smallholder farming sector remains low although some improvements have been reported in the last years (Atanf, Tesfaye, & Kifle, 2015).

Small land holdings of less than one hectare on average leaves the primarily subsistence farmers with few financial resources, vulnerable to climatic shocks, such as droughts and floods which regularly lead to crop failures. Additionally, a high population growth rate increases the existing high pressure on farmland in the highlands which leads to further fragmentation of plot sizes and agricultural expansion into unsuitable areas and into the few non-agricultural habitats. Land degradation due to the high land pressure, the current drought animal-powered tillage system, low inputs of organic matter and very narrow crop rotations is a serious problem. Particularly erosion leads to fast decline of soil fertility and additionally threatens the production potential of the soil. This situation threatens the food security of the country and leaves it increasingly dependent on staple food imports and international food prices (Jan Nyssen et al., 2004; Teshome, 2014).

Organic matter flows are a critical issue in most smallholder farming systems. Low yields leave relatively low crop residues. These residues should be used on the fields to maintain the soil's organic carbon levels, supply nutrients and serve as protection cover. However, the residues are required as animal feed, especially for the oxen that have a high-energy requirement particularly in the tillage season due to the rather inefficient tillage system. The manure is gathered and largely used as fuel for cooking. If compost and manure are applied to the fields, this is usually only to the plots close to the homesteads as a result of scattered plots and low farm power availability (Pender, Place, & Ehui, 2006).

In addition, the availability and affordability of external inputs that could potentially lift the system into a higher productivity status is limited because of the low market access of farmers and little or no savings, as well as minimal access to micro-credits. This constitutes stagnation or even a downwards spiral with negative social, socio-economic and ecological effects.

Many actors now see new economic and socio-economic conditions as a chance to mechanise the Ethiopian smallholder agriculture. The increasing scarcity of the labour force in rural areas due to migration of mainly young men to urban areas constitutes a great challenge to poorer farmers, often women-headed households (Baudron et al., 2015; Sims, Hilmi, & Kienzle, 2016; Ströh de Martínez, Feddersen, & Speicher, 2016).

Institutions and scientists have proposed different farm power levels of on-farm mechanisation as a key change to the farming systems. These include an improved animal-powered system, the use of multipurpose two-wheel tractors and large-scale mechanisation with tractors and combine harvesters (Baudron et al., 2015; Duerr, Hess, & Spohn, 2016; Temesgen, Hoogmoed, Rockstrom, & Savenije, 2009). The suitability of different tillage systems (conventional vs. conservation) brings another variable into the debate with complex interactions with the power source. The potential of different pairings of these two variables to break the afore-mentioned downwards spiral and their implications on social, socio-economic and ecological conditions to the smallholder system in Ethiopia will be explored in this thesis. Bottlenecks and solution approaches for the further development of the different mechanisation levels are presented.

## 2. Conceptual framework

The combination of low land productivity, a rapidly-increasing population and a continuous natural resource degradation through high land pressure presents an imminent threat to rural livelihoods and to food and nutrition security in Ethiopia. To increase yields, mechanisation driven by higher farm-power levels is proposed by several scientists as a possible solution (Baudron et al., 2015; Sims et al., 2016; Ströh de Martínez et al., 2016). This work combines a literature review with qualitative key-stakeholder interviews and a farmer's focus group discussion. It displays the current status of mechanisation and discusses the impact of different farm-power-levels of mechanisation on social, socio-economic and environmental parameters.

### 2.1. Research objectives

- (1) To provide an overview of the status of mechanisation in Ethiopia
- (2) To conduct an impact assessment of different mechanisation levels on the smallholder sector
- (3) To identify challenges for further development of agricultural mechanisation and show solution approaches

### 2.2. Research questions

- (1) What is the current situation of agricultural mechanisation in Ethiopia?
- (2) What are the advantages and disadvantages of different levels of on-farm mechanisation in Ethiopia (related to power source and tillage intensity)?
- (3) What are the challenges to more effective on-farm mechanisation and how can they be approached?



### 2.3. Outline

Research Background	Research Objectives	Research Questions	Theoretical Concepts	Methods
<p>General low yields (per hectare) of the smallholder sector in Ethiopia is failing to cover the fast-increasing domestic food demand and threatens the livelihoods of the smallholder farmers</p> <p>High land degradation through the current form of land management is aggravating the situation</p>	<p>To gain an overview of agricultural mechanisation in Ethiopia</p> <p>To conduct an impact assessment of different mechanisation levels on the smallholder sector</p> <p>To identify challenges for further development of agricultural mechanisation and show solution approaches</p>	<p>What is the current situation of agricultural mechanisation in Ethiopia?</p> <p>What are the advantages and disadvantages of different levels of on-farm mechanisation in Ethiopia (related to power source and tillage intensity)?</p> <p>What are the challenges for more effective on-farm mechanisation and how can they be approached?</p>	<p>Definition of agricultural mechanisation</p> <p>Conventional vs. conservational tillage/agriculture</p> <p>Sustainable/ecological intensification</p>	<p>In-depth literature review</p> <p>Key stakeholder interviews</p> <p>A farmer's focus group discussion</p>

### 3. Literature

#### 3.1. Overview and problems of farming system

This section briefly introduces the farming sector in Ethiopia, its significance for the country and the problems it faces.

Agriculture in Ethiopia plays a crucial role both for the livelihoods of the people and the economic development of the country. In 2015 approximately 81 % of the population lived in a rural area and earned the majority of their income through agriculture (Food and Agriculture Organization of the United Nations, 2018). The economic importance is illustrated by the high share of agricultural production of the gross domestic product (GDP). Despite declining in 2016 the share was still 37.23 % (Trading Economics, 2018).

The farming sector in Ethiopia is dominated by smallholder farmers (< 2 ha). Whilst commercial farming is on the rise, at one million hectares (2013/14) of cultivated land this is still relatively insignificant. Its significance in terms of cultivated area is with one million hectares (2013/14) still low. Commercial farms focus more on the exportable high-value crops such as sesame, cotton and coffee (Bachewe, Berhane, Minten, & Taffesse, 2015) while smallholder farmers represent 90 % of all farming households (Agricultural Transformation Agency, 2014) and cultivate more than 94 % of the total cultivated land (2013/14) (Bachewe et al., 2015). More than half of the farming population cultivates one hectare or less (Kebbede, 2016) and around 36 % of rural households are categorized as marginal farmers with less than 0.5 ha (marginal < 0,5 ha, small 0,5-1 ha, semi-medium 1-2 ha) (Agricultural Transformation Agency, 2014).

Due to the small farm sizes and the relatively low land productivity most farmers are mainly self-sufficient and market little of their production surplus. Shrinking farm-sizes caused by the rapid population expansion threatens rural livelihoods. Additionally, farm land is fragmented, as a national survey in 2004 show. The average farm is fragmented into 2.3 plots with 0.35 ha each (Teshome, 2014). The number of smallholder farmers increased between 2004/5 and 2014/15 from 11 to 15.3 million with an average growth rate of 3.8 % (Bachewe et al., 2015).

Farming systems in the highlands are mostly summarised as mixed-crop-livestock systems (Mengistu, 2006). A more specific definition for the whole of Ethiopia is given by (Westphal & Westphal-Stevens, 1975). According to them there are four main agricultural systems in Ethiopia. These systems refer to the smallholder sector and do not include large farms.

- To account for the extremely diverse cultural and agro-ecological conditions (see Figure 1), Westphal and Westphal-Stevens (1975) subdivide the systems into more specific sub-systems. The borders between the systems are fluent. Whereas the seed-farming complex can be found in the majority of the Ethiopian highlands and the ensat-farming in the south-west of the highlands, pastoralism and shifting cultivation are mainly located in the lowlands. The next section focuses on the status and problems of the most common seed-based farming complex.



### *Status and problems of cereal-based smallholder system*

Crops cultivated in these systems are chiefly cereals and to a lesser degree pulses and oil crops. Bachewe et al. (2015) show that grains accounted for about 96 % of the total cropped area during 2004/5-2013/14. Cereals (teff, barley, wheat, maize, and sorghum) covered three-quarters of total cropped area followed by pulses and oilseeds. These numbers highlight the importance of grain cropping in Ethiopia.

Among the cereals teff is grown on the largest share of area, whereas maize has the highest share of the total production (see Table 1). Regarding the total production sorghum and wheat come after maize and teff (Trypanosomiasis et al., 2015). Faba bean is the main pulse species grown, followed by chickpeas and haricot beans (Central Statistical Agency, 2016).

Table 1: Yields of major crops

Crop	Number of Holders	Area in Hectares	Area in %	Production In Quintals	Yield (Qt/He)
Teff	6,536,605.00	3,016,062.55	24.03	47,506,572.79	15.75
Wheat	4,614,159.00	1,663,845.63	13.26	42,315,887.16	25.43
Maize	8,685,557.00	2,114,876.10	16.78	72,349,551.02	34.31
Sorghum	4,993,368.00	1,834,650.81	14.57	43,391,342.61	23.69
Pulses	7,931,562.00	1,558,422.02	12.42	26,718,344.54	15.5
Oilseeds	2,936,158.00	855,762.91	6.82	7,600,993.24	11.80

Source: (Trypanosomiasis et al., 2015)

Westphal and Westphal-Stevens (1975) identify five regional sub-forms that vary from others in terms of crop and type of mechanisation (hoe-culture or oxen-cultivation).

The agroecological conditions in the highlands vary considerably. Important factors that determine the farming system are precipitation patterns, length of growing period, altitude, mean temperatures topography and soils. The diverse agro-ecological and cultural landscape is responsible for the formation of different subsystems that characterize the highland agriculture.

### ***Problems with the seed-based smallholder system***

Despite recent gains, the land productivity level of smallholder farmers in Ethiopia remains low. Production increases in the past were mainly due to the extension of cultivated area and only to a lesser extent due to higher yields (Friedrich & Kassam, 2011; Taffesse, Dorosh, & Asrat, 2011). The low production level leaves farmers with low income from selling surpluses and few economic securities to deal with crop failures. Moreover, the country's farming sector fails to supply the growing urban areas with food. This is also reflected by growing wheat imports (see Figure 2) in the past decades (Duerr et al., 2016).

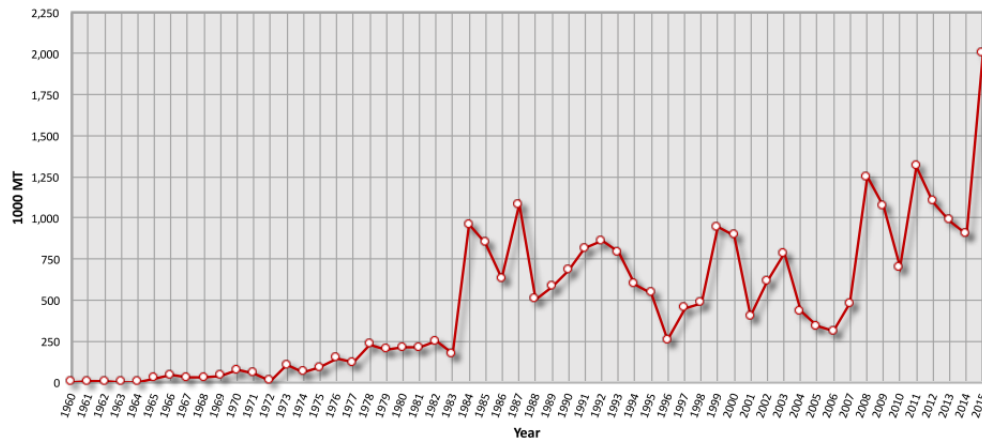


Figure 2: Wheat imports to Ethiopia between 1960 – 2015

Source: (Duerr et al., 2016)

The main reasons for low smallholder productivity can be categorised in three groups:

- Climate and soil related problems
- Farm management related problems
- External factors including access to input-and output markets and land policy

Climate-related problems refer mainly to precipitation. Since irrigation only plays a significant role in some regions, smallholder farmers heavily depend on adequate and timely rainfall. In the past, droughts have severely affected the population and caused several famines (Cheung, Senay, & Singh, 2008). Another problem connected to rainfed agriculture is the management of vertisol areas. Vertisols cover 12.6 million hectares in Ethiopia and form the dominant soil type in the highlands. They are prone to water-logging because of their hydro-physical parameters and farmers often have to wait until the end of the rainy season to cultivate the plots meaning that they miss out on the main parts of the growing period (Araya, Nyssen, Govaerts, Deckers, et al., 2016). Not cultivating the plots during the rainy season also leads to losses through water run-off as the fields remain unprotected (Astatke, Saleem, Jabbar, & Erkossa, 2002).

The category of farm management problems includes current tillage practices that are associated with land degradation (described in detail in section 3.2.1), and organic matter management. According to Araya, Nyssen, Govaerts, Deckers, et al. (2016) the removal of crop residue after harvest, intensive aftermath grazing in cropland, burning of crop residues and the use of crop straw and animal dung for fuel are problematic. These practices leave the soil unprotected and reduce soil organic matter and consequently contribute to erosion and reduced water-holding capacity. The authors explain that agricultural systems in northern Ethiopia were characterised by intensive fallowing of between 1-5 years, but that these practices of fallowing that can restore soil fertility are hardly used anymore due to the rise in pressure on land in the last two decades.

## ***Intensification***

To improve productivity many authors embrace sustainable intensification for SSA. What is understood under this term varies. However a common understanding seems to be the careful and efficient use of scarce resources (in Ethiopia mainly land and water) to increase productivity (Araya, Nyssen, Govaerts, Baudron, et al., 2016; Baudron et al., 2015; Friedrich & Kassam, 2011; Kienzie, Ashburner, & Sims, 2013).

For this purpose, the use of external inputs like improved varieties, (mineral) fertilizer, pesticides and engine-powered mechanisation to improve the water and land use efficiency are frequently suggested. For many farmers however these inputs are not affordable and not available in sufficient quantities, which is particularly the case for marginal farmers. Tiftonell et al. (2016) however, whilst confirming the need for intensification in order to guarantee food supply to growing urban areas, count less on external inputs, favouring ecological intensification instead.

Whether farmers can afford to use external inputs like mechanisation also depends on the size of the farm. The debate about suitable forms of agricultural intensification touches on the question of the need for structural transformation of agriculture towards higher farm entities. It is also argued that the current land-tenure system discourages farmers from investing in the farms. Land in Ethiopia is state-owned making it impossible to sell land or to use it as collateral for loans. Thus land-transfers to more productive farmers are inhibited.

The government gives high priority to the productivity of the smallholder sector (Headey, Dereje, & Taffesse, 2014). The overall economic policy is determined by the Agricultural Development Led Industrialization Strategy (ADLI). It promotes the use of labour-intensive methods to increase agricultural output and productivity. Higher agricultural output is meant to fuel industrial development. This strategy is implemented in the Growth and Transformation Plan (GTP) and the GTP contains the Agricultural Growth Programme (AGP). (Tefera, Tesfay, Elias, Diro, & Koomen, 2016).

The next section focusses on the opportunities and challenges of mechanisation as an input for sustainable intensification in Ethiopia.

### 3.2. The current situation and impact of mechanisation in Ethiopia

As will be explained in chapter 4, this thesis embraces a broad understanding of mechanisation that includes the use of oxen-powered systems and manual tools alongside tractorisation. After a general introduction of mechanisation and farm power in Ethiopia, the three levels of draught animal power, two-wheel tractors and four-wheel tractors are described in detail referring to their current use and to their potential social, socio-economic and environmental implications.

The rationale for increasing, or efficient mechanisation is to increase land and labour productivity through facilitating management opportunities such as row seeding and the efficient application of agrochemicals or organic fertilizer. Further mechanisation is an input itself that can allow more timeliness of operation and better quality of work for instance in soil tillage. Mechanisation is also meant to save natural resources, especially the soil for instance through the adoption of conservational agriculture practices (Duerr et al., 2016). Another goal is to reduce the workload burden in agriculture in Ethiopia which affects youth and particularly women. The empowerment of women in agriculture not only contributes to improving women's living conditions, but the effects on the overall nutritional situation and agricultural productivity are fairly certain. This is in line with research results on SSA in general and Ethiopia in particular (Moller, 2015; Mume, Umeta, Yimamu, & Deressa, 2014; Sims, 2017; Ströh de Martínez et al., 2016). Against this backdrop it is remarkable that farm power in SSA-Africa stands in contrast to three other developing regions largely based on manual power (see Table 2).

