Hohenheim Working Papers on Social and Institutional Change in Agricultural Development


Working Paper 003-2020

# Impacts of agricultural mechanization: Evidence from four African countries

Thomas Daum, Ygué P. Adegbola, Geoffrey Kamau, Alpha O. Kergna, Christogonus Daudu, Roch C. Zossou, Géraud F. Crinot, Paul Houssou, Lawrence Mose, Yarama Ndirpaya, A. A. Wahab, Oliver Kirui, Fatunbi A. Oluwole

Universität Hohenheim

June 2020

Hohenheim Working Papers on Social and Institutional Change in Agricultural Development (003-2020)

# Impacts of agricultural mechanization: Evidence from four African countries


## Authors Details

Thomas Daum (University of Hohenheim, Germany)

Ygué P. Adegbola (Institut National des Recherches Agricoles du Benin, INRAB, Benin)

Geoffrey Kamau (Kenyan Agricultural and Livestock Research Organization, KALRO, Kenya)

Alpha O. Kergna (Institut d'Economie Rurale, IER, Mali)

Christogonus Daudu (Agricultural Research Council of Nigeria, ARCN, Nigeria)

Roch C. Zossou (Institut National des Recherches Agricoles du Benin, INRAB, Benin)

Géraud F. Crinot (Institut National des Recherches Agricoles du Benin, INRAB, Benin)

Paul Houssou (Institut National des Recherches Agricoles du Benin, INRAB, Benin)

Lawrence Mose (Kenyan Agricultural and Livestock Research Organization, KALRO, Kenya)

Yarama Ndirpaya (Agricultural Research Council of Nigeria, ARCN, Nigeria)

A. Wahab (National Agricultural Extension Research & Liaison Services, Nigeria)

Oliver Kirui (Center of Development Research, ZEF, Germany)

Fatunbi A. Oluwole (Forum for Agricultural Research in Africa, FARA, Ghana)

## Corresponding Author

Thomas Daum (thomas.daum@uni-hohenheim.de)




Suggested citation: Daum, T., Adegbola, Y. P., Kamau, G., Kergna, O. A., Daudu, C., Zossou, R. C., Crinot, G. F., Houssou, P., Mose, L., Ndirpaya, Y., Wahab A. A., Kirui, O., A. Oluwole, F. A. Impacts of agricultural mechanization: Evidence from four African countries. Hohenheim Working Papers on Social and Institutional Change in Agricultural Development. 003-2020. University of Hohenheim.

Title Picture Credit: Thomas Daum

Download this working paper from our homepage: https://490c.uni-hohenheim.de/en/75736

## Abstract

Agricultural mechanization is on the rise in Africa. A widespread replacement of manual labor will change the face of African agriculture. Despite this potentially transformative role, only few studies have looked at the potential effects of mechanization empirically, mostly focusing on yields and labor alone. This is the first paper that explores agronomic, environmental and socioeconomic effects together, thereby revealing linkages and trade-offs, some of which have been hitherto unknown. Data were collected using a novel data collection method called “Participatory Impact Diagrams” in four countries: Benin, Kenya, Nigeria and Mali. In 130 gendered focus group discussions, 1,330 respondents from 87 villages shared positive and negative effects experienced due to agricultural mechanization and were able to develop their own theory of change. This is the first study that gives a voice to the rural population on mechanization and allows them to identify causal impact chains. Regarding agronomic and environmental aspects, respondents perceived mechanization as a way to reduce labor shortages, improve timeliness and enhance land preparation, leading to higher yields. However, it is also associated with the cutting of farm trees as well as farmland expansion, and, subsequently, deforestation and a decline in firewood availability. Respondents also experienced that (plough-based) mechanization can have detrimental effects on soil fertility and cause erosion, which was associated with yield drops and risks in the long-term. Regarding socioeconomic effects, mechanization was reported to increase incomes, reduce drudgery and free up time for other farm and off-farm activities. However, mechanization was also linked with social tensions and conflicts, for example, related to land issues, which can pitch farmers against pastoralists. Tensions and conflicts also play out across gender. Some effects remain ambiguous. For example, depending on local factors, mechanization reportedly increases or decreases employment. Further research and policy efforts are needed to ensure that mechanization contributes to an African agricultural transformation that is sustainable from a social, economic and environmental perspective.

## Key Words

Agricultural mechanization, rural transformation, tractors, yields, employment, soil fertility, deforestation, gender, Africa

## Acknowledgments

We are grateful for the financial support from the “Program of Accompanying Research for Agricultural Innovation” (PARI), which is funded by the German Federal Ministry of Economic Cooperation and Development (BMZ). We are grateful for excellent feedback from Prof. Dr. Regina Birner as well as numerous PhD students at the division “Social and Institutional Change in Agricultural Development” of the University of Hohenheim.

## 1. Introduction

Many African governments have resumed supporting agricultural mechanization during the last years, particularly focusing on tractors for crop production. Governments promote mechanization through the public distribution of subsidized machinery, the creation of machinery assembly plants and public or public-private machinery hire schemes (Sims et al., 2016). Besides public action, there is evidence of emerging private markets for machinery and services (Diao et al., 2014; Takeshima et al. 2015). Thus, while mechanization levels are still low across much of Africa (FAO, 2016), this is likely to change. The recent experience of Asian countries has shown that mechanization can unfold rapidly once a real demand and enabling environment exists (Diao et al., 2014; Wang et al., 2016).

A widespread replacement of manual labor with mechanical power (or animal traction) would change the face of African farming and rural areas as the history of today's mechanized countries has shown (see, for example, Jansen, 1969, for Europe). Many believe that mechanization has largely positive effects, for example, releasing farmers from heavy physical work and enabling higher yields (Sims et al., 2016; Malabo Montpellier Panel, 2018), however, there are also fears of unemployment and land expansion at the cost of forests and savannah, among others (Daum & Birner, 2019). Empirical research in Africa has mostly focused on the effects of mechanized crop production, mostly during land preparation, on yields and labor (Adu-Baffour et al., 2019; Cossar, 2019; Houssou & Chapoto, 2015; Kirui, 2019; Yukichi et al., 2017), but has neglected other aspects or covered them merely "en passant". Notable exceptions are Kansanga et al. (2018) studying effects on crop diversity and farm trees and Kansanga et al. (2019) and Fischer et al. (2018) exploring gender roles.

The narrow focus of the literature is alarming as organizations such as the FAO (2013) clearly emphasize the need for countries' mechanization strategies to consider all three pillars of sustainability: social, economic and environmental. To which extent this occurs in rural villages has not been explored. Moreover, the narrow view on mechanization effects in the literature, focusing on yield and labor, makes designing good policies and programs promoting or accompanying agricultural mechanization challenging. In addition to yields and labor, mechanization may have additional effects, some of which have been rarely explored or may even be entirely unknown to researchers and policymakers. For example, mechanization may change crop diversity and food prices, and, subsequently, food and nutrition security (Kansanga et al., 2018). Moreover, the use of tractors may affect the environment. At farm level, mechanization may affect soils and the presence of trees, for example (Benin et al., 2013, Kansanga et al., 2019). Beyond the farm level, mechanization,

which enhances the farm power available to farmers, may re-shape land-use patterns, including the presence of forests and savannah, and subsequently can also affect biodiversity and climate (Daum & Birner, 2019). While some of the changes related to mechanization may be positive, others can be negative. In the latter case, complementary policy measures accompanying mechanization efforts would be needed to ensure that it unfolds in an economically, environmentally and socially sustainable way.

The objective of this paper is to explore potential agronomic, environmental and socio-economic effects of agricultural mechanization in Africa, with the aim to guide future research and policy as well as private sector efforts. Data were collected with the help of qualitative methods in different regions of four African countries, namely, Benin, Kenya, Nigeria and Mali. For this, an innovative participatory data collection tool called "Participatory Impact Diagrams" (PID) was used. PID allow the assessment of the positive and negative effects related to the adoption of new technologies as perceived by community members themselves. In particular, the method allows community members to identify both direct and indirect effects through so called "change trees" (Kariuki & Njuki, 2013), enabling them to develop their own theory of change, as further explained below.