Table 2: Farm power in SSA

Region	Hand	Animal	Engine
SSA	65	25	10
3 other developing regions*	25	25	50

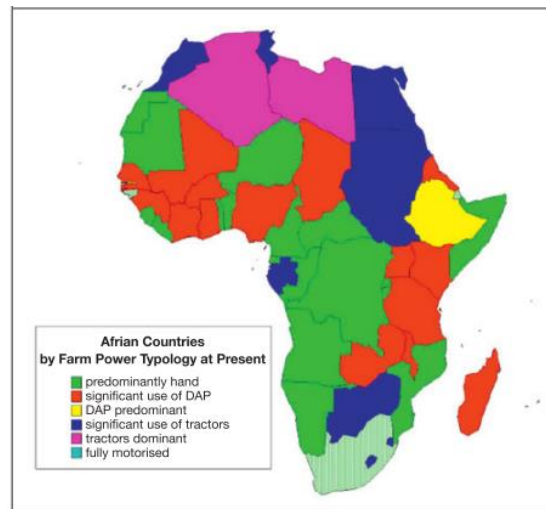
\* Asia, Near East and North Africa, Latin America and Caribbean.

Source: (Food Agriculture Organization of the United Nations, 2008)

The predominance of oxen power is therefore a unique characteristic of the Ethiopian highlands and is not found in this intensity in other SSA countries (see Figure 3). However, there are areas in the Ethiopian highlands where hoe-cultivation is the dominant system (Westphal & Westphal-Stevens, 1975).

Nevertheless farm power is low and Baudron et al. (2015) see the need to improve farm-power balance in SSA for sustainable intensification. They see farm power as a limiting factor in many

production systems in SSA. This balance can be improved by reducing the energy demand or by increasing farm power.



*Figure 3: Source of farm power in Africa*  
Source: (Ströh de Martínez et al., 2016)

The Agricultural Transformation Agency, a governmental institution funded by the Bill and Melinda Gates foundation, is working on a national mechanisation strategy (Ethiopian Agricultural Transformation Agency, 2014). The strategy follows a wide understanding of mechanisation and integrates continued support for the development and adoption of low-mechanisation-implements for human and animal power. In the literature roughly three strategies referring to mechanisation can be identified:

- (1) Improvement of implements and management of the traditional oxen-plough system and a shift towards conservational agricultural practices
- (2) The adoption of two-wheel tractor-power in combination with conservational agricultural practices
- (3) The adoption of tractor-based farm management in combination with conventional and conservational agriculture practices and the use of combine harvesters

Whereas the first strategy builds mostly on private ownership the other two models rely more heavily on service provision.

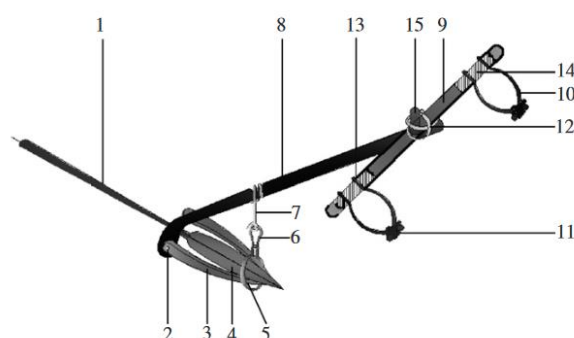
### 3.2.1. Small-scale mechanisation with oxen

Given the high significance of oxen-power this section describes the current system and its impact on social, socio-economic and environmental parameters, and explores the attempts to improve technology and management.



Traditional soil preparation in Ethiopia requires three elements: the operator, a pair of oxen and the tillage implement (Aune, Bussa, Asfaw, & Ayele, 2001). The implement for soil tillage in Ethiopia is the *maresha* (see Figure 4).

The tool has been used in its current form in Ethiopia for around several thousand years. The development of its use started in the northern highlands of Ethiopia from where it gradually spread to the south. A set of specific conditions are believed to be the cause for the introduction of the *maresha* which were not found in any other highland parts of Eastern Africa. The cereal-focussed farming system and especially the cultivation of the tiny-seeded teff, that needs a fine seedbed, along with short vegetation periods of the dryer northern climate were the main reasons for the development of this implement. Furthermore, the absence of the tsetse fly and political relations are named as reasons for its development (Aune, Bussa, Asfaw, & Ayele, 2001).



Three-dimensional sketch of the Ethiopia ard plough 'Maresha': (1) handle; (2) wooden pin; (3) side-wing; (4) ploughshare; (5) lower metal loop; (6) upper metal loop; (7) leather stripe; (8) beam; (9) yoke; (10) neck holder sticks; (11, 12) leather strap or rope; (13) rubber as washer; (14) leather for safety; (15) centring pin.

Figure 4: Maresha

Source: (Gebregziabher et al., 2007)

Farmers use the *maresha* to create a fine seed bed, to suppress weeds and to increase water infiltration (Araya, Nyssen, Govaerts, Baudron, et al., 2016). In its construction form the *maresha* is a beam ard plough, similar in its development to those in other parts of the world (Hopfen, 1981). Apart from the plough share and the metal loops all parts of the implement are made of wood (Gebregziabher et al., 2016). According to Aune et al. (2001) it weighs between 12-20 kg. The working depth of the *maresha* is usually reported to be 5-10 cm (Aune et al., 2001), however repeated passes might increase the depth. Astatke et al. (2002) explain that with the last pass up to 20 cm can be reached.

The operations principle of the *maresha* makes repeated cross-ploughing necessary. Each pass is carried out perpendicular to the previous pass to ensure that the whole field is tilled. The tillage

frequency depends on different factors such as crop and soil type and weed infestation. Most sources name three to five times. Teff in particular needs a well-prepared fine seedbed (Aune et al., 2001). According to Gebregziabher et al. (2006) legumes only need one to two passes whereas cereals need three to four passes and long-term fallows up to seven. Increased tillage is also a strategy to reduce weeds. The last pass is usually carried out with less depth after sowing to cover the seeds.

There are cultural differences between the different ethnic groups in Ethiopia according to traditional gender role allocation. Ploughing, sowing and threshing for instance are all operations performed with oxen and throughout Ethiopia are considered an exclusively masculine domain. Usually women do not carry out land preparation tasks but are strongly engaged in weeding which is largely performed manually with hand-hoes (Belay, 2016; Mume et al., 2014; Sims, 2017). Despite this generalised perspective there are several social and ethnic exceptions. Gella and Tadele (2014) report a number of cases in which women are breaking with traditions. This can be seen in the case of the widow farmer, indicating that traditional role allocation might be less rigid when it is required to be. Women are also forced to take on a male's agricultural workload when their husbands or older sons migrate to cities to look for work. The migration leads to a continuous rise in women-headed households. In their Gender Study in Hawassa and Asella in Ethiopia, and Bungoma and Laikipia in Kenya (van Eerdewijk & Danielsen, 2015), the authors observe that the continuing trend of male migration to urban areas results in women's an increasingly central role in agricultural production and commercialization. However, women still have little access to mechanisation and the authors have not found many signs of mechanisation to reduce the workload for women in weeding, and other tasks.



*Figure 5: Women farmer ploughing in Tigray*  
Source: (Gella & Tadele, 2014)

Not all farmers own a pair of oxen. Especially farmers with small land holdings are unable to sustain a pair of oxen because of the required amount of feed. According to Aune et al. (2001) for farmers with less than one hectare it is hard to maintain a couple of oxen. These farmers have to make use of different exchange mechanisms. Due to the fact that oxen owners charge high amounts of the harvest for their service (up to 75 %) it is clear that such an exchange mechanism is a heavy burden for those farmers that have to make use of them. In general, it is young and female farmers who are the ones with lowest land holdings who have to use the exchange mechanisms. Farmers without oxen usually also sow later, have lower yields and have more erosion on their fields.

Overall there is high percentage of farmers who are forced to make use of the expensive oxen-service. In a study in southern Ethiopia 83 % of women-headed households and 67 % of male-headed households faced a shortage of oxen to undertake agricultural activities. One example of dealing with oxen shortages is the practice of *mekenajo* in which two households each with only one oxen bring them together to a couple for ploughing. Also the borrowing of oxen is practised (Duguma, 2015).

Oxen ownership also means that feed resources cannot be used for other purposes such as milk production, because high amounts of straw are fed to the oxen. Animals are also allowed to free graze after harvest, leaving the field without residues and causing compaction on the fields. The compaction is then addressed by ploughing. This also limits the scope of conservational agriculture where the straw is potentially needed as mulch material for permanent soil cover (Araya, Nyssen, Govaerts, Baudron, et al., 2016).

To sustain a pair of oxen a considerable amount of feed resources are required and due to grazing land scarcity oxen prices have almost doubled between 2001 and 2016 threatening the livelihoods of smallholders (Berhane, Dereje, Minten, & Tamru, 2017). On the other hand, oxen provide a form of insurance for financially difficult times. This is visible in the declining number of livestock in which the number of oxen are less reduced compared to the number of milking cows, suggesting the importance of oxen in the farming system (Aune et al., 2001).

In addition to the afore-mentioned economic problems the necessary repeated passes of cross-ploughing when working with the *maresha* causes soil degradation through erosion, soil organic carbon loss, compaction and crusting (Gebregziabher et al., 2016). In a maize trial in the rift-valley it was shown that long-term *maresha* ploughing leads to higher crop susceptibility to droughts and dry-spells (Biazin, Stroosnijder, Temesgen, Abdul Kadir, & Sterk, 2011).

Furthermore, this ploughing practice is considered as a hard work for the farmer who has to walk long distances in the already ploughed field. A typical farmer uses a pair of oxen for around 450 hours a year for cultivation and threshing (Gebregziabher et al., 2006).

### ***Adapted traditional mechanisation systems***

The previous section showed that the oxen-power system in the Ethiopian highlands offers advantages to farmers but also faces social, socio-economic and environmental problems. However, the economic situation of many smallholder farmers and their absence of market access will not allow them to switch to higher power levels. For this reason the system requires improvement (Biazin et al., 2011; Gebregziabher et al., 2016).

There have been many attempts in the past to introduce new implements to the oxen-system or to modify existing implements. Gebregziabher et al. (2016) present a long list of those attempts and give the example of the Italians who introduced oxen-draught mouldboard ploughs. Farmers rejected these, which lead to the view that they were too conservative. The authors present a different reason, stating that the farmer's practices were not studied sufficiently and that it needed a more systematic approach. The authors describe how the ploughs were too heavy and argue that any new design has to "take into account the agricultural and industrial systems, within which the implement are manufactured and operated" (Gebregziabher et al., 2016).

A technology that earned acceptance amongst farmers in Ethiopia was the introduction of broad bed makers (BBM) (see Figure 6 and Figure 7), which are used on vertisols with waterlogging problems during the rainy season. Farmers used to wait until the end of the rain season to cultivate the fields. This meant that they could only make use of a short growing period, with the uncovered fields also being subject to erosion during the rainy season. Using BBM, farmers can drain the fields and direct access water towards ponds to use it for irrigation. In this way cereals can be grown in the main season and a second crop usually a legume after the harvest (Astatke et al., 2002; Rutherford, 2008).



*Figure 6: Broad Bed Maker*

Source: (Wubie, 2015)



Figure 7: Aybar Broad Bed Maker

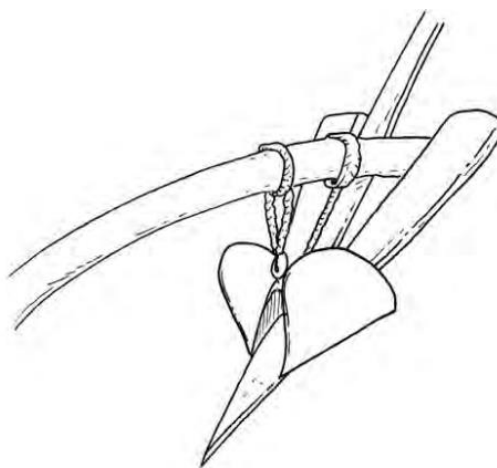
Source: (Temesgen & Biazin, 2014)

Another way of managing vertisols was examined in a long-term trial, where adapted indigenous practices of two different bed-and-furrow systems (*Terwah* and *Derdero*) were assessed in terms of water erosion, draught power demand, time and labour, weed infestation, and yields performance. The system traditionally practiced in some parts of Tigray was modified in such a way that beds and furrows were established permanently, and crop residues left on the fields. The authors conclude that the combination of traditional resource-conserving methods with the conservation agriculture principle of vertisols in northern Tigray brings multiple benefits such as reduced runoff and soil loss, increased yields and a better economic performance overall. While the yield benefits only become evident after several years other economic advantages can be realised at the start. One drawback of the system appears to be the need for herbicide application. Initially the trial was designed without herbicide application but it had to be introduced as weed infestation in teff crop became too high (Araya, Nyssen, Govaerts, Baudron, et al., 2016).

Temesgen (2015) explored the feasibility of his own development called *Arashogel* (see Figure 8) which is an extension of the *maresha*. In contrast to BBMs which are used for secondary tillage this implement is meant to replace the *maresha* for primary tillage. Through its different working mode, it can be operated in one direction for example along the contour and reduces the required passes to two. The author therefore views it as a way of implementing conservational tillage. Preliminary results indicate that the tool increases yields, reduces run-off, erosion and energy requirements. The main advantage is that the tillage is not performed in the direction of the slope, so that the created furrows do not direct the water flow downhill. Thus, runoff and erosion can potentially be reduced. Further long-term trials are needed to better understand the effects of the implement. However,

these first results encourage further developments to improve the traditional tillage system directing it more towards conservational agriculture.

Reducing the traction requirement by adopting conservational agricultural practices can rise the livestock production output. Oxen can for example be replaced by milking cows or milking goats which has been shown to improve the overall economic performance of the system (Aune, Asrat, Teklehaimanot, & Bune, 2006).



*Figure 8: Arashogel (Oxen-drawn implement)*

Source: (Temesgen, 2015)

Further ideas to improve the oxen-system are to improve the feed management and to use cows or single oxen for tillage, particularly for less demanding conservational tillage (Aune et al., 2006).

### 3.2.2. Engine-driven mechanisation

At on average 0.1 kw/ha engine farm power is at a low level in Ethiopia (Ethiopian Agricultural Transformation Agency, 2014). Furthermore, there are a relatively low number of tractors (2.24 per 100 km<sup>2</sup>) in comparison to neighbouring countries such as Sudan (9.6) and Kenya (26.28) (Spohn, 2016).

These low numbers can be explained by the extensive use of oxen in agriculture. On Figure 3 the unique role of draught animal power in Ethiopia is depicted. However, increasing land pressure and decreasing feed resources makes it doubtful that the level of draught animal power (DAP) will be maintained.

The profitability of mechanisation is dependent on land and labour availability. Ströh de Martínez et al. (2016) state that mechanisation is most profitable in areas where land is abundant and labour scarce. This seems not to apply for Ethiopia however, as the rise in primarily young men migrating to



cities has led to an increasing number of households suffering from labour shortages which mainly impact children and women (Sims, 2017).

Nevertheless, the rationale for engine-driven mechanisation in Ethiopia is to increase the timeliness of operations, to facilitate the efficient use of inputs, to increase labour productivity and thereby increasing the productivity and income of farmers and other rural stakeholders. It is also believed that it can reduce the workload for women and improve the situation of women-headed households. This should ultimately lead to more sustainable production systems (Duerr et al., 2016; Sims, 2017; Ströh de Martínez et al., 2016).

### 3.2.2.1. Intermediate mechanisation with two-wheel tractors

In contrast to countries in South-East-Asia the adoption of two-wheel tractors (2WTs) in Ethiopia is still low. Table 3 however shows that in recent years a considerable number of two-wheel tractors were imported to Ethiopia especially from China.



*Figure 9: Two-wheel-tractor (Chinese model)*

Source: own picture

According to Spohn (2016) most of these tractors are not in use. He questions the feasibility of using the two-wheel tractors for ploughing, which would only work under optimal conditions. Thus their viable usage is most likely confined to conservational farming systems (Ströh de Martínez et al., 2016).

Duerr et al. (2016) also consider 2WTs unsuitable as a service provider-based business model. Furthermore, they regard the quality of work achieved with these machines as low. These assumptions refer to the most common implements currently used with 2WTs in Ethiopia such as mouldboard ploughs and rototillers.

These may be the causes for the sharp decline in sales of two-wheel tractors through the Adama Agricultural Machinery Industry (METEC), a military run industry enterprise (Berhane et al., 2017).

For the above-mentioned reason Cimmyt, who are proponents of the two-wheel tractor in Ethiopia, explore the feasibility of two-wheel tractors for conservational agriculture in the FACASI project. The combination of these two factors would improve the farm-power balance by decreasing draught requirements and by increasing the farm power. The FACASI project targeted eight locations in Ethiopia, Kenya, Tanzania and Zimbabwe (Ströh de Martínez et al., 2016).

Baudron et al. (2015) have studied the development of mechanisation with two-wheel tractors in India, China and Bangladesh and analysed their models of applicability for SSA. They found that development in Bangladesh is promising for their adaptation in SSA, where an entire service sector has been established around the two-wheel tractor that allows poor farmers to also request mechanised services. The government does not subsidise the sector but has created favourable conditions for the development of the sector. The cheap Chinese 2WT-models made a fast market development possible.

Furthermore, the authors explain how the recent development of different types of seeders for reduced tillage or no-till makes the adoption of two-wheel tractors for conservational agriculture more promising. Through the reduction of feed demand for the substituted oxen more soil residues can be retained on the fields which is one pillar of conservational agriculture.

The multipurpose nature of two-wheel tractors makes them particularly interesting as they can be used for tillage, weed control and as a water pump for small-scale irrigation. The 2WTs can also be equipped with trailers. Transport is crucial for farmers to link them to in-and output markets. However the opportunities for off-farm activities especially in transport and road construction is also likely to meet increased demand and could lead to high use rates of the machines (Baudron et al., 2015).

The authors recognize however that smallholder individual ownership of two-wheel tractors is not feasible. In contrast to Duerr et al. (2016) they regard a system based on service providers as viable and refer to experiences in Bangladesh. Different service provider models can be explored. Group ownership or independent service providers are mentioned. Further it is explained that these service models are already common in SSA, such as the above-mentioned oxen exchange mechanisms and hiring of external labour (Baudron et al., 2015).

Animaw, Nkanya, Nyakiba, Woldemariam, and Takeshima (2016) however, point to the differences between Bangladesh and East Africa concerning soils and topography. They see difficulties in the use



of 2WTs on heavy soils but potential on lighter soils and where small-scale irrigation can be applied. In addition, they mention their potential for harvest.

*Table 3: Agricultural machinery imported to Ethiopia between 2005-2015*

	Combine Harvester	Tractor	Disc Harrow	Disc Plough	MB-Ploughs	2-wheel tractor	Total Implements
China	41	3674	6403	7580	0	4717	22415
Turkey	1	168	3641	0	70	7	3887
Italy	0	707	1525	1425	7	44	3708
Others	19	12	296	1661	4	10	2002
India	25	349	158	1433	4	0	1969
Pakistan		128	21	1520		2	1671
Brazil	85	551	241	730		21	1628
Poland	58	365	1171	0		0	1594
Czechia				0		1480	1480
USA	7	302	1030	104	10	26	1479
Germany	353	917	89	16	33	3	1411
Belarus	0	690	0	0		0	690
Israel			633	0		0	633
UK	31	336	85	27		5	484
Slovakia	0	440	0	0		0	440
UAE	0	296	58	0		0	354
France	2	119	43	95		3	262
Portugal			116	120		0	236
Japan			156	6		56	218
Georgia			122	0		0	122
Sweden			120	0		0	120
Iran			69	0		0	69
Total	622	9054	15977	14717	128	6374	46872

Source: (Spohn, 2016), data: Ethiopians Customs Authority

### 3.2.2.2. Large-scale mechanisation

This section looks at the rationale for promoting large mechanisation in Ethiopia and current examples of large mechanisation in some areas.

As previously mentioned, the rationale of national politics and international development aid to promote (large-scale) mechanisation is mainly to increase the outputs per area of land. Duerr et al. (2016) suggest that there are four key drivers in the production increase through mechanisation: (1) more efficient use of labour, (2) timeliness of operation, (3) more efficient use of inputs, (4) more sustainable production systems. They estimate that through the mechanisation of all farm operations yields can increase by 80 % from currently 2.2 t/ha to 4 t/ha in the Arsi region.

Several efforts to introduce tractors to Ethiopia have been made in the past. State-owned hiring schemes that were running between 1970 and 1990 collapsed due to the financial burden (International Maize and Wheat Improvement Center, 2014). A similar development took place in many SSA countries, hence there has often been a call to focus efforts on private sector involvement (Baudron et al., 2015; Duerr et al., 2016).

This demand falls on fertile ground as in different regions of Ethiopia the recent evolvement of private service providers for tractor and combine harvester services enables farmers to mechanise main farm operations such as ploughing, harrowing and harvesting (Berhane et al., 2017).

According to Berhane et al. (2017) the price of oxen and labour are an important driver of this trend. Real wages of unskilled rural labour have increased between 2000 and 2016 by 50 %, however they are still low compared to other East African countries (Tanzania and Kenya). Oxen prices have doubled between 2001 and 2016 (see section Small-scale mechanisation with oxen).

Large mechanisation is most significant in the zone Arsi and Bale due to the combination of various favourable factors. The area is flat in many parts, stone-free and has a high percentage of commercial farms (> 25.2 ha) as well as smallholder farms with relatively large farm sizes. Furthermore, Arsi was subject in the past to national and international mechanisation efforts. Finally, labour prices in the region are comparatively high and the rain patterns allow for a second short season which requires relatively fast harvest and land preparation. Other zones where large mechanisation is spreading are Western Tigray, South Gondar, West Gojjam, East Shewa and parts of the Somali region (Berhane et al., 2017). Mechanisation is driven by private service providers, that shift their operating area depending on the season (see Figure 10).

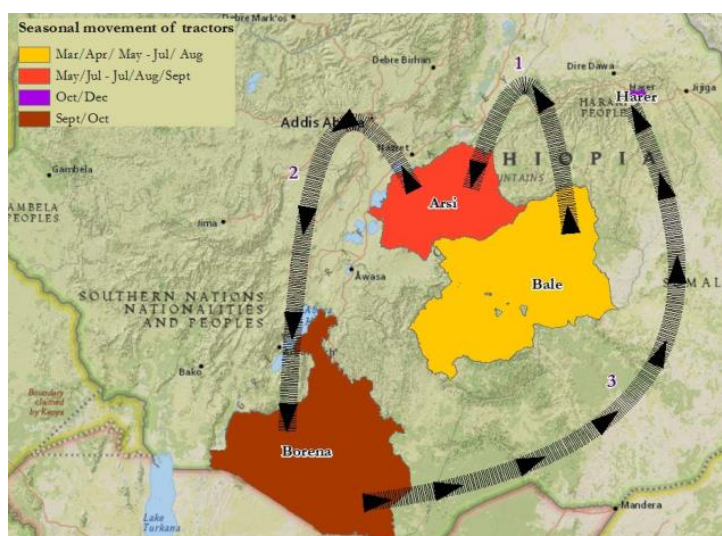


Figure 10: Seasonal shifting of service provider

Source: (Berhane et al., 2017)

Tractor imports have rapidly increased in the past decade, but slowed down recently, whereas the import of combine harvesters is steadily increasing. Figure 11 shows the changes in agricultural machine imports between 2001 and 2014.

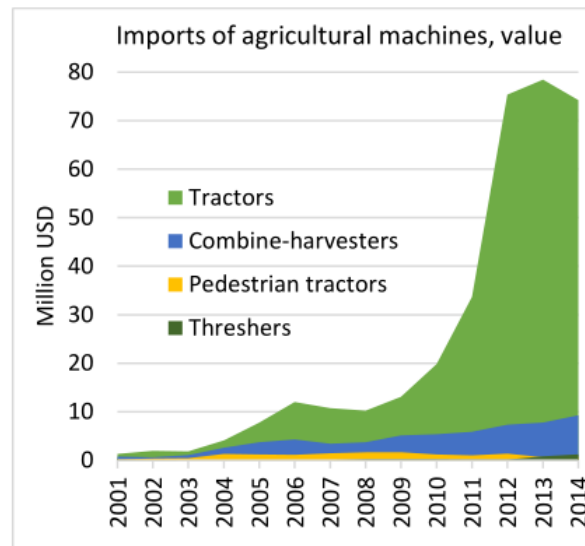


Figure 11: Imports of agricultural machines

Source: (Berhane et al., 2017)

How the increasing trend of large machinery use increases the yields was investigated based on survey data. For tractor ploughing no yield increases could be found (Berhane et al., 2017). For combine harvesters the effect on yield is more evident and is most likely to be related to the reduction of post-harvest losses that are high in traditional methods (Berhane et al., 2017; Hassena, Ensermu, Mwangi, & Verkuil, 2000).

The rather minimal productivity increase through large mechanisation has been at the heart of various projects by the German Agency for International Development Cooperation (GIZ) that aims to improve the quality of mechanised operations and increase the range of operations.

Duerr et al. (2016) conducted a study within the scope of the GIZ project Support to Sustainable Agricultural Productivity in Ethiopia (SSAP). Calculations for different agricultural mechanization technology levels including all relevant tractor field operations, like ploughing, harrowing, seeding and fertilizer as well pesticide application. The four levels ranged from 80-100 hp tractors with more simple implements (disc plough and disc harrow) to 125-150 hp tractors with more advanced implements for combined operations (mouldboard plough, power harrow with seed drill). The calculations were based on a private service provider model. Oxen- and two-wheel tractor mechanisation were included in the calculations, however it was assumed that two-wheel tractors are not suitable for a service provider model. The higher the mechanisation level the higher the calculated gross margins for service providers and smallholder farmers. A sensitivity analysis showed that an intermediate technology is most favourable for service providers as it guarantees the highest cash flows at 25 % reduced annual utilisation rate. The model implies available financing both for service providers and farmers. For farmers coming from animal drought technology the intermediate technology would mean a gross margin increase of 37 % and 85 % for both high technology levels.

GIZ Ethiopia's Green Innovation Centre (GIC) tested interventions of “improved agronomic practices” on smallholder farms in the Arsi region. The effects were assessed on 593 randomly sampled smallholder farms in 2016. Interventions linked with mechanisation brought significant yield increases. Tractor ploughing, harrowing and row seeding increased the yields on farms by 21 %, 9 % and 28 % respectively. An economic advantage for harrowing was very low at a mere 0.4 % increase in gross margin, whereas for tractor ploughing and row-seeding the advantage was significant (24 % and 30 %) (Ellssel, Rahmann, & Freyer, 2017).

Within the scope of the ASSAP project the Agricultural Training Centre (ATC) in Kolumsa is working on capacity building and is conducting trials with various tillage systems. In a field trial the centre compared conventional tillage with reduced and conservational tillage. The yield and the economic performance varies depending on the year. In 2016 (third year of trial) the conservational version displayed the highest yields and gross margins, which can explained by positive effects on water conservation (Deutsche Gesellschaft für Internationale Zusammenarbeit, 2017).

## 4. Theoretical framework

This section introduces a number of important definitions and concepts that are used in this thesis to provide a common understanding, as the scientific and grey literature is not always consistent in its interpretation. Firstly, it is explained how mechanisation is understood and in which areas of mechanisation the focus is placed. Moreover, the different soil preparation systems, the understanding of intensification and main indicators for socio-economic, social and environmental impact are presented. Finally, the farming systems that are part of the analysis are described.

### ***Terms of mechanisation***

This thesis adopts the FAO definition of agricultural mechanisation (Food agriculture Organization of the United Nations, 2016; Sims & Kienzle, 2006). The definition includes the process of mechanisation as an increase of farm power level and also as the introduction or improvement of tools and implements.

Similarly to Ströh de Martínez et al. (2016) different intensities/levels are differentiated. intensities/levels are differentiated. However, in comparison to Ströh de Martínez et al. (2016) in this work hoe-culture is not referred to as an own level of mechanisation. Instead three main levels of mechanisation in terms of the power supply are differentiated: animal-powered systems (small-scale), two-wheel tractor powered systems (intermediate) and four-wheel tractor driven (large-scale) systems.

These categories refer to the main power source that is used. Manual labour for weed control with tools is also practiced in all these systems. Nevertheless, the opportunities to improve and develop mechanisation with manual tools are acknowledged. Some actors address two-wheel tractors when talking about small-scale mechanisation and others use the term “modern mechanisation” in the context of motorised (large) mechanisation.

Furthermore, the focus is on the mechanisation of plant production systems; post-harvest and animal production systems are not addressed. The need for mechanisation of down-stream sectors for agro-processing to absorb and process the increased agricultural output as expressed by Ströh de Martínez et al. (2016) is recognised but beyond the scope of this work.

In the discourse about mechanisation in Sub Saharan Africa (SSA) the increase of farm power usually through motorisation is often referred to. However farm power is only one indicator of mechanisation. Higher efficiency using suitable tools and implements is also relevant and might reduce the farm power requirement. Thus, mechanisation in this thesis is understood in terms of balancing farm power needs and available farm power.

Soil tillage is usually the most energy-demanding farm task. However, the farm power required for this varies significantly between different cropping systems, soil tillage systems and soil fertility systems.

A further relevant area is the efficient transmission of farm power e.g. into traction power or power-take-off-driven implements. The farm power which is usually expressed in horse power (hp) is not always sufficient to explain how well the farm operation can be conducted.

Sims and Kienzie (2006) further describe the aims of mechanisation in increasing yields, expanding farm land, allowing for additional tasks, improving work and product quality and reducing the drudgery of farm work.

As increasing yields is a major aim in the Ethiopian context it is usually also the main rationale for promoting and supporting mechanisation by different stakeholders. The fact that mechanisation has the potential of increasing yields is on the one hand based on facilitating the use of internal and external inputs, but on the other hand mechanisation is an input that can by itself improve yields. Important here is for instance the potential to improve the timeliness of operation (Duerr et al., 2016; Sims et al., 2016).

However, mechanisation has the potential not just to increase yields but to increase the entire agricultural output. The main reasons for this are the reduction of harvest and post-harvest losses and a better product quality. In addition, the intensification of production e.g. by multiple cropping in an extended cropping period can lead to higher farm productivity

This thesis focuses I on mechanisation of operations for crop production, mainly tillage and harvesting. Post-harvest mechanisation and other operations are either partly addressed or not addressed at all.

### ***Tillage systems***

The question of appropriate mechanisation is closely related to the method of soil preparation. The current debate about the “right” system of soil preparation in Europe and in SSA is highly polarised In the Ethiopian context different systems of soil tillage are practised.

- Alongside the hoe-culture there exists a relatively superficial but intensive tillage which is conducted through a kind of tine-plough called *maresha* which is often referred to as an ard plough. The implement is mainly used for the repeated cross-ploughing at an approx. depth of 10 cm.

- Inspired by western “modern” agriculture, ploughs that require large-scale mechanisation with tractors are used in regions which have favourable conditions in terms of topography, road access and farm size. The common implement here is the disc-plough. Recently the mouldboard-plough has begun to be promoted for secondary tillage disc harrows are commonly used.
- A further tillage system is conservational tillage, also referred to as minimal or reduced tillage. It is promoted as an effective means to stop soil degradation and to increase soil fertility. Conservational tillage includes the use of a variety of tools and implements and can be applied with various power sources ranging from manual power to highly motorized power sources.

It is often argued that conservational tillage alone is not effective or even harmful and that only a combination with other measures such as permanent soil cover and the implementation of a crop rotation can lead to the desired effects. This is usually referred to as conservational agriculture. Therefore, trials often look at conservational agriculture which makes it hard to identify the single effect of the tillage system.

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### ***Sustainable intensification / ecological intensification***

There seems to be a consensus between stakeholders in Ethiopia that there is a need to increase agricultural production. As the scope of expansion of agricultural land is limited land productivity in the smallholder system must increase. At the same time the country struggles with massive resource degradation, particularly through erosion. Under sustainable intensification we find a broad set of practices that is supposed to increase productivity and at the same time protect the natural resources (Sims et al., 2016). Ecological intensification on the other hand relies less on external inputs and instead focuses on ecosystem services (Bommarco, Kleijn, & Potts, 2013; Tittonell et al., 2016).

### ***Farming system***

This thesis focuses on the mixed crop livestock system of the Ethiopian highlands (Chamberlin & Schmidt, 2012; Mengistu, 2006), that is more in detail described by Westphal and Westphal-Stevens (1975) as the seed-farming complex which is further differentiated into subsystems. Beyond that, to

understand the influence of mechanisation on the smallholder highland farming systems in Ethiopia, its effect on rural communities as a whole for instance the development of rural labour markets and the up- and down-stream sectors must be addressed (Ströh de Martínez et al., 2016). Rural livelihoods depend largely on the farming sector and therefore will determine migration decisions (Kosec, Hosaena Ghebru, Holtemeyer, Mueller, & Schmidt, 2016). Therefore, parameter of rural livelihoods as yields, income, drudgery and labour were used to assess agricultural mechanisation opportunities. Among environmental parameter the focus is on the natural resources for farming, particularly the interlinkages between soils and water.