The advantages of such a qualitative approach is its flexible and open-ended nature, which allows respondents to share their perspectives without being guard-railed by pre-coded survey questions. This helps to gain new insights or discover new aspects that are not on the research agenda but are potentially highly relevant. Next to methodological considerations, the use of qualitative approaches also has practical benefits. While some of the aspects studied here may be quantifiable, the cost and efforts to study all the effects covered here using such methods in four countries would have been prohibitively high. Thus, this paper presents a systematic exploration of potential effects which can generate 'working hypotheses' (Garbarino & Holland, 2009) and provide guidance for future quantitative agronomic, environmental and socioeconomic research.

## 2. Research countries, sampling and methods

### 2.1. Research Countries

This research was conducted in Benin, Kenya, Mali and Nigeria under the research project "Program of Accompanying Research for Agricultural Innovation" (PARI).[1] The countries have different agro-ecological zones and socio-economic characteristics (see table 1).

[1] See https://research4agrinnovation.org/

## Table 1 Characteristics of the four case study countries

| | Benin | Kenya | Mali | Nigeria |
|---|---|---|---|---|
| **Agro-ecological zones** | Tropic: warm-subhumid/semi-arid | Tropic: warm- semi-arid/humid and cool-subhumid/semi-arid | Tropic: warm-semi-arid/arid | Tropic: warm-humid/subhumid/semi-arid |
| **Farming systems** | Root crops, cereal-root crop mixed | Maize mixed, agro pastoral (sorghum, millet), pastoral | Irrigated cotton, cereal-root crop mixed, agro pastoral (sorghum, millet), sparse (arid) | Tree crops, root crops, cereal-root crop mixed, agro-pastoral (sorghum, millet) |
| **Common crops** | Yams, cassava, maize, cotton, rice | Maize, wheat, potatoes, groundnuts tea, coffee, sisal | Millet, sorghum, rice, maize, groundnuts, cotton | Yam, cassava, sorghum, millet, maize, rice, groundnuts |
| **Cereal yield** | 1.5 tons per ha | 1.5 tons per ha | 1.5 tons per ha | 1.5 tons per ha |
| **Arable land (person)** | 0.25 ha | 0.12 ha | 0.36 ha | 0.18 ha |
| **Arable land (of total)**[2] | 24% | 10% | 5% | 37% |
| **Forest cover (2016/2000)** | 38% / 45% | 8% / 6% | 4% / 5% | 7% / 14% |
| **Rural population** | 53% | 73% | 58% | 50% |
| **Employment in agriculture (male/female)** | 47% / 30% | 49% / 61% | 62% / 63% | 44% / 24% |
| **Mechanization status** | 76 % cultivated by hand; 23% by animals and 1% by tractors (PPMA, 2015) | 2% own tractors; 33% own draught oxen (De Groote et al., 2018)<br>13% own/hire tractors (Kirui, 2019) | In 2014: 3,400 4-wheel and 3,330 2-wheel tractors as well as 315,000 animal traction sets (DNGR, 2015)<br>0.4% own a tractor (RGA, 2006)<br>40% of the land cultivated by animals (DNGR, 2011) | 4% own/hire tractors<br>In the North, 50% use animal traction. In the South, few use animals because of heavy soils, tsetse flies and root/tree crops<br>Tractors for land preparation and transportation (Takeshima & Lawal, 2018) |

***Note:*** *Agro-ecological zones based on Kate (2009); Farming systems based on Dixon et al. (2001); Cereal yield (per ha), rural population, employment in agriculture, arable land per person, arable land (of total), and forest cover from World Bank (2017)*

[2] "Arable land includes land defined by the FAO as land under temporary crops" (World Bank, 2017)