At a household level the impact of mechanisation on farmer's family members may differ. This thesis addresses the role of women in particular as they often are subject to high workloads due to household and farming duties. The increased male urban migration leading to a "feminization" of agriculture increases the role of women in agriculture. Here the distinction between female household members and female household heads might be necessary (Belay, 2016; Mume et al., 2014; Sims, 2017).



## 5. Material and Methods

The research for this thesis was conducted between October and December 2016 during an internship at the Green Innovation Centre of the German Agency for Development Cooperation in Addis Abeba, Ethiopia. During the field phase the political situation was tense and did not always allow for field visits. However, farm visits and visits to the mechanisation section of the Ethiopian Institute of Agricultural Research in Melkassa (EIAR), the Agricultural Training Centre (ATC) in Kolumsa and of a seed cooperative provided first insights into farming systems and the status and issues surrounding mechanisation in the Arsi region. As early as the start of 2016 coffee and enset farms in Oromia and mixed crop livestock farms around Bahir Dar in Amhara region were visited in the context of a university field trip. This experience formed the basis of a better understanding of the farming sector in Ethiopia. For example, the soil erosion problems in many parts of the country could be observed at first hand and the dominance of the oxen-mechanisation system was impressive. From this initial knowledge a first literature review was conducted in order to gain a better understanding of the status, potentials and risks of on-farm mechanisation in Ethiopia. This was used to identify potential institutions and individuals for the interviews.

### ***Sampling***

Stakeholders were selected with the objective to get a broad understanding of the topic and diverse perspectives including stakeholders from farming, politics, research, development cooperation and small- and large businesses. GIZ facilitated some contacts, while others were directly approached through e-mail and telephone.

*Table 4: List of key informant interviews and FGD*

<b>Interview code</b>	<b>Institution/stakeholder</b>	<b>Function</b>
I#1	Melkassa research centre of EIAR (mechanisation section)	Head of institute / Researcher
I#2	Kaleb Service Farmers House Plc (large machinery wholesaler)	Employee
I#3	GIZ – Integrated soil fertility management project	Project manager
I#4	Aybar engineering plc (development and manufacturing of oxen-drawn implements)	Head of enterprise/ researcher
I#5	Welthungerhilfe	Senior program advisor
I#6	MoA – mechanisation directorate	Specialist on mechanisation at ministry for agriculture
I#7	IP- Consult (consultancy working for GIZ)	Researcher
	Cimmyt (Interview could not be recorded and served only to get an overview of Cimmyts involvement in mechanisation)	CIM/GIZ integrated expert
FGD	Farmers in Kebele Lode-Hitossa in Arsi	

Furthermore, a focus group discussion that was facilitated by IP-consult and local agricultural experts was carried out in an agricultural training centre close to Iteya in the woreda Lude-Hitossa in Arsi. The group was composed of five male and one female farmer with different socio-economic backgrounds. The farmers are situated in an area to the south-east of the capital at the edge of the rift valley. In this area service provision with tractors and combine harvesters is common. As a result, the farmers were able to report first hand about their experiences. However, it must be taken into consideration that their answers may have been more positive in order to encourage development cooperation efforts. To avoid biased answers, they were informed that the FGD was not part of the GIZ project but that the results were only being used for personal research.



Figure 12: FGD in Lode-Hitossa

Source: own picture

### **Data acquisition**

The interviews were conducted in quiet environments (offices) and were recorded. Interviewees were mainly based in Addis Abeba, only *Interviewee#1* was interviewed in Melkassa, Arsi. The participant selection and the interview guidelines aimed to achieve a complex understanding of the topic. The interviews were carried out with the help of semi-structured questionnaires with individual modifications to account for their individual knowledge (see example in Annex).

For the focus-group discussion farmers of different ages, gender and socio-economic backgrounds were selected. The FGD was facilitated by IP-consult. It took place in an agricultural training centre in Hitossa. A member of IP consult translated the questions from English into the local language (Afan Oromo). The group discussed the questions and the outcomes were reported to me by the translator. The focus group discussion was recorded.

### ***Data analysis***

The interview recordings and the recording from the focus group discussion were transcribed using Atlas ti software. A content analysis was carried out according to Mayring (2014).

A category system was developed with deductive and inductive approaches. Codes were initially developed based on a pre-defined structure that derived from the research questions and working hypotheses. To identify suitable sub-codes all interviews were read once. Once the coding structure was complete several coding rounds were conducted. The combination of deductive and inductive coding is examined by Saldaña (2015).

## 6. Results

In this section the outcomes from the interview analysis are depicted and structured equivalent to the research questions. The main sections are about the current status of different levels of mechanisation in Ethiopia, the impact of mechanisation on social, socio-economic and environmental parameters, the challenges of implementation and solution approaches for the adoption of improved mechanisation.

### 6.1. Current situation of mechanisation in Ethiopia

The interpretation of the status of mechanisation in Ethiopia by different actors varied, which can be explained primarily by different understandings of what defines agricultural mechanisation. With one exception, actors first talked about motorised mechanisation when asked about mechanisation. In the course of the interviews oxen-mechanisation was then also addressed.

*Yeah, it is very important, because the mechanisation level in Ethiopia is at this time, the data shows we are at 0.1 kw per hectare [...]. The number of tractors are around 12 000, about 1 000 combine harvesters in this area, but we have over 40 million farmers at this time. Compared to the potential the mechanisation level is very very very low. (I#6)*

*Interviewee#6*, who works as a mechanisation specialist at the ministry of agriculture, assessed (motorised) farm power (kw/ha) and the number of machines as very low. Although he did not directly mention he considered the figures in the international and SSA context and compared the numbers of tractors and combine harvesters to the number of farmers.

The interviewees named different levels of mechanisation as relevant for the smallholder system of the Ethiopian highlands. The lowest level is the hoe-culture which, according to *Interviewee#3* still plays a significant role in different parts of Ethiopia. How this level of mechanisation can be improved without changing the power source was not part of the interviews. Instead the focus was on the dominant oxen-powered system, the recently promoted two-wheel tractors and the large-scale mechanisation with four-wheel tractors and combine harvesters primarily in well accessible areas.

#### 6.1.1. The oxen-powered system

According to *Interviewee#4* the oxen-system developed more than two thousand years ago in the highlands and marks the first level of mechanisation.

*The mechanisation took place maybe one or two thousand years ago, which means transformation from manual labour to animal power. So, farmers in Ethiopia, especially the highlanders have been*

*using animal power for over two thousand years. So that was the first level of mechanisation [...]. (I#4)*

Further he explained that the transformation to an oxen-powered system (several thousand years ago) allowed the cultivation of larger areas compared to the use of hand tools and increased the labour productivity.

*[...] if we are talking about the power source, because when it comes to labour productivity or the expansion of cultivated land we are referring to transferring from one level of power source to the next, from human labour to animals. That makes it possible to cultivate larger areas of land compared to the hoe-culture. (I#4)*

He described the oxen-powered system in Ethiopia as more developed compared to other parts of Africa, where hoe-culture prevails.

*[...] When it comes to Ethiopia there are two main factors: one is the culture, the culture with animal power is a highly developed one, it is not something you find in other parts of Africa, where largely farmers employ hoe-culture. (I#4)*

He argued that currently there is limited scope for expanding cultivated land through mechanisation and the lack of land is perceived as the greater problem for farmers. He indicated that he sees no need to shift to higher levels of power sources. However, he relativized this statement by mentioning the in general low quality of field operations.

*And because the land has been largely cultivated, in most cases it is shortage of land that you hear from farmers not so much shortage of power, but sometimes that can be disguised. You may find that the quality of work is not sufficient. (I#4)*

However, in the course of the interview he described that there are many problems with the current oxen-powered tillage practices. Especially the need to cross-plough with the *maresha*-implement can lead to a whole series of problems like erosion and delayed planting (addressed in detail in sections 6.2 and 6.3). Part of the problem is the operating principle of the traditional *maresha*, which is explained as follows:

*Now this is the traditional plough, they have these wooden wings at the side and they are blunt. They use the part at the centre to break but the side cutting is done by this blunt wood. (I#4)*

Furthermore, the interviewee stated that the blunt wood increases the traction demand and that the constructive form of the implement forces the farmer to leave space between two tillage furrows, to prevent the plough from “slipping” into the former furrow. So, land remains unploughed and the

next pass needs to be done perpendicular to the last one and so forth. This cross-ploughing is particularly problematic at inclined sites. He also refers to the construction of physical soil conservation structures, in which the government invests large amounts of money (also *Interviewee#7*). As these would disrupt the farmers from their field work, they often destroy or damage them by tillage. These structures are established along the contours. They interfere with the up-and down tillage passes and force the farmer to turn the oxen more frequently

*Ploughing up and down the slope, how stressful it is for oxen and how they are struggling with walking down the hill and also up the hill. And now this is with bunds. I asked one expert, 'so what is the life span of the soil band?' He asked me, 'are you writing this?' I said, 'no, no'. He said, 'it is one month'. (I#4)*

There have been many public research attempts to adjust animal-drawn implements and to introduce other implements for oxen work, to increase the performance of the system. The mechanisation section of the Ethiopian Institute of Agricultural Research (EIAR) in Melkassa has according to *Interviewee#1* developed over 40 technologies of which 25 got acceptance. Others have been imported and tested. He explained that the developments of the institute are then trained to manufacturers who are supposed to directly deliver the implements to the farmers.

*But we have projects here, that objective is to train manufacturers on the machines [...], so that they can produce and deliver to the farmers. So, manufacturers in different parts of the country where we distribute our machinery [...]. (I#1)*

*Interviewee#4*, who also lead that section in the past, in contrast pointed out that no developments have had significant success and neither have been successfully commercialised.

The majority of the interviewees did not refer to the potential of improvement or modification of the oxen-system when asked about mechanisation in the first place. When they were questioned on this matter, all agreed that the development of this system is essential as solutions for the different conditions have to be found.

During the focus group discussion with the farmers from the woreda Lude-Hitossa in the Arsi zone experiences with one of the introduced implements were reported. The farmers are located in an area where private service providers offer tractor ploughing and combine harvesting for smallholder farmers. The farmers were more in favour of “modern” mechanisation instead of small- and intermediate solutions and indicated that improvements of the oxen-system were not successful.

*For instance, they used the improved mouldboard last year. They mention that improving the traditional maresha is ok. But according to his observation, the improved mouldboard is much heavier*

*than the traditional one. It requires improved breed, but actually they don't have that improved breed. So, the oxen have problems when they plough the land, here and there. Even though it was a good approach it is not effective. So, he mentions that it is better to move to the modern machineries, or to mechanisation instead of looking at the intermediate technology, due to some problems, heaviness, or improved oxen, or things like that. (FGD)*

*Interviewee#4* established a business that develops small-scale farming implements and has successfully commercialised an implement that is used for secondary tillage, the *Aybar BBM* (see Figure 7), which is designed for use on vertisols, with water-logging problems. These soils are a wide-spread soil type and out of 13 million hectares 7.6 million are prone to water-logging. With the help of broad bed makers, the fields can be drained, and the growing period extended. Without that technique the field can only be used in the short time after the rainy period with the residual soil moisture.

*The broad bed is where the crop grows, the furrow is where the water is drained, so we remove that access water and we make that land available for farming [...]. (I#4)*

According to *Interviewee#4* in contrast to the *Aybar BBM* previous BBMs version did not get broad acceptance among farmers. The implement is used after primary tillage has already been conducted with another implement.

*The Aybar does not replace the maresha for ploughing. It comes at planting. Only one operation. But before that you can use any type of implement. It doesn't matter. But with the maresha you do cross-ploughing. (I#4)*

Additionally, according to the interviewee the implement is used in dry regions as a tie-ridger to create furrows for irrigation.

*The Aybar can also be used as a tie-ridger in dry areas. So, you leave the part, that makes the bed, you only use the furrow maker. So, you alternatively lift and drop the whole plough, it is not that difficult and then you make a series of basins in the field that hold capture the rainwater. So, it is also being used in dry areas. (I#4)*

*We have sold something like 40 000 to dry areas to be used as a tie-ridger. In general, over the last 4 or 5 years we sold something like 100 000. (I#4)*

### 6.1.2. Motorised agriculture

For engine-powered mechanisation solutions in Ethiopia two-wheel and four-wheel tractors with different horse-powers are in use. *Interviewee#1* stated that individual farmers do not usually have the capacity to purchase machinery. This is in line with the opinions of the other interviewees.

*Yeah, our farmers do not have the capacity to purchase the machinery, machinery like tractors, which [...]. (I#1).*

*Interviewee#3* in contrast explained that single farmers might be able to finance two-wheel tractors, but most farmers do not. Service providers or rental service models for motorised mechanisation options instead of private ownership is therefore the only option for most farmers and was embraced by all interviewees as suitable for the country.

*Interviewee#1* explained that the mechanisation section in Melkassa (EIAR) will move the focus from small- and intermediate mechanisation to large-scale mechanisation, indicating that improvement of oxen-mechanisation is not seen as promising.

#### 6.1.2.1. Intermediate mechanisation

Stakeholders express very different opinions about two-wheel tractor (intermediate) technologies in Ethiopia. *Interviewee#7* reported about negative experiences in practise, deriving from usage of the machines and the training.

*Well, not only Cimmyt, but even the government itself tried many years back. I don't know most of the reports and which I hear from some individuals which use these two-wheel tractors they say, they are not efficient. But I don't think they are not efficient, but the way we are using them in the training itself, we are not integrated you know promoting these things. (I#7)*

In addition, although the farmers in the FGD had no first-hand experience of the technology, they expressed doubts regarding it.

*Really, we want but they doubt the effectiveness, because it needs some muscular guy, otherwise, it is vibrating and shaking. (FGD)*

In line with this scepticism *Interviewee#4* claimed that two-wheel tractors are not suitable for implements that need high pulling forces such as ploughs. Furthermore, he sees the operation of rotating devices, the most wide-spread use of the machines as equally critical as this would lead to the pulverisation of the soil. However, he regards the use of power-take-off-driven (PTO) implements as suitable in terms of power transmission.

*You know that a pair of oxen is capable of pulling more traction force than a two-wheel-tractor. Now the two-wheel tractor is suitable with the rotovator with power-take-off drive. With the rotovator, because of the way power is transmitted they can be fitting. (I#4).*

He also claimed that the 2WTs have no advantage over oxen in the use in CA. On the other hand, *Interviewees#3, #6 and #7* reported positive experiences with different devices. *Interviewee#6* has no



issue with the type of machinery itself, and when asked about the unsuitability of two-wheel tractors and ploughing, he only stressed the need for training. He further reported about plans to enable youth groups to offer services with two-wheel tractors.

*No, no the two-wheel tractors are working, but the problem is, even where we are working now. Even where we are working now with them, we have a big program by which small tractors will be given to the farmers, maybe youths groups or individual farmers. The problem is the other support activities, like skill of operation, operating skill, the management of the business and so on. (I#6)*

*Interviewee#7* has similar views and refers to positive experiences from Kenya and the hello tractor project in Nigeria.

*I know a case around where Cimmyt was promoting these two-wheel tractors. The report says, they are ok, farmers demand them and even in our project, which is called Green Innovation Centre we are trying now, but still there is a lot of work to be done, how two-wheel tractors should work. The right implements, the right timing, the right training, all that should be incorporated as a package. Otherwise I think, I have seen reports, which is from agricultural and mechanisation training project of Green Innovation Centre that in Nigeria they are doing it very well. I saw even Obama and the Kenyan president, where the guy giving service using these [...]. (I#7)*

Experience of using 2WTs in Ethiopia were shared by *Interviewee#3* who in a project explores the applicability of two-wheel tractors for conservational agriculture reported of the successful application. It is only where seeds are placed that the soil is tilled, while the rest remains undisturbed. However, at the same time he sees the requirement of some technical modifications, expressing optimism that they can be solved.

*Yeah, you have two units basically, one placing the fertilizer and the other one placing the seed and they were both fitted on one unit and it did not move. So, if one unit was on top of the soil and the other one was above a depression it not really adjusts the height, and these are things that still need to be sorted out and that is where CIMMYT and here the institute of agricultural research Melkassa [...]. (I#3)*

Especially for mountainous areas that are difficult to access and where the operation of large machinery is problematic two-wheel tractors could represent an alternative to the oxen-system, as *Interviewee#5* pointed out.

*In Ethiopia, it is a very mountainous country, some parts at least, in that area smaller tractors could be more efficient, even for mobility. (I#5)*

*Interviewee#1* generally questioned the quality of machines that are imported to Ethiopia, especially from China. This does not just apply to 2WTs.