## 2.2. Sampling and study sites

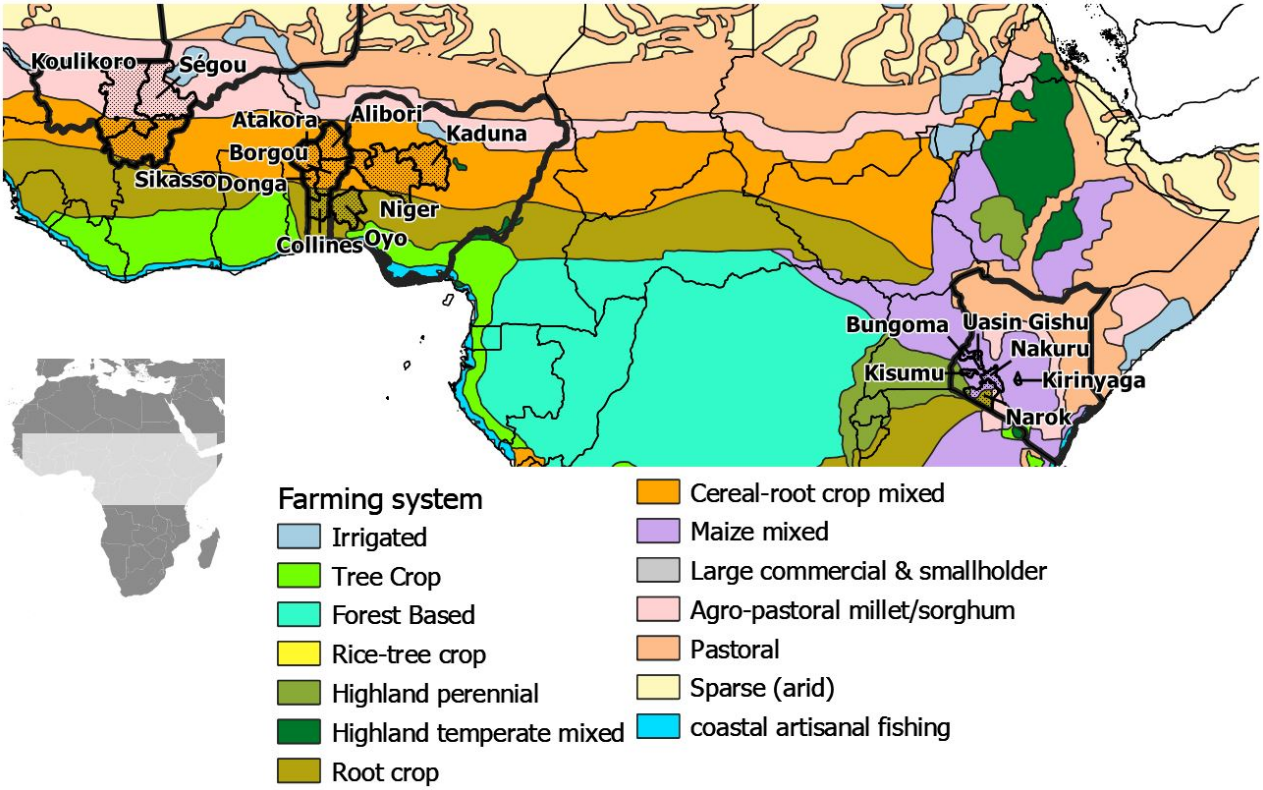
The villages for the focus group discussions (FGDs) were sampled following the sampling strategy of a complementary survey on the economics of state-led and market-led mechanization. For this, lists of beneficiaries of government programs distributing tractors were obtained and 150 beneficiaries were randomly selected under the condition that the communities also were home to owners of privately purchased tractors of similar age. A sub-set of these locations was chosen randomly for the FGDs. Thus, FGDs were held only in areas where mechanization, in particular in the form of tractors, takes place and where villagers are therefore experienced with mechanization. In each of these villages, lists of villagers were generated and participants for the FGDs were randomly selected. Table 2 provides an overview of the FGD conducted in the four countries and Figure 1 visualizes the selected sampling sites and their respective farming system. The FGDs were conducted between January and October 2019.

**Table 2. Sampling framework for focus group discussions (FGDs)**

| | Regions | Villages | Male FGD | Female FGD | Total FGDs (Average participants) | Total participants |
|---|---|---|---|---|---|---|
| **Benin** | ADH2, ADH3, ADH4 | 23 | 23 | 20 | 43 (10) | 430 |
| **Kenya** | Narok, Kisumu, Nakuru, Bungoma, Uasin-Gishu, Migori, Kirinyaga | 9 | 6 | 4 | 10 (10) | 106 |
| **Mali** | Koulikoro, Segou, Sikasso | 33 | 29 | 19 | 48 (10-12) | ca. 500 |
| **Nigeria** | Kaduna, Niger, Oyo | 22 | 15 | 14 | 29 (10) | 294 |
| **Total** | 16 | 87 | 73 | 57 | 130 | ca. 1,330 |

***Source: Authors***

**Map 1. Study areas and farming systems**




***Source:*** *Sarah Graf. Administrative areas from the GADM database on Global Administrative Areas; Farming systems of Sub-Saharan Africa from www.fao.org/geonetwork/srv/en/main.home*

## 2.3. Method: Participatory Impact Diagrams

The FGD were structured using an innovative qualitative approach called Participatory Impact Diagrams (PID), which is inspired by the idea of Mind-Maps and the Participatory Rural Appraisal approach. PID or similar approaches were used, for example, by Douthwaite et al. (2007) to assess the impact pathways of an integrated weed management project in Nigeria and by Kariuki & Njuki (2013) to evaluate a community development project in Kenya. PIDs allow the examination of both positive and negative effects related to the introduction of new policies and programs, or new technologies as experienced by community members themselves. PIDs capture both direct and indirect effects. As suggested by Kariuki & Njuki (2013), the mapping was done separately for men and women to ensure both genders felt free to talk openly, and also to capture gender differences.

The actual focus groups discussion with the PID went as follows: At the beginning, the facilitator asked some general questions to the communities such as how many farm households live there and how many use manual, animal and mechanical traction. Then, all participants introduced themselves and said how much land they cultivate and if they use manual, animal and mechanical traction. After this introduction, the actual PIDs were drawn. For this, the facilitator drew a tractor on a large sheet of paper to represent agricultural mechanization. The sheet was divided into two halves: on the right, positive impacts were noted, on the left, negative impacts were written down.

Participants were asked to mention both positive direct changes related to mechanization and the facilitator drew the mentioned change on the paper (to the extent possible with simple illustrations). Participants were encouraged to discuss the mechanisms of the change and to assess whether the change affected mostly men or women. In Benin, Kenya and Nigeria it was also asked how many participants of the FGD have experienced or agree with this change. Once the direct impact was discussed, the facilitator asked for second round effects or subsequent change of the direct changes, leading to the emergence of causal impact chains or so called “change trees”, thereby allowing respondents to develop their own theory of change (see also figure 1 and 2 for example of actual PIDs). After discussing the different direct and indirect positive changes, negative aspects were discussed, following the same procedure. At the end of the session, the findings, and in particular, the drawn diagram were cross-checked with participants.

## 2.4. Quality Assurance

To ensure scientific rigour and transparency during data collection and analysis, this study applied the standards of qualitative research recommended by Bitsch (2005). Since the FGDs could reveal sensitive topics, they were conducted in neutral environments. In particular, tractor service providers (or their close family) were excluded so that participants could freely discuss, without, for example, the need to fear not being served during the subsequent farming season. In addition, governmental officials including extension workers were excluded. FGDs were conducted separately with female and male participants. Before every discussion, it was emphasized that participants should be honest in responding; in particular, that they should feel free to report also negative effects of mechanization. It was made clear that the discussions are related to a research project that will not lead to the provision of tractors to the village.

The facilitators were instructed not to propose or suggest possible impacts in order to avoid any influence on the discussion. The role of the facilitators was merely to structure the discussion and to ask follow-up questions on already identified impacts. In addition, the facilitators helped to encourage shy participants to speak and at times to curtail dominant speakers to give space to others. All the discussions were recorded and the paper-based drawings digitalized. Given the large number of FGDs, we can be reasonably confident that a point of saturation was reached (*persistent observations*, as suggested by Bitsch, 2005). In addition, emerging findings were discussed with research peers and experts at the local, national and international level (*peer debriefing* and *member checks*, as suggested by Bitsch, 2005). In each research area, additional stakeholder interviews, for example with extension officers and experts from the local branch of the agricultural ministries, were conducted to triangulate the data, thus ensuring credibility and confirmability of the results.