*Because of that a lot of machines, there are different machinery importers. A lot of machines are imported to the country, most of them are Chinese-made, they are not working, their capacity is very limited and also the horse-power is different from the one that they been for. (I#1)*

In contrast to large machinery however the two-wheel tractors might be affordable for some smallholders. According to *Interviewee#3* single farmers can afford these machines.

*For the small-scale tractors, the tractor costs 3000 dollars or so and the equipment is a few hundred dollars here and there, so with 5 or 6 thousand dollars you get one full set. At least for some farmers with access to credit this is affordable. (I#3)*

At the same time, he acknowledged that most farmers still do not have the capacity to purchase that kind of machinery. He reported that farmers were interested in getting support to purchase the machinery for offering services. Overall the experiences of and knowledge about two-wheel tractors are mainly based on projects and only derive to a small extent from farming practise. The combination of two-wheel tractors and conservational tillage is a relatively new approach in Ethiopia.

#### 6.1.2.2. Large-scale mechanisation

*Interviewee#3* stated that agricultural mechanisation in Ethiopia is at a very low level.

*[...] because I have never been in a country where agriculture has been as poorly mechanised as in Ethiopia. It is amazing. (I#3)*

This quote refers to all forms of engine-supported mechanisation. *Interviewee#7* sees signs for an increasing mechanisation in the country both for intermediate and large-scale mechanisation, while coming from a low level. He also stated that the Arsi and Bale regions have the highest concentration of these machines, whereas mechanisation in other regions, for instance the Amhara region has started more recently. Farmer's interest in this large-scale mechanisation service appears to be high as he reported for the Amhara region.

*And as a wheat belt of the country and suitable for such mechanisation Bale and Arsi might take the lead in number of these tractors and combine harvesters as compared to other regions. If you take the second largest region Amhara, they started very recently, except you know those large-scale farmers. I heard this year some of this service providers for ploughing and combine harvesting have shifted to Amhara to give service. (I#7)*

*And I have seen on the media also that farmers are highly interested to use them [...] This is for sure,*

*but it has started here, in Arsi and Bale, but it is continuing with a slow pace to other parts of the country. (I#7)*

In line with this observation the farmers in the FGD also showed high interest in increased quality and expansion of these services. This trend can also be observed in the increasing market of agricultural machinery and implements, as described by *Interviewee#2*, who works for a wholesaler of large agricultural machinery. The demand is mainly driven by the higher investments in large-scale farming for instance in the Gambela region, by the private service providers and the cooperative unions, the latter two working more in the smallholder sector.

*The most customers are, for combiners private contractors, it is private contractors who harvest for the farmer and they fix the price based on quintal. [...] Union, they have bought, each union in Arsi area have bought combiner, also tractor, but farmers organising themselves, I haven't seen that. For others, for tractors there are private investors, in the West, Gambela. (I#2)*

*Interviewee#6* described that two unions in Arsi and Bale have started to engage in giving mechanised services with tractors and ploughing. Despite management problems, he suggested increasingly targeting the unions to increase competition between different service providers. The price variation for mechanised services shows that the market for mechanised services is in different developing stages depending on the regions, described here for the case of combine harvesters by *Interviewee#2*.

*Yeah, unions, they have started from three years ago, unions are coming up, particularly in Arsi, Bale region. (I#2)*

*The price range around 40 to 60 birrs around Arsi and Bale. If you go to Gojam, this is in Amhara region, it is up to 100, in Jijiga 80 birr. It varies depending [...]. (I#2)*

*Interviewee#1* explained that farm mechanisation (talking about motorised mechanisation) in Ethiopia has its origin around 40 years ago and was treated very differently by the successive regime. In the past mechanisation took place on farms held by landlords and later on state farms. The government's focus on mechanisation is quite new as far as smallholders are concerned, as *Interviewee#1* explained.

*Since the last two years they are talking about mechanisation. [...] The yield increment is very low, and the land holding size of the families is very low [...] so the youth are going to the cities, so we have to have mechanisation, the farms must be mechanised [...]. They are trying to put farmers in clusters so that they can have big machines from service providers. (I#1)*

The cluster approach which is followed by the government should enable farmers to hire (large-scale) mechanisation services and is also mentioned by other interviewees (#4, #6, #7). However, the implications of the cluster approach are not discussed further. *Interviewee#4* has doubts about the cluster approach and is more in favour of rental services.

*Some people say we can increase the land holding by bringing different farmers together. I don't believe that. Some people also say renting, that can work to some extent. (I#4)*

Another governmental activity which is described by several interviewees is the provision of funds for job creation for young people which aims to create youth groups for mechanisation services (*Interviewee#1, #3, #4, #6, #7*).

*Look at the Ethiopian government now, they are very much positive, they are pushing mechanisation, they are lending the group of youth tractors and machinery, there is a big campaign. (I#4)*

*Interviewee#2* explained that the market is increasing gradually, but that it is highly dependent on financing from banks.

*Yeah, I think it is increasing every year. It is increasing, because particularly the past three to four years the banks are also financing, the Development Bank of Ethiopia, most of the loan form agriculture comes from that bank. It is a state-owned bank. So, when they finance the market will grow, when they stop, recently they have stopped, I don't know the reason, now it is slowing down. (I#2)*

The dominant practice for primary tillage with tractors is ploughing with disc ploughs. However, *Interviewee#2* predicted a change towards mouldboard ploughs. According to him the tractors and combiners are mainly European, Brazilian and Chinese brands. Additionally, METEC assembles Belarus tractors. The quality of implements ranges significantly (*Interviewee #1, #2*).

*You know, for land preparation probably people may change to reversible plough, mouldboard. Up to now, I don't know the dominant primary tillage is disc plough, or other combinations. In the future we may have seed drills, we already have in stock, but it is not taking off yet. Probably three to four units per year. (I#2)*

*There are different importers [...] so most of the implement that come from China are not performing well, especially threshers METEC bought from China, [...] almost wasted, almost all of them are bought from China. (I#1)*

## 6.2. Social and socio-economic impact of mechanisation

In this section the impact of mechanisation on the rural population is assessed through the parameters of labour development, yields, income and drudgery. In addition, the impact on female household members and household heads and youths is addressed. Furthermore, the topic of food security which concerns the Ethiopian population as a whole is addressed here.

### 6.2.1. Labour replacement / labour creation

The influence of higher levels of agricultural mechanisation on labour availability is evaluated differently among the interviewees. The main argument in favour of “modern” mechanisation is that jobs can be created as a result of maintenance, operation of machines and even through manufacturing. Furthermore, the development of an up- and downstream sector would provide additional jobs. This argumentation is followed by *Interviewee#1, #3, #5, #6*, whereas *Interviewee#4* followed a different line of argumentation, explaining the risks of too rapid mechanisation and referring to the development in industrialised countries.

Also, *Interviewee#5* from the Welthungerhilfe in Addis Ababa mentioned that the threat of farm mechanisation could be the release of labour from agriculture. However, he also pointed to the fact that through manufacturing, small-scale business and processing of agricultural crops released labour could be absorbed and stated the need for investment in those sectors.

*Yeah, the threat could be people spending their time working with the oxen-driven applying system. If now mechanisation will be there, some people may be idle. This could be one threat. (I#5)*

*Yes, yes, there is a lot, but also needs policy support and also intervention from the government side, like I said manufacturing could be, like in cottage industry, or in a bit higher kind of manufacturing. There should be a lot of investment in that sector, so that it can absorb [...] from the farming sector, the traditional farming with oxen. So, the government has to take them, like food processing and small-scale food processing, cottage industry, oil production. (I#5)*

Following the same argumentation *Interviewee#1* presumed that the mechanisation sector itself would create jobs.

*My opinion is, you know when there is any implement or machinery you have to train the operator, there will be service providers, not only service providers, there will be persons who will work on the maintenance and everything. So, you are creating more jobs rather than losing the jobs. (I#1)*

Similarly, *Interviewee#7* did not see the risk of labour replacement in the short-term and medium-term through mechanisation, since he predicts the development of mechanisation at a low pace.

*But at this time, if you see the development of this mechanisation, is very slow, so maybe the coming 20, 30 years maybe we don't have to fear such situation will happen in Ethiopia, because the concentration of mechanisation per unit area is really below many development countries. So, it will continue the same pace for some time. So, for the current time it might not be a problem. (I#7)*

He also pointed to the current job possibilities and the need of further diversification of income opportunities. Also, farmers can offer their children higher education through increased income which would lead to better job opportunities. Jobs in industries and opportunities for start-ups would develop.

*We have to diversify also the income generation. Not only on-farm income generation, you have to go also off-farm income generation. So, I think if you increase yield there could be some other options where you can look for, for job creation and processing is there. There are a lot of off-farm jobs. So, I don't, for me I don't feel the issue of mechanisation will bring unemployment. Since when you increase yield using mechanisation the farmers might have money to send their children to school and then when they continue to a higher level. Maybe they look for their own jobs. Factories and other sectors are developing, so they might absorb such an employment if they are educated. (I#7)*

According to Interviewee#3 this trend can already be observed. He stated that labour for agriculture is already becoming scarce and hence more expensive, as the urban construction boom attracts workers. He sees mechanisation as a necessity to reduce labour costs for farmers, especially for the increasing number of female household heads.

*[...] and many households now are in the situation where the husband has left. They work in construction on roadsides, on railways and the women are left with their farm and they really struggle to find labour to till their farms. (I#3)*

Similarly, the farmers from the kebele Lude-Hitossa in the Arsi region confirmed in the FGD that there are new job and business opportunities arising from mechanisation. They describe in detail the diversity of occupations of the household members.

*Some are working day labourers, carpenter and like that, some are learned in university and they are working, private or government or. Even the available children, after school they come home and help with petty trade, small trade, kiosk or shops, like that, they are involved in that. And the rest are feeding cattle. There is dairy cattle, fattening, this are all the activities. They are shifting to on-farm or off-farm labour. He mentions, he has five children, one is at university, graduated from there, and he mention at the moment only the mother and father are staying at home, he feels alone. He is so busy just working on [...] of agriculture. This is the advantage of mechanisation. (FGD)*

A sceptical attitude about the effects of mechanisation on the labour situation was expressed by *Interviewee#4*. He referred to industrialised nations that employ only 2 to 3 % in agriculture and questioned whether other sectors will provide enough jobs. He seemed to fear that it could further fuel social crisis and impact political stability.

*I mean some people argue, 'mechanization does not replace labour, they can have some employment one way or the other, they can create some job'; but that is not true. Go to the developed countries you find that 2 or 3 % of the population is engaged in agriculture, only 2 or 3 %. Now come to Africa you find that 80 % or 85 % is engaged in Agriculture, so look at the whole set there is a labour replacement there is no question about it. The labour displacement is there. Now as long as you don't have other sectors to absorb the displaced labour it will lead to crisis in any way. It will lead to social crisis because there will be unemployment. Whether this current employment in agriculture is efficient or not, it is disguised, it is another question. But in any case, if you look from the social aspect, from the political stability aspect it has a meaning. (I#4)*

Comparing the situation to Europe he did not see that the Ethiopian industry had the potential to absorb large amounts of the labour force. He elaborated that Ethiopia will not be able to compete with other countries like China on the export markets.

*But in Africa we import those industrial products and now trying to export will be an uphill because many industries finding it difficult to compete with Chinese factories for instance or European factories. Those products are imported here, and they are sold at lower price than the local ones, than that what the local factories can afford to sell at, with all the transportation, the tax they still find it very hard to compete with them and instead of, let alone exporting, so is there a space to expand the industry to enable the factories to export to other countries so that they can absorb more labour that is been displaced from agriculture, so that is an uphill. So, trying to mechanise or tractorise the farming has its own risk, it has its own limitation, that in terms of employment. (I#4)*

This is in contrast to *Interviewee#3* who regards Ethiopia as competitive because of the low wage level. *Interview#4* called for a cautious approach towards mechanisation, without denying the application areas for large-scale mechanisation.

*I don't fight the places where tractorisation can work, but otherwise the [...] would not be good. Then people would say tractorisation doesn't work, and that would be another dangerous generalization, we don't want to have that. What we want to have is a very selective, very cautious, well-studied mechanisation effort. (I#4)*

### 6.2.2. Drudgery and time requirement

The interviewees agree that the current oxen-driven mechanisation system in Ethiopia constitutes a huge burden for the farmer's household, as it is time consuming and represents hard physical work for the farmers.

*I mean farming in Ethiopia is really a drudgery. You wouldn't want to do it, I wouldn't want to do it and farmers out there don't want to do it. (I#3)*

The tillage operation in particular was frequently named as very time-consuming and physically tough. The main reason for this appears to be the fact that farmers need to conduct several perpendicular passages with the *maresha*-implement.

*The traditional farmer ploughs between five and eight times before he seeds. (I#3)*

*Interviewee#4* stated that this practise constitutes a waste of time for the farmers as they plough parts that have already been tilled. The tillage of slopes is an additional challenge and the farmer is forced to also plough up and down the hill instead of only working along the contour. This requires constant adjustment of the *maresha* and is physically demanding.

*So close to 50 % of the time is wasted running over already ploughed land [...]. So, they waste more time running on already ploughed land. (I#4)*

*But this time it is changing, every pass, every time it is changing, and it is a challenge and even for themselves to walk up the hill and down the hill compared to walking along the contour. (I#4)*

In the focus group discussion, the farmers stated that saving time and reducing drudgery was an argument for choosing large-scale mechanisation, in their case. The transportation of water served as an example to explain the relevance of adopting new technologies.

*Our sister mentioned, 'previously we have been fetching water on our back, but today we are using tractors. Who knows tomorrow we will be using tap water in our house'. (FGD)*

Transportation is a central topic for farmers as *Interviewee#6* confirmed. As in this quotation reflected mechanisation is generally seen as a way to reduce the drudgery and the amount of time needed for different operations.

*[...] since our farmer are small-scale, and we need mechanisation to reduce many things, you know, related to the drudgery of, you know, oppressions on the country side. (I#7)*

*Interviewee#3* stated that farmers if they get the opportunity for motorised solutions will adopt it easily, since the burden on household members increase and the requirement for more labour productivity is high.



*If they have another alternative they jump at it and many households now are in the situation where the husband has left. (I#3)*

This is in stark contrast to the views of *Interviewee#4* who argued that the oxen-system as a level of mechanisation has already been reached and this constitutes a reluctance to adopt alternatives. He seemed to be the only one among the interviewees that sees a potential to decrease the drudgery in the oxen-system. When reducing drudgery and time requirements the interviewees were mostly referring to motorised mechanisation. However, *Interviewee#4* sees also high potential in the current oxen-driven system for drudgery reduction. He referred here mainly to his own field research, when testing self-developed modifications of the *maresha* together with farmers. A new implement is about to be commercialised. The ploughing frequency could according to him be reduced to 1-2 times.

*[...] but with oxen power you can still handle ten hectares, so they can survive, and the drudgery can be reduced with some improvements in the implements. (I#4)*

*Two times is enough, one just at the start of the raining season and one at planting. That is what farmers like about. They don't need to do cross-ploughing, no need for cross-ploughing, no need for repeated ploughing. (I#4)*

On the other hand, *Interviewee#6* expressed the opinion that the young generation is unwilling to work with the *maresha*.

*You know these days people start getting very educated even farmers. The generation coming, they are educated, and they have skill. Even the farmers, they are fed up with very tiresome farming operations. They are abandoning the animal-drawn maresha. [...] the oxen, because oxen fattening is more profitable than using the oxen for land preparation. They prefer good working condition, they prefer the machines, the tractors, the combiners. (I#6)*

### 6.2.3. Yields, income and food security

The interviewees agree on the significance of mechanisation to raise the yields. *Interviewee#6* assumed that a doubling of yields with motorised mechanisation is possible.

*The mechanisation is very important. We have trouble in different areas. Giving the other factors, like the fertilizer, the improved seed, by using only mechanisation it is possible to double productivity. (I#6)*

However, it seems difficult to foresee what yield gains can be achieved just through mechanisation. *Interviewee#7* mentioned that the inputs cannot be seen independently. Mechanisation can be an

input that increases productivity (yields per hectare) as well as the total production for example by reducing post-harvest losses.

*Well we have to see it as a whole. We cannot separate one input from the other. The conclusion might vary, but mechanisation has a big impact in increasing yield, increasing production and productivity. If you plough, if you make a good seedbed and if you reduce post-harvest loss using good harvesters and so on. This has a big impact. So, it is a big contribution. Normally they say seeds comes first, because it has the genetic potential of higher yields. (I#7)*

This is supported by Interviewee#3 who sees mechanisation as a prerequisite for using certain other inputs and to apply “improved agronomic practices”.