## 3. Results and discussion

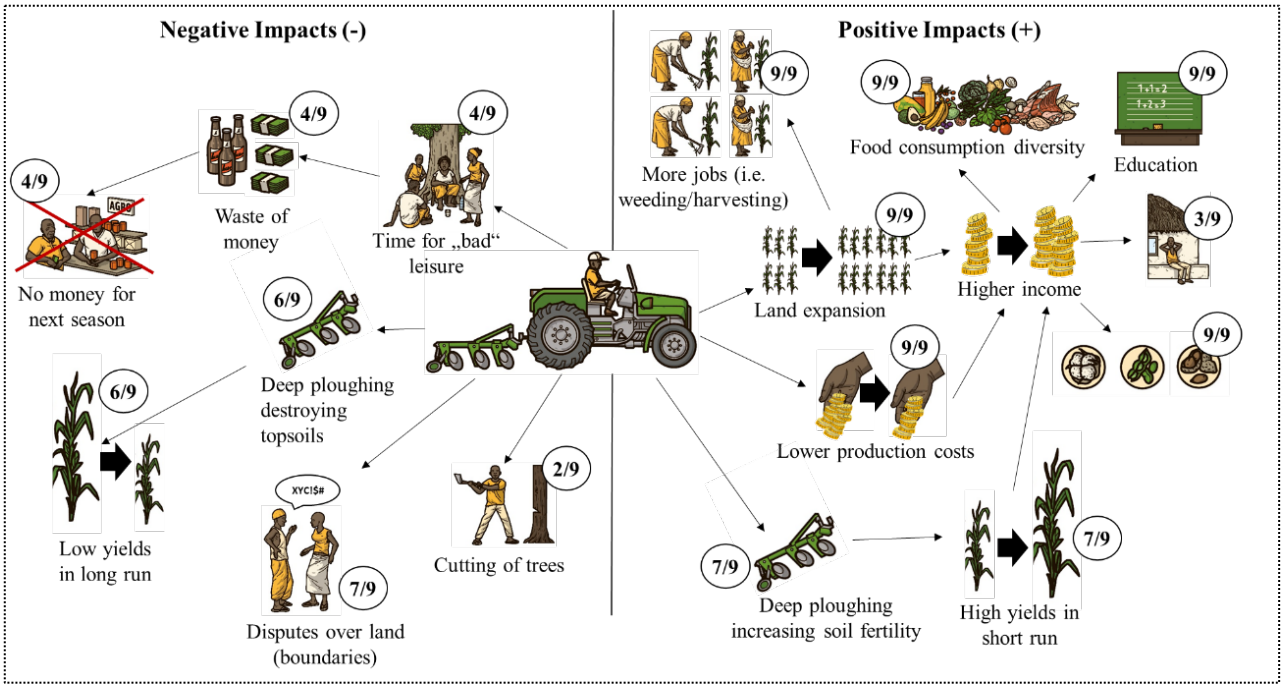
In the following section, three participatory impact diagrams are presented in detail to illustrate the type of results obtained (see 3.1.). In the subsequent sections, positive (see 3.2.) and negative effects (see 3.3.) of mechanization will be discussed at a more aggregated level, summarizing results from all the FGDs conducted.

### 3.1. Illustrative Participatory Impact Diagrams

Figures 1 and 2 show exemplary diagrams representing three actual PIDs, with pictures added for the purpose of illustration: figure 1 shows a diagram drawn in an FGD consisting of nine men in rural Kenya; figure 2 A] shows a diagram drawn with 12 women in Nigeria; figure 2 B] shows a diagram from the same Nigerian village drawn with 15 men. Figure 1 shows that all (nine out of nine) participants reported that mechanization allows farmers to cultivate more land – and this at a lower cost per ha – which raises their income. Households use the additional income for better diets, to pay school fees and diversify their farms. Three out of the nine participants reported that they are now able to spend more time on leisure.

All participants reported that, as farmers now cultivate more land, they now require more hired laborers for not yet mechanized activities such as weeding and harvesting, thereby creating employment. In addition, they reported that the deep ploughing associated with mechanization initially increases yields. However, this eventually destroys the topsoil, in particular when the disc plough is used, and leads to lower yields in the long term, as noted by six out of the nine participants on the negative side. Four out of nine participants discussed that the increase in leisure time is associated with “bad” leisure and a waste of money – in some cases farmers thus lack money to buy the inputs needed for the subsequent farming season. Discussants also mentioned that mechanization leads to disputes over land and the cutting of trees on fields.

## Figure 1. Participatory Impact Diagram (Male, Kenya)



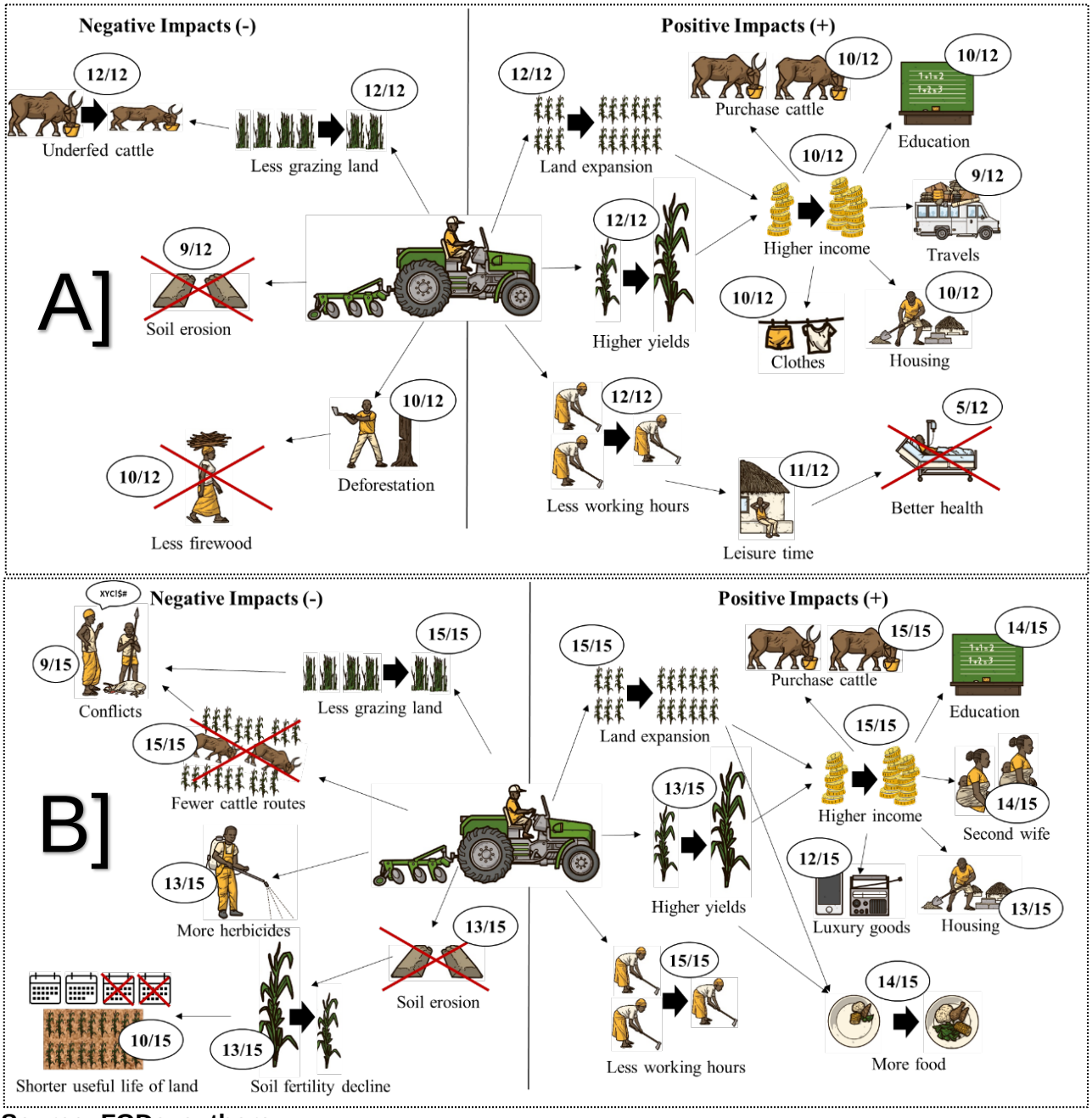

***Source: FGDs, authors***

Figure 2 A] shows findings from a FGD with women in Nigeria. Similar to the example from Kenya, they report farmland expansion and an increase in yields leading to additional income. All participants reported that mechanization reduces their workload and frees up time, which everyone but one woman use for more leisure. Reportedly, this aids participants in achieving better health. On the negative side, women reported that the area expansion that is triggered by mechanization leads to deforestation and that subsequently it is more difficult to gather firewood. The increase in farmland reportedly leads to a reduction of grazing land and consequently underfed cattle. Nine out of twelve women mentioned that mechanization, in particular the use of the disc plough, causes soil erosion.