*I think, it is quite important, maybe not the most important factor, but I think it is very important, because some technologies can only be used if you have mechanised agriculture, like application of fertiliser, herbicides, insecticides, agrochemicals, for deep ploughing you need mechanised agriculture. (I#3)*

In deep ploughing for example and in the application of agrochemicals there is the potential to increase the yields and bring the production system to a higher level.

*So, we can give them other alternatives to mechanisation, and farmers can also increase their incomes through increased productivity then this downward spiral would gradually turn into an upward spiral. And then starting with better seeds, better fertilizer, better crop agronomy and then later maybe reduced tillage, conservation agriculture, then we can move the entire system into a different direction, which will be more sustainable and more productive. (I#3)*

The FGD with farmers in Arsi indicated that in their case yields increased through tractor-mechanisation and the use of combine harvesters. Additionally, they see the causes of yield increase mainly in the timeliness of operation, as tractors make an earlier tillage possible, when the soil is still not workable with oxen.

*Previously they mentioned rather than using the animal power, using mechanisation, tractor plough, or harrowing, the productivity is much higher than oxen power, that is due to the deepness of the plough, the pulverisation [...]. (FGD)*

*For instance, when you come to land preparation using the machinery prior to the rainy season, when the land is dry like this, which is not possible with the oxen plough due to the dryness of land. That is one advantage. The other is that they have rainfed agriculture they are competing with climate, they are competing with the rain in order to prepare their land, harrow their land and seed on time due to*

*mechanisation. This all has the process in the income, the income, the productivity, the productive income. (FGD)*

Further they mentioned the advantages in the harvesting season. Again, it is the timeliness of operation that secures the harvest. Greater production also increases their income and improves livelihoods.

*When it comes to the combine harvester, during the harvesting season there are unpredictable rainfalls, which is very difficult to save lots of the crops by using the hand-mown or [...], but when it comes to combine harvester it harvests the bulk of their product and they can store if they want or they can take it to the market which is very attractive, to give them attractive price. All in all, due to mechanisation increasing the production, productivity as well the income, which is contribution in form of their livelihood. (FGD)*

*Interviewee#7* stated that oxen-driven mechanisation also makes high yield gains possible, but that the farmers suffer from decreasing land size.

*The problem is the land holding of farmers, it is decreasing every year and the pressure on land is increasing because of the population increase. So, if you have one hectare, and if your family is increasing that will not be balanced, so you do one hectare with oxen plough to some extent, but that is not the problem, the big problem, but it is possible, because we managed, if you take wheat four, five, six, seven tons is possible. (I#7)*

This is in line with the argument of *Interviewee#4* who considers land scarcity more problematic than low farm power. He gave an example of how to improve the yields in an oxen-driven system. With the introduction of the Aybar broad bed maker (BBM) in a vertisol area it was possible to significantly increase the yields.

*Even with those farmers who have already been ploughing the land, who are already been cultivating the land, they are getting a yield increment of up to 300 % in some cases. There was a survey conducted by the ministry of agriculture in one of the areas called Digalo-Tijo in Arsi where farmers reported that before the introduction of this BBM they were getting between 5-15 quintals per hectare, this is 100 kg. Whereas with Aybar BBM they from 38 quintal to 75 quintal. That was reported by the local agricultural experts. Now that is so much increment, just by changing how the land is shaped while still using the oxen. (I#4)*

The tool does not replace the *maresha* but is used to form furrows and beds after the primary tillage. A further new implement has been developed to be attached to the *maresha* which according to the

interviewee is also increasing the yields. The implement was mentioned in section 6.2.2 (under the name *Arashogel*) as a development to avoid cross-ploughing and reducing drudgery.

*Now we have fifteen farmers testing the [Berkain] maresha this season in one area where there is moisture stress. All of them got higher yield compared to the traditional. With teff average 30 %, with wheat something like 70 %, there is only one farmer actually. With lentils even more than that. But even that 30 % increased yield of about ten farmers, even that one is so much. Now this is in addition to the less ploughing time. (I#4)*

As concerns the costs of mechanisation two different perspectives are reflected in the interviews. One is that through the reduction of oxen the scarce fodder requirements that are needed for the whole season for the oxen are reduced.

*Interviewee#4* on the other hand compared the two-wheel tractor system with the oxen-system and described the cost disadvantages of the two-wheel tractor. He assumed in this example that farmers would own the machines themselves instead of buying the services. He explained how oxen not only serve in farm operations but are also sold after fattening.

*You buy a two-wheel tractor that is more expensive than a pair of oxen and then at the end of the season, there will be some problems with spare parts, with maintenance, with repair. So, if you want to sell it, you sell it at a lower price than you bought it, but if you buy oxen. What farmers do is that they buy oxen, one oxen for 4000 oxen birr, and then a pair of oxen for 8000 birr, or maximum 10000 birr. They use them for ploughing and then they feed them the crop residue and they fatten them a little bit and they sell sometimes a double the price. (I#4)*

The question as to whether conservation agriculture can contribute to higher yields and income could not be clearly answered by the interviewees. The sustainability of the system was usually pronounced, however *Interviewee#6* doubts the productivity of the system. He sees potential for CA in the flat lowlands.

*Yeah there is paradox as far as conservation agriculture, we are currently applying the..., so we have to maximum utilize the potential of the soil, but this conservation or reduced tillage it is not yet well proved in Ethiopia, not yet well tested, but in terms of maintaining the soil fertility they are very important. But we have to prove whether these interventions will in terms of reducing the productivity. We are working on securing the food security. (I#6)*

*Yes, but there are areas where we can apply this conservational. If you go to the western part of where the land holding is very big, and the soil is very young there is a possibility to apply conservation agriculture without affecting the productivity. (I#6)*

the interviewees stressed that conservational tillage can reduce traction requirements and thus costs for mechanisation and energy. Besides increasing the income through increased yields, it is highlighted that mechanisation allows more income to be generated for the family through other on-farm or off-farm employment activities.

*We have to diversify also the income generation. Not only on-farm income generation, you have to go also off-farm income generation. So, I think if you increase yield there could be some other options where you can look for, for job creation and processing is there. (I#7)*

The Interviewee specified the income opportunities that family members have and described the policy efforts to target youths. This might have an impact on the income intensification of the family.

*These small-scale businesses, in every sector including, I'm not sure but they might also give land for youth for some exportable commodities and in the towns also the small business [...]. So, they have a design for that, that might help. So, job creation is not only in big downs, in all small towns in the countryside, woreda level, kebele level and so on. So that is a way out. (I#7)*

The farmers in Hitossa experience their children engaging in off-farm opportunities, as they are required less to work on the farm (see section 0).

#### 6.2.4. Female farmers and youths

As raised in previous sections *Interviewee#3* stressed the “feminisation” of agriculture that is caused by the migration of mainly young men to the towns and cities. This causes a burden for women working in agriculture. In addition rising labour costs result in a potential increase in precarious situations (see also 0 and 6.2.3).

*Epecially for many women-headed households they find it really difficult to get labour, the labour is relatively expensive. So, for them it is an issue to get their farms worked on and for other farmers who rely on hired labour, where the farm size is a bit bigger, it also becomes problematic. (I#3)*

In the focus group discussion, the only female member was also the only one that was using oxen for ploughing. For harvesting in comparison, she requested combine harvesting services. All male farmers were using both tractors for ploughing and the combine harvester. The offering of mechanised services could potentially help female farmers as they traditionally do not work with oxen.

*Our sister says she used oxen for ploughing, but she used combine harvester for harvest. This guy he says totally he is using tractor, as well as combine harvester. And this taller guy he mentioned that he knows that using tractors, or machineries is better than using oxen, or animal plough. But in order to*

*compare, to understand which one is better he use half of his land for oxen plough, for ploughing and the tractors for half of his hectare, but he totally he uses combine harvester for harvesting and the other guys also mention that they are tractors as well as combiners. (FGD)*

Interviewee#3, #6, #7 argued that young farmers would also profit from “modern” mechanisation. The establishment of youth groups that offer mechanisation services is one example that could create jobs in rural areas and thereby reduce the need to migrate. Interviewee#6 mentioned the youth groups that could be formed to give mechanised services.

*No, no the two-wheel tractors are working, but the problem is, even where we are working now. Even where we are working now with them, we have a big program by which small tractors will be given to the farmers, maybe youth groups or individual farmers. The problem is the other support activities like skill of operation, operating skill, the management of the business and so on. (I#6)*

Further, Interviewee#7 argued similarly that education options for farmer’s children could increase if they were less needed on the farms and if farmers had greater financial resources.

*Since when you increase yield using mechanisation the farmers might have money to send their children to school and then when they continue to a higher level. Maybe they look for their own jobs. Factories and other sectors are developing, so they might absorb such an employment if they are educated. (I#7)*

An example of how motorised mechanisation can reduce the burden of youths was given in the FGD.

*Previously they mentioned before the combine harvester was coming they were using animal power for threshing. At that time the children are just going on the threshing activity and they don't go to the school. But today they are learning in the school, staying at the school. (FGD)*

On the other hand, Interviewee#7 pointed out that as education does not guarantee employment some farmers do not invest in the education of their children. Job opportunities in the countryside are still low and sometimes education is seen as a waste of resources. According to Interviewee#3 and #7 the government is therefore investing significant amounts of money in job creation.

*The development of the other sector also, to absorb these educated youths at the countryside level. So, farmers cry sometimes, they sacrifice their resources to educate their children and their children are not getting jobs and sometimes they decline to invest on educating their children. This is happening in some parts. I know some cases in the Amhara region. It might be same [area]. That is way even because of the riots the government has put significant amount of money for job creation. This is a way out maybe. So, I think things will improve. (I#7)*

### 6.3. Environmental impact of mechanisation

The connection between agricultural mechanisation and the environment was not answered in a straight forward way by the interviewees. This is mainly because many different factors determine the actual impact of a technology. By far the most addressed topic is the connection of soil tillage and soil fertility. Other environmental parameters were only occasionally named.

#### 6.3.1. Soil and soil water

Soil degradation and specifically erosion was named as a big problem by most interviewees (*Interviewee#1, #3, #4, #7*).

*Erosion is one of the problems, because people are ploughing steep slopes, that will aggravate because of shortage of land. They want to increase farm land. So, can you not die looking to the deep slope and leave it at is, if you plough soil will be eroded. (I#7)*

The causes of erosion are multifactorial and not only connected to a specific form of mechanisation. Interviewees named the ploughing of steep slopes, the practice of flat but intensive cross-ploughing, deep ploughing with tractors and the use of rotovators (two-wheel tractors with rotary harrows). In the following two quotations *Interviewee#4* described the problems that occur with the oxen-system.

*You go up to the north, their soil is washed away. It is because of the management, it is because of cross-ploughing. It is because of repeatedly ploughing, it is because of up and down the slope ploughing. (I#4)*

*Not only they waste their time, but they pulverize the soil unnecessary, they damage the soil in terms of too much work on it. It is already ploughed and then you plough it again. (I#4)*

And *interviewee#1* elaborated that the intensive tillage for centuries has created plough pans that make subsoiling necessary.

*There is a problem this land actually, for example, before sowing the seed of teff you have to go 7 times, sometimes 9 times to prepare the land and this thing actually for almost 2000 years, so there is a plough-pan formed underneath the soil. So that soil has to be subsoiled at least every five years. But we don't have the machinery, so research focus will be at this point. (I#1)*

The use of the two-wheel tractor with rotary devices which has been the most popular form until now is regarded also as an unsuitable form of usage, as it may lead to very high mineralisation of SOM and subsequently to SOM loss. *Interviewee#4* generally sees invasive tillage operations as problematic as shown in the following quotes. He explained that the higher soil temperature of

tropical countries leads to faster mineralisation compared to temperate climates. This applies for example to the traditional *maresha* tillage, but also for deep ploughing with tractors (*Interviewee#4*).

*In the tropics ploughing with tractors has found to be unsustainable. Ploughing with tractors causes land pulverization and the loss of organic carbon because of too much pulverisation, you impact more energy into the soil, you pulverise the soil, in the process you expose the soil, the soil organic carbon to mineralisation by different microorganisms leading to CO<sub>2</sub> emission. You lose the soil organic carbon, you lose soil quality, soil fertility, but at the same time you contribute to global warming, CO<sub>2</sub> emission. (I#4)*

The impact of using two-wheel tractors with PTO-driven rotary tillage devices (rotovators) on the soil is described by him as even more severe.

*Now we were already condemning mouldboard plough for causing soil pulverization and causing loss of soil organic carbon. The rotovator is even worse. Now with rotovator what happens is you cut a small slice soil and you through it, you through it with centrifugal force with a [...] speed of that rotovator and you hit against the ceiling - usually there is a ceiling, otherwise everything would go up in the air - that is like a hammer mill. (I#4)*

This effect is potentially higher in the lowlands than in the highlands, since the average temperatures are higher here. The areas potentially well suited to large-scale mechanisation such as the flat areas of the rift valley particularly vulnerable to soil degradation according to *Interviewee#4*. In addition to the afore-mentioned problems he added further degradation risks like compaction.

*Because of the high temperature the use of tractors in such areas can lead to rapid deterioration of the soil quality compared to the highland. The highland is relatively better, still we are talking about relatively. But when you go to the lowland the damage will be there. Definitely, in the first few years there will not be a problem, because there is much soil organic carbon. But as that organic carbon gets depleted then the soil structure gets damaged, there will be compaction problem, hard setting soil, crusting and sealing which makes it very difficult, because you lose soil organic carbon rapidly. I'm not saying you don't lose soil organic carbon Arsi, you will still lose, but the rate at which you lose the soil organic carbon is higher in the rift valley. (I#4)*

*Interviewee#5* also mentioned the threat of deep ploughing and the threat of erosion for health of the soil.

*Sometimes to plough the land very deep is not good, because it would make the soil vulnerable to soil erosion, due to wind, or run-off. In that case I think care should be taken, like yeah. So, even the soil is*



*very essential for the plant growth, the top soil because it contains some humus from the animal and plants. (I#5)*

Interviewee#3 did not exclude any level of mechanisation or tillage practise, although he favoured conservational agriculture. He did however see the main potential for degradation reduction in massively increasing the yields on cultivated areas to allow the use of steep areas, that are most threatened by erosion, for forest or permanent forage.

*First and foremost it is absolutely necessary to boost productivity, get more units of output per units of input, especially in terms of land, drastically increase land productivity and in a medium-term this will lead to a situation that the less well [...] areas, the hilly, the slopes, that they could be left aside, under permanent forage, or ideally forest and agriculture could be concentrated on those areas where the erosion and physical degradation risk is lowest and then really concentrate on those areas and this will be areas where large-scale mechanisation has an important role to play, but again this is a gradual process and that will take decades before we get there. (I#3)*

He regarded the necessity of conventional agriculture/tillage as more promising in the short-term for intensification whilst conservational agriculture is more a long-term perspective. He also mentioned the possible trade-off between CA and the need for herbicide application.

*Well in the medium-term I think conventional agriculture, in the medium and longer term I would hope for minimum tillage and conservation agriculture, moving into that direction. Whether with or without herbicides remains to be seen. I think to large extent that will depend on the labour availability. That is more or less the path that I would foresee. (I#3)*

Interviewee#6 acknowledged the importance of conservational agriculture for soil conservation, on the other hand he pointed out that in his opinion research into the yield performance of conservational agriculture in Ethiopia is not advanced enough yet. When asked about the opportunities of conservational agriculture with tractors, Interviewee#4 answered:

*But they don't do it, that is the problem, they don't practice it. If they do that would be a good option. (I#4)*

The role of water conservation was not named by other interviewees. Interviewee#4 however stressed the need of rainwater harvesting and the connection to soil erosion. He pointed out that water and soil conservation have to be thought about together.

*Well, water management is very important, rainwater management. In dry areas we have shortage of rainfall. In general, it is not shortage of annual rainfall. When we look at the annual rainfall it is usually sufficient, the problem is the distribution. The rainfalls come in an erratic manner. You lose*

*rainwater in the form of run-off, you also lose the soil. If you find a means of hindering that run-off you can conserve more moisture, you can retain the rainwater in the field, at the same time you can conserve the soil. (I#4)*

He further explained the different challenges different regions face in relation to rain water management.

*There are two types of soil moisture loss, one is surface run-off and the other evaporation. If you find a means of reducing the soil evaporation you can improve the soil moisture in dry areas. In high areas especially the soils with poor infiltration rates, you have this problem of waterlogging. So, the highland vertisols for example cover about 7.6 million hectares, where you have this problem of water-logging. (I#4)*

### 6.3.2. Other environmental problems

The interviewees expressed the need to reduce the land pressure to conserve non-farming ecosystems.

*First and foremost, it is absolutely necessary to boost productivity, get more units of output per units of input, especially in terms of land, drastically increase land productivity and in a medium-term this will lead to a situation that the less well [...] areas, the hilly, the slopes, that they could be left aside, under permanent forage, or ideally forest and agriculture could be concentrated on those areas where the erosion and physical degradation risk is lowest. (I#3)*

*Interviewee#7 took a similar position, emphasising the importance of reducing land pressure in order to leave the steep slopes for forests.*

*So, I think we have to work on how to reduce the pressure on land and the population per hectare and so on and the forth. That will help other issues to be resolved like degradation. If you increase forests through planting to new land, steep slope, avoiding farming on steep slope. This is the way I feel it, I'm not a soil conservation guy. (I#7)*

The effect of soil management on climate change is hardly addressed. Only *interviewee#4* mentioned that the loss of SOM contributes to global warming, as quoted in section 0. *Interviewee#3* stated that the problem of low yields has to be challenged before addressing topics like climate change mitigation.

*But in many discussions, I completely miss the productivity part and people get carried away with carbon sequestration and ecosystem services, yes perfect idea, but people here have to make a living*

*and if we don't consider that they need to increase their food production and their income is a waste of time, it becomes an academic exercise. (I#3)*

## 6.4. Challenges and solutions approaches

The interviewees described many challenges for the development to the different mechanisation levels.

### **Land tenure system**

One topic that concerns the farmers regardless of the level of mechanisation is that of the land tenure system. Land in Ethiopia belongs to the state. However strategic investments, such as those in soil fertility, depend on the certainty for farmers that the family will farm the land in the future, as mentioned by *Interviewee#1* and #3

*From our point of view improved soil fertility, requires improved soil organic matter, and that is a task that takes years and a farmer starts now his children will probably benefit from it. So, no farmer will do it if they don't have an insurance that their kids will still be allowed to use that land. So, it is crucially important. (I#3)*

Especially for motorised mechanisation, which requires high financial investments from the farmers, insecurity of land tenure is an obstacle. According to *Interviewee#1* farmers are not willing to invest in mechanisation because of this insecurity.

*The second is maybe the land policy itself. This actually is my opinion. In Ethiopia you cannot sell land. All the land is owned by the government that is their policy. Because of that farmers don't have confidence to purchase machineries and because they don't feel that the land is theirs, so that has to be changed. (I#1)*

Examples of land that has been taken from farmers in the past fuel these insecurities.

*They don't feel that they can pass the land to their children. At any time, anybody, any investor could come and take the land if he offers money. So that would create problems. Actually, that created problems in almost most part of the country, Gambela as an example. So, the land policy has to be seen again. (I#1)*

There are efforts to challenge this insecurity, for example by issuing land certificates to farmers that guarantee them the use of the land unless they leave it idle. According to *Interviewee#3* this is a viable way.

*But again, there are huge projects going on now, being implemented where farmers have at least what is called not the title, well some get the title deed, but many have at least an insurance that they can use it as long as they want, as long as they use it. If they leave it idle the government can come and take it away. (I#3)*

*So, this is a good step into the right direction and I think once they are completed farmers will most likely be more interested in mechanisation and for us this is also a key issue, why should farmers invest in soil fertility. (I#3)*

Another aspect of the tenure system is that farmers are not able to use the land as collaterals for loans.

*Yeah, that is very important. You cannot take the land as a collateral for getting loans. So, this should also be taken into considerations. Otherwise it will take so many years until farmers will have the capacities to own machines. (I#1)*

A further issue related to the tenure system is the structure of the farming system. It contributes to keeping the status quo of a smallholder structure, as the selling of farmland is not possible.

*Interviewee#3* sees a need for a gradual structural change of the farming sector in the long term, with increased land holdings and less people depending on farming.

*But in that sense, I would see mechanisation as a gradual process, that we hopefully over the next 25, 50 years can reduce labour input, increase farm sizes, increase farm incomes and have overall much less people engaged in agriculture than there are nowadays and that is where we need to start somehow, because I have never been in a country where agriculture has been as poorly mechanised as in Ethiopia. (I#3)*

### **Challenges for the development of the oxen-system**

The economic circumstances of the oxen-system are changing. Oxen prices in Ethiopia have increased since alternative uses for oxen have become more important, as suggested by the following quote.

*They are abandoning the animal-drawn maresha. [...] the oxen, because oxen fattening is more profitable than using the oxen for land preparation. (I#6)*

Oxen-tillage and other oxen-powered operations are labour-intensive and practices that potentially could raise the yields cannot be applied because they are too time-consuming and the use of external labour becomes more expensive (see section 0).

*So even for small-scale farmers if you take the need for ploughing, the need for harrowing, the need for seeding, row-seeding. If you take wheat, it really takes a lot of family labour, sometimes it is not possible to plant in rows, or to do some of the recommendations, unless supported by mechanisation. (I#7)*

Furthermore, the power supplied by oxen (usually a pair) does not allow for energy-demanding operations or limits their application, e.g. the work with the mouldboard plough. These experiences were reported by the farmers in the FGD.

*For instance, they used the improved mouldboard last year. They mention that improving the traditional maresha is ok. But according to his observation, the improved mouldboard is much heavier than the traditional one. It requires improved breed, but actually they don't have that improved breed. So, the oxen have problems when they plough the land, here and there. Even though it was a good approach it is not effective. (FGD)*

*Interviewee#3* and *#6* claimed that farming has a bad image among the younger generation, which could also limit the further development of the oxen-system. Several interviewees described the drudgery of the current system (see section 6.2.2). According to *Interviewee#3* agriculture would be more attractive for young people if they could use modern machinery. In line with this, the FGD showed that farmers are interested in new technologies and are not concerned about the loss of cultural practices. In contrast to this perspective, *Interviewee#4* describes a reluctance among farmers to change from the use of oxen to tractors, because farm power is essentially sufficient.

*It is much easier to transfer people from hoe culture to tractors because it is a complete transformation, you reduce the drudgery and it is much more attractive. (I#4)*

*Interviewee#4*, who develops implements for small-scale mechanisation, lays the focus rather on changing the management and the implement, instead of the power source. His business works in the improvement or modification of the traditional *maresha* and in the development of new implements that allow to more efficiently apply farming operations such as tillage and seeding.

*So, it can be the same animals, the same oxen, the power source being the same, but if you change the plough they are using then you can change the labour productivity, the timeliness of preparation and also the land productivity, you can improve quality of work. (I#4)*

In the case of the Aybar BBM, the interviewee described an option to improve the current land use system without increasing the mechanisation level. Oxen-power is used to create furrows and beds to drain the fields from water and thereby extend the growing period and increase land productivity (see section 6.2.3.). He further describes a recent implement development that can be used instead

of the *maresha*, which enables the farmer to work only in one direction thus reducing the required passes to one or two (see section 6.2.3). The need of inter-row-seeders that can also be used for fertilizer application and inter-row-weeders are other projects that are supposed to increase efficiency and productivity of the smallholder system. Row-seeding as opposed to the traditional broadcasting is one key practice that was mentioned by different *Interviewees* (#3, #4, #7) as an important improvement for arable systems.

*These are some of the needs in the pre-harvest, but before leaving the land preparation aspect you also need row planters. It has been repeatedly shown that planting crops in rows make it easy to do interrow-weeding, but at the same time it increases yield dramatically. Now farmers are planting teff manually. It is a very back-breaking exercise, so we need row-seeders and also interrow-weeders to do the weeding. But this can all be done using animals as long as you have an appropriate implement, without disrupting the system, with making very little deviation from the current system. (I#4)*

### **Challenges of motorised mechanisation - Financial capacity and financing**

The abilities of farmers to invest in (motorised) mechanisation are limited according to *Interviewee#1*.

*Yeah, our farmers do not have the capacity to purchase the machinery, machinery like tractors, [...]. (I#1)*

He sees this as a consequence of predominantly low productivity increases of the past years, which has not lead to a significant income increase. *Interviewee#3* also believes that most farmers will not be able to purchase machinery such as two-wheel tractors or four-wheel tractors. Single farmers however showed interest during a project and requested support for purchasing two-wheel tractors to offer services. The *Interviewees* (#1, #3, #4, #6, #7, #8) therefore favour intermediate and large-scale mechanisation models where the farmers do not purchase the machinery but rent the service or the machines. Farmers could also act as service providers with small machinery. The models range from private service providers and unions renting machinery or giving services to farmers with two-wheel tractors.

*Yeah absolutely, the areas where we are working the farmers will not and should not buy small, even two-wheel tractors. The farms are too small, the machines are too expensive, and we follow also a service provider model, whereby one farmer that is commercially oriented and has interest in mechanisation gets the machine, but then provides services against costs to others. So, I think the model is basically very similar, only the scale. (I#3)*

Another approach is to enable youths for service provision e.g. with two-wheel tractors.

*Even where we are working now with them, we have a big program by which small tractors will be given to the farmers, maybe youth groups or individual farmers. (I#6)*

The cluster approach is a further way that actors mentioned making large-scale mechanisation accessible for smallholder farmers. It is a way of “clustering” farmers so that they synchronise their activities to be able to demand mechanised services. However, how this system can be implemented and what impact the system would have on social and environmental conditions was not addressed. Interviewee#4 expressed doubts about the plans.

*Some people say we can increase the land holding by bringing different farmers together. I don't believe that. (I#4)*

### **Import modalities and taxation**

Interviewee#2 referred to the taxation laws as an obstacle for (large-scale mechanisation). The law allows tax-free import of agricultural machinery, if the commodity is sold within a certain time-frame. This makes it impossible to hold machinery on stock, instead the wholesaler imports on order, which causes long waiting times.

*We don't hold stock, you know there is a tax policy. These tractors and combiners can be imported duty free, until four month the stock you can hold, if it passes four months you have to pay tax. So, for that reason we don't hold stock. We sign agreement, for apply for everything, we have to receive an order, to hold stock. The problem is this tax system. It is prohibited, even though advantage for the [...], it is not good for us. (I#2)*

Interviewees#2 and #3 agree that the state has to improve import conditions. Interview#3 also pointed to the high bureaucratic and logistic obstacles that need to be reduced from the state side.

*I mean importing stuff into Ethiopia is a nightmare, it is a bureaucratic nightmare, it is a logistical nightmare, these things would need to be made easier and this is entirely up to the government to make this happen. (I#3)*

### **Quality of machinery and implements**

Interviewees#1, #2 and#4 mentioned problems with the quality of machinery and implements. It is mainly the import of low quality machinery which is described as a problem for the mechanisation development.

*Yeah, the first things as I said, the tractors, the implements being introduce to the country [...] they are from different countries. The quality is very low. This could you know [...] that has to be changed. As I said they say are trying to conduct, but this has to be implemented soon. (I#1)*

The quality of products that are imported and assembled through METEC, a state-owned industrial company, was questioned by *Interviewee#2*.

*They import from China, different brands, without part, without support. I think our customers consider that as low quality. (I#2)*

Furthermore, Interview#4 also sees no positive contribution of the mechanisation section of the EIAR in Melkassa in terms of the development of implements and machines for small- and intermediate mechanisation. He sees the role of the institute as a state institution rather than a body responsible for the testing and certification of machinery.

*But there is a good job for them. Melkassa could be a very good research centre, but instead of developing prototypes they can set standards, they can set testing procedure, they can do extensive evaluation of all these coming from the private sector. But they are the [...] the referee and the player. (I#4)*

### **Public vs. private engagement**

There is a common understanding that the government should set favourable conditions for mechanisation and that it should withdraw its engagement in the development and production of machinery or other commodities. One example was given by Interviewee#3 when comparing the state efforts for lime production and the opportunities that arise from private sector engagement.

*Yeah, it is always easier to talk about things than actually do this. And the government believes, they consider lime as a strategic commodity, they don't want to give it out of their hands and they don't want the private sector to play a major role in this. (I#3)*

*Well one factor, or one important issue would be that the government recognizes the private sector has an important role to play. The government should facilitate where necessary but otherwise restrict its role to providing quality control and guidelines and setting out a level playing field for all interested actors. But the actual implementation should be left to the private sector and I think there [...] ample way to enhance this by providing credit to farmers, to service providers, to importers to make it easier. Right now, many importers find it very difficult to actually import these machines due to tax issues. We had one round table discussion and there was an issue: they import machines, they put it in their warehouse and they don't sell it within six weeks or so, they have to pay taxes and [hefty] taxes. (I#3)*



## 7. Discussion

The scientific literature and the interviewees are in agreement about the need to intensify agriculture for food and nutrition security and to protect rural livelihoods and natural resources. About suitable measures there are more diverse opinions. Diverse opinions exist how measures should be taken.

### 7.1. Oxen-mechanisation

The traditionally most widely used tillage implement, maresha has been used in an almost identical way for thousands of years. In the last few decades this system has come under increasing pressure as several developments such as reduced farm sizes, shrinking feed resources or increasing labour costs have altered the frame conditions for agricultural production in Ethiopia (Aune et al., 2001), (I#4).

As there is little scope for extending agricultural area in the highlands the pressure on existing areas rises because of population increases and resource degradation. More and more inclined land is used, which in combination with the intensive cross-ploughing practise is causing ever more land degradation through erosion (Gebregziabher et al., 2016). There is a high usage competition between organic matter resources such as straw and dung, since it is used not only as fuel for cooking but is also needed for manure and mulch material as well as for feed for oxen and other livestock (Baudron et al., 2015).

Although oxen increase the farm power, the time-demanding tillage and harvesting practices often create the need for external labour, yet rural labour costs are rising due to higher urban migration rates (Berhane et al., 2017). The interviewees agree that despite its weaknesses the oxen-system will continue to play a significant role in the highlands as many areas are less suited for motorised mechanisation, the infrastructure is not suitable or the economic capacity of the farmers is simply too low (I#1, I#3, I#4). Many attempts in the past to improve or replace the maresha have failed (Gebregziabher et al., 2016). Nevertheless, there are suggestions that a modification of the maresha and the development of new implements could have a significant impact on yields, labour burden and erosion control. As an example the introduction of broad bed makers made the cultivation of vertisols during the main raining season possible and thus lead to an increase of production and less erosion (Araya, Nyssen, Govaerts, Deckers, et al., 2016), I#4.

Improvements however should not only focus on the implements used but must also consider the broader system, i.e. the organic matter management to effectively improve the system (Araya, Nyssen, Govaerts, Deckers, et al., 2016). In this context conservation agriculture is often proposed

since it combines minimal/reduced tillage, permanent soil cover and crop rotation (Araya, Nyssen, Govaerts, Deckers, et al., 2016; J. Nyssen et al., 2011), I#3, I#4.

Interviewee#4 pointed out that using oxen for conservational agriculture could improve farm power balance by reducing the required energy. From the farmer's perspective this might have the advantage that an old tradition could be maintained through minimal modification, avoiding a more invasive intervention. Interviewee#4 reflects this opinion, stressing the importance of the maresha as a component of Ethiopian culture. However, the farmers from Arsi rejected the idea, during the FGD that mechanisation could threaten their traditional practices. On the contrary, they have experienced the advantages of large-scale mechanisation services and demand further improvements and extension to this development.

Another question is whether improvements of the oxen-system would benefit female household members and female household heads. Interviewee#3 mentions that female household heads find it increasingly difficult to find labour for tillage operations. More efficient tillage systems are likely to improve their situation, regardless whether this improved efficiency comes with oxen or other power sources.

As a result of the fragmentation of land and the decrease in farm sizes and scarce feed resources, marginal farmers (those who are young and female farmers) who are often young and female farmers, have to rent oxen-services which constitute an additional financial burden (Aune et al., 2001). Despite these difficulties approaches to reduce the burden do exist, for example when two farmers combine their single oxen to create a pair. In general however, there are significant challenges to maintaining oxen.

## 7.2. Two-wheel tractor-powered system

The two-wheel tractor technology in Ethiopia has not been widely adopted despite the significant import of machines in the last decade (Spohn, 2016). There is a dissent regarding the question of whether the use of two-wheel tractors can improve farming systems. Critics refer to the low suitability for ploughing, as the implement is too light to generate enough traction power (Spohn, 2016). In reference to this, Interviewee#4 states that the draft power a pair of oxen can generate is higher compared to the 2WT, even though it is equipped with more horse-power. In addition, exorbitant costs for individual farmers (I#4) and the unsuitability for service provider models are stated (Duerr et al., 2016).

In contrast 2WTs have been successfully adopted in service provider models in countries such as Bangladesh and Nigeria. In this context the potential of an entire service sector emergence, as in the

case of Bangladesh with manufacturers, workshops and service providers can be seen (Animaw et al., 2016; Baudron et al., 2015). The development of this service sector would have positive implications for the rural job market and could lead to a decrease of urban migration.

One reason for the varying assessment of the suitability of the technology may be found in the low quality of imported machinery, as Interviewee#1 suggests. Also, Interviewee#3 identifies some remaining technical problems in particular with seeding implements. However, generally he regards the 2WT as promising for use in conservational agriculture, as the existing problems can be solved.

Against the background of the stated unsuitability for ploughing Baudron et al. (2015) also emphasize the suitability of 2WTs for conservational agriculture. The reduced feed requirements through the replacement of the draft oxen can benefit the soil fertility and/or increase animal production. Also, the light weight of the two-wheel tractors can benefit the soil in terms of less compaction (Ströh de Martínez et al., 2016).

*Interviewee#3* also mentions the multifunctionality of the 2WTs. They can be used for all field operations (except probably for deep ploughing). Additionally, they can be equipped with a trailer for transportation and be used for off-farm income generation. Another important aspect might be the usability of the engine as a water-pump for small-scale irrigation.

Despite the theoretical potential which was identified in the scientific literature (Baudron et al., 2015) and the promising implementations which to some extent have been achieved in projects in Ethiopia (I#3) the 2WT-system has yet to be investigated further under Ethiopian conditions and the concrete effects on yields and economic performance (I#6) evaluated.

### 7.3. Large-scale mechanisation

Large-scale mechanisation in the smallholder sector is currently situated in areas where there is good infrastructure, flat topography and relatively high farm size structure with a high share of commercial farming (Berhane et al., 2017), (I#2, I#7). ), (I#2, I#7). The system relies on private service providers who offer their services in different regions depending on the seasonal demand.

The positive effect of tractor services on yields could not yet be proved on the basis of household survey data (Berhane et al., 2017). However, GIZ assessed the effect of different interventions on wheat yields in mono-factorial on-farm trials. For the mechanised field operations tractor ploughing, harrowing and row seeding yield increases of 21 %, 9 % and 28 % respectively were recorded (Ellssel et al., 2017). Duerr et al. (2016) conducted calculations with different technology levels of tractor-mechanisation and found that the profitability for service providers as well as for farmers increases with the level of implemented technology. These results show the high potential of large-scale

mechanisation to increase yields. As Interviewee#6 claims, the productivity could be doubled by introducing mechanisation even without increasing other inputs. Nevertheless Duerr et al. (2016) point out that the quality of used implements and services needs to be improved. In the FGD farmers also referred to a low quality of the services, at the same time expressing the hope that more competition will lead to better service quality.

Large mechanisation is generally seen in a context of increased use of other external inputs such as improved varieties and agrochemicals. At least part of its potential lies in the facilitation of those other inputs. But for the higher input usage farmers will require seasonal loans. Ströh de Martínez et al. (2016) frame this as high-risk-high-output strategy and Taffesse et al. (2011) state that uncertain rainfall and very low levels of irrigation make intensive cultivation risky.

The effect of large-scale mechanisation on labour replacement is a controversial discussion and will depend largely on the question of whether mechanisation actually leads to a structural change of agriculture. Interviewee#3 for instance favours a gradual increase of farm sizes and a labour shift from agriculture towards other sectors. This position is questioned by Interviewee#4 who finds it doubtful that replaced labour could be absorbed by other emerging sectors. It appears that different time scales are one reason for those different approaches, as well as the differing assessment of the prospects of job creation through industrial development in the country.

Interviewee#4 questions the need for increased farm power as for many farmers the lack of land is more urgent. Additionally, he criticizes the approach of using heavy machinery for deep ploughing, referring to the high mineralisation of organic matter through invasive tillage practices and the risk for compaction.

## 7.4. Tillage System

The suitability of conservation agriculture for SSA and Ethiopia is discussed controversially in the scientific literature (Baudron, Jaleta, Okitoi, & Tegegn, 2014; Giller, Witter, Corbeels, & Tittonell, 2009; Lalani, Dorward, & Holloway, 2017). Particularly Interviewee#3 and #4 stress the relevance of CA in the Ethiopian context as a system to reduce soil erosion and to increase water infiltration and storage capacity. CA practices are potentially applicable in all mechanisation levels since they reduce the power-demand. Effects on labour needs depend on how effective weed control is managed. If glyphosate is not applied, weeds can become a problem in the CA-system (Araya, Nyssen, Govaerts, Deckers, et al., 2016). Interviewee#4 sees a dilemma in the need for the application of glyphosate and points to its potential health risks. As an alternative he refers to the option of using cover crops for weed control in areas where there is enough rainfall or the possibility to irrigate.

The reliance on herbicides is a weak point as they are usually costly (Aune et al., 2006) and potentially harmful for humans and the environment. Most approaches adopting conservation agriculture integrate the use of glyphosate, while at the same time the discussion on the potential negative effects in Europe continues (Zaller, Heigl, Ruess, & Grabmaier, 2014). Alternatives are amounts of mulch material (often not available), the use of cover crops (only where enough water is available) and better manual and mechanical weed control. Also, the harvest of weeds as feed can be considered. Another challenge of conservation agriculture is nutrient management.

Vanlauwe et al. (2014) and Sommer et al. (2014) discuss the use of mineral fertilizer as a fourth principle for CA alongside minimum soil tillage, permanent soil cover and crop rotation. The discussion shows that permanent soil cover is a challenge under conditions of SSA farms since crop residues are usually a scarce source.

Among the interviewees conservation agriculture is generally seen as a good approach whereas Interviewee#6 sees the need for further research on the productivity impact of that system. However, CA is not aiming at fast yield increase, but at resource conservation with long-term more stable yield improvements (Baudron et al., 2014).

## 7.5. Challenges of adoption and solution approaches

Solution approaches that were proposed by different interviewees focus mainly on the need for governmental policies to change.

Interviewee#2 for instance regards the financing through state-owned banks as the main bottleneck for the further development of large-scale machinery markets. When the availability of financing through the banks declines the demand for machines equally slows down. Another difficulty for market development are certain regulations. For instance, the tax-free import of machinery is only possible if machines are sold within four months after import. This regulation prohibits machines from being held in stock and leads to long delivery times (I#2, I#3).

A further challenge is the low quality of imported machinery and the lack of spare parts, that leads to a situation where many machines are out of function (I#1). For this reason, Interviewee#1 and Interviewee#4 propose the need for certification and quality control through the public mechanisation centres. Interviewee#4 goes one step further and suggests that the public sector should not engage in the development of machinery and put emphasis on a quality control instead. This argument is founded mainly on the low adoption rate of implements and tools that are developed by Ethiopian public research. Interviewee#3 agrees with this point and advocates less regulation and a larger role of the private sector. He gives the example of lime production that can

be organised much cheaper by private cement companies compared to state-owned lime-crushers. This might be particularly important as lime constitutes a key input on soils with low pH-levels.

Another point that might hinder investment in land and thus also in mechanisation is the current land tenure system. Interviewee#1 and #3 explain that insecurities of farmers as to whether they will be able to farm their land in the future leads to reluctance to invest in it. However, Interviewee#3 states that progress has been made as farmers get certificates that confirm their right to use the land as long as they cultivate it. Interviewee#1 claims that not owning the land still prevents farmers from gaining access to loans, because they cannot use the land as collateral.

## 8. Conclusion

Both the scientific literature and the stakeholders interviewed agree that improved mechanisation can contribute to food security and improved livelihoods by increasing productivity and conserving natural resources. For the most part they also agree that there are suitable areas to which all levels of mechanisation can be applied, from improved oxen-mechanisation (small-scale), and two-wheel tractor powered mechanisation (intermediate) to tractor and combine harvester powered technology (large-scale). The prerequisites for mechanisation vary considerably in the Ethiopian highlands. Whereas small-scale and intermediate scale mechanisation is related to energy limitations and its suitable application confined to conservational tillage practices, large-scale mechanisation is suitable for conservational and also conventional tillage practices. Large-scale mechanisation is therefore more promising in terms of short-term productivity increases. Cautious voices however refer to the risk of labour replacement and soil degradation through compaction and soil organic carbon loss through deep mouldboard ploughing. Large-scale mechanisation and external input use could lead to a rapid structural change of the farming sector with social and environmental risks. The high dependence on external inputs potentially means more profitability for farmers but also higher risks. Yet the current oxen-system (small-scale mechanisation) also causes high soil degradation through erosion. Due to the low land productivity farmers are in need of constant land extension with negative impact on other ecosystems. In remote, marginal and topographically more demanding areas, the system will doubtlessly persist for a long time to come. There are indications that the system can be effectively improved by combining technical innovations with management adaptations (especially organic matter management). To neglect this system in governmental policies and development projects would lead to a stagnation of large parts of the rural population.

Two-wheel tractors can also constitute an alternative to the oxen-system. Their advantage can be seen in their multifunctional application opportunities. Next to field operations they can serve for small-scale irrigation and as a means of transport. Additionally, they reduce the need for feed, which can help to improve soil fertility and increase animal production.

The service provider model is considered effective to introduce motorised mechanisation, for both intermediate- and large-scale mechanisation, since the financial capacity of smallholder farmers is not sufficient for individual ownership. The interviewees agree that the government has to reduce regulations and instead limit its role to facilitating and supporting mechanisation whilst establishing a system for certification and quality control of agricultural implements and machinery. The public domain could therefore guarantee effective use and increase the trust of smallholder farmers in mechanisation.

Improved and particularly motorised mechanisation can favour female farmers, if their needs in relation to mechanisation are integrated in the mechanisation strategies.

In conclusion efforts to mechanise Ethiopian agriculture have to be seen in the context of other management opportunities. All levels of mechanisation can contribute to food security and improved livelihoods, if they consider the diverse socio-economic and environmental conditions of the smallholder sector. In this way it can be guaranteed that farmers with little economic capacity and their specific farm environment have access to improved mechanisation and can gradually increase their productivity.



## 9. Abstract and summary

Ethiopia's smallholder farming sector faces big challenges due to a rapidly increasing population, a low land productivity status and high land resource degradation, caused by an increasing land-use pressure combined with unsustainable land-use practices. In the context of sustainable intensification, this master thesis examines the potential of different intensities of agricultural mechanisation and explores their possible social, socio-economic and environmental impacts. To get an overview of the status, potential and problems of agricultural mechanisation in Ethiopia qualitative key stakeholder interviews and a farmer's focus group discussion were conducted in combination with an in-depth literature analysis. Different power sources for mechanisation are compared: from improved oxen-powered systems to intermediate multipurpose two-wheel tractors and large-scale mechanisation such as tractors and combine harvesters. Evidence shows that due to differing regional agro-ecological and socio-economic prerequisites, all mechanisation intensities face challenges and should be further researched and developed. Furthermore, all levels have the potential to rise and stabilise yields through more efficient use of resources and better timeliness of operation. This would reduce the pressure on land, reversing the current trend to expand agriculture to degradation-prone areas. The suitability of different tillage systems is also analysed. Results show that the promotion of conservation agriculture could lessen land degradation. Still, questions remain unanswered regarding the reliability of its productive performance. Consequences for the rural population will largely depend on whether mechanisation leads to a structural change or not and whether rural labour markets succeed in developing towards down- and upstream sectors. Higher levels of on-farm mechanisation are expected to have a positive effect particularly on female-headed households.

Key words: agricultural mechanisation, Ethiopia, sustainable intensification, conservational agriculture, oxen-mechanisation, two-wheel tractors, large-scale mechanisation

### ***Deutsche Kurzzusammenfassung***

Der kleinbäuerliche Sektor in Äthiopien ist zunehmend mit Problemen einer rasch wachsenden Bevölkerung, einer niedrigen Flächenproduktivität und einer zunehmenden Degradierung der Bodenressourcen konfrontiert, die aus steigendem Landnutzungsdruck und nicht nachhaltigen Landnutzungsformen resultieren. Im Kontext von nachhaltiger Intensivierung untersucht diese Masterarbeit das Potenzial verschiedener Grade landwirtschaftlicher Mechanisierung und geht möglichen sozialen, sozioökonomischen und ökologischen Auswirkung nach. Um einen Überblick über Status, Potenzial und Problematik der landwirtschaftlichen Mechanisierung in Äthiopien zu

bekommen, wurden qualitative Interviews mit Schlüsselpersonen und eine Fokusgruppendifkussion mit Bauern mit einer In-Depth Literaturanalyse kombiniert. Es wurden verschiedene Antriebsquellen, von verbesserter Technologie der Ochsenanspannung, über den multifunktionalen Einsatz von Einachs-Traktoren bis hin zu großer Mechanisierung mit Traktoren und Mähdreschern verglichen. Die Ergebnisse zeigen, dass durch regional sehr verschiedene agrarökologische und sozioökonomische Voraussetzungen für alle Mechanisierungsgrade Verbesserungen nötig sind. In allen Graden der Mechanisierung können durch den effizienteren Einsatz von Ressourcen und durch die termingerechtere Arbeitserledigung höhere und stabilere Erträge erreicht werden. Dadurch würde der Druck sinken degradationsgefährdete Flächen zu kultivieren. In diesem Zusammenhang wurde auch die Eignung verschiedener Bodenbearbeitungssysteme betrachtet. Die Ergebnisse zeigen, dass durch den Anstieg von konservierender Landwirtschaft Bodendegradation reduziert werden kann, allerdings bleiben noch Fragen bezüglich der Produktivität des Systems. Konsequenzen für die ländliche Bevölkerung werden davon abhängen ob Mechanisierung zu einem Strukturwandel führt und inwiefern der ländliche Arbeitsmarkt durch vor- und nachgelagerte Bereiche gestärkt werden kann.

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## I. Annex

### Guiding questions for Interview and FGD

#### **Guiding Questions Interview with Steffen Schulz (Example)**

- (1) In the literature mechanization is often called a key factor for raising agricultural yields on the other hand it is hard to separate the effects from other inputs. If we consider raising yield as a main objective, how important is mechanization?
- (2) What scale of mechanization do you think is appropriate for Ethiopia? (Improved drought animal powered implements, 2WT, 4WT)
- (3) The Green Innovation Center is working on large-scale mechanization in the Arsi region which is known as the wheat belt of Ethiopia. Do you think this is applicable in other parts of the country?
- (4) Some NGO's promote the use of 2-wheel tractors also in combination with no-till practice. How do you see this approach?
- (5) You are working on integrated soil fertility management. What strategies can be applied to increase soil fertility and at the same time increasing mechanization?
- (6) What are the critical operations that need to be mechanized in terms of crop production? (tillage, seedbed preparation, seeding, fertilizing, plant protection, harvesting)
- (7) Mechanization potentially replaces jobs. How can we avoid negative social impacts of higher degrees of mechanization?
- (8) What tillage systems do you think are most promising in Ethiopia?
- (9) Conservation tillage is much promoted nowadays, but it usually goes with high pesticide application. Conventional tillage on the other hand is prone to erosion and soil compaction. What is a sustainable way forward?
- (10) Erosion and land degradation are major problems in Ethiopia as agriculture mainly takes place in the highlands. How can these trends be reversed and what are strategies related to mechanization?
- (11) Has drought animal power a future in agriculture in Ethiopia?
- (12) How do you see Ethiopian agriculture in 20 years?

#### **Guiding questions Focus group discussion with farmers at Hitossa woreda**

- (1) How important is agricultural mechanization for you as farmers?  
Follow up: What is the main reason for further mechanizing?
- (2) Do you use machines or improved implements for tillage?  
Follow up: For harvest, post-harvest, storage, transport?
- (3) How do you see improvements of traditional oxen plough implements?  
Follow up: Mouldboard plough? Aybar broad-bed maker? Berkain maresha?
- (4) Do you think the ploughing with oxen will still be practiced in the 20 years?
- (5) There are the different levels of mechanization: you can improve the oxen-drawn implements, some organizations support 2WT and others more large-scale mechanization with big tractors. From your perspective what level of mechanization is suitable?  
Follow up: What operations on the farm need to be mechanized? (Ranking: Tillage, Seeding, Weeding, Plant Protection, Harvesting, Storage, Transport)
- (6) What are the main advantages of agricultural mechanization? (Yields, income, less hard work)

- (7) What disadvantages do you see related to higher levels of mechanization?  
Follow up: Work with oxen cultural heritage?
- (8) Many organization now support the idea of service providers. These service providers plough and harvest the fields. What is your opinion about that?  
Follow up: Do they feel comfortable with other people doing your field work?  
Follow up: How is the work quality of these service providers?
- (9) What are the main obstacles for you to further mechanize your farming?
- (10) Higher levels of mechanization save time. For what activities would you use them?