Figure 2 B] shows findings from a FGD conducted with men from the same village, highlighting both similarities and differences across gender. Similar to their female counterparts, men notice farmland expansion and yield effects, leading to higher incomes. Similar to women, men report that money is used to buy cattle as well as for education and housing, yet, they also reported buying luxury items and obtaining second wives (as compared to clothes and travel, which are mentioned by women but not men). Unlike in the female FGD, men report that more food is available as a consequence of mechanization. While men also report a lower workload for activities on the field, they do not report an increase in resting time. Men do not report deforestation as a negative effect – and subsequently the decline in firewood is not noted. Like women, they report a decline in grazing land. In addition, they report that cattle routes are encroached on, leading to conflicts with pastoralists. Like women, men report soil erosion effects, however, they expand the impact chain with a decline in soil fertility and yields and, subsequently, a decline in the “useful” life of land. Men highlight that mechanized

farmers use more herbicides since controlling weeds on the increase acreage is no longer feasible by hand.

**Figure 2. Participatory Impact Diagrams from same villages in Nigeria (A=Female, B=Male)**




**Source: FGDs, authors**

## 3.2. Positive impacts

Across the four countries, the respondents identified several positive effects related to the use of agricultural mechanization. Table 3 shows agronomic and environmental effects, showing both the share of FGDs and of individuals identifying impacts. The share of FGDs is reported for each of the four countries and the average across the countries. The share of individuals is reported only for Benin, Kenya and Nigeria (and the average across these countries) since this information was not

collected in Mali. To make the average share of FGDs and the share of individuals comparable, Table 4 also contains columns showing the average share of FGDs identifying impacts without Mali.

Across the four countries, the most often mentioned positive effect was an increase in yields (as reported in 72% of all FGDs), which was attributed to mechanization improving the timeliness of farming and reducing weed pressure. This reflects Adu-Baffour et al. (2019) and Yukichi et al. (2017). Farmers highlighted that mechanization enhances the quality of land preparation, for example, enabling better seedbed preparation as well as better burial incorporation of weeds, all of which helps to raise yields as illustrated by the following quote:

*"When (…) using tractors, we are able to incorporate weeds easily and this increases soil fertility unlike preparation by hand where we remove the weeds and pile them on the sides" (FGD, Kenya)"*

Farmers reported that agricultural mechanization increases soil fertility in 36% of all FGDs. Across the countries, farmers highlighted that tractors help to achieve adequate ploughing depths, which is good for the soil. In Benin, respondents in 73% of all FGDs reported that tractors led to a reduction of the use of bushfires for land clearing, which is reportedly better for soil fertility (as well as the environment).

Another major positive effect identified has been the expansion of the land size that farm households cultivate (reported in 61% of all FGDs). Using hand tools, the maximum amount of land cultivatable per household is limited by labor constraints; either related to family or hired labor. Using tractors, more land can be cultivated, which together with the increase in yields, helps farmers to increase agricultural production, as illustrated in the following quote:

*"Many farmers have land that they can't farm, it is let as fallow. With the tractor, the land is farmed and produces volumes of crops beyond the consumption capacity of the household" (FGD, Mali)*

There are additional positive agronomic impacts. Reportedly, mechanization allows farmers to grow a larger diversity of crops, an observation shared in 19% of all FGDs, which also has implications for food and nutrition security. Interestingly, this was reported in 30% of all male FGDs but only 8% of all female FGDs. Similarly, gender seems to play a role in the perceived effects of mechanization on weeds: 17% of all female FGDs reported a lower weed pressure but only 1% of all male FGDs, potentially because women are often responsible for weeding.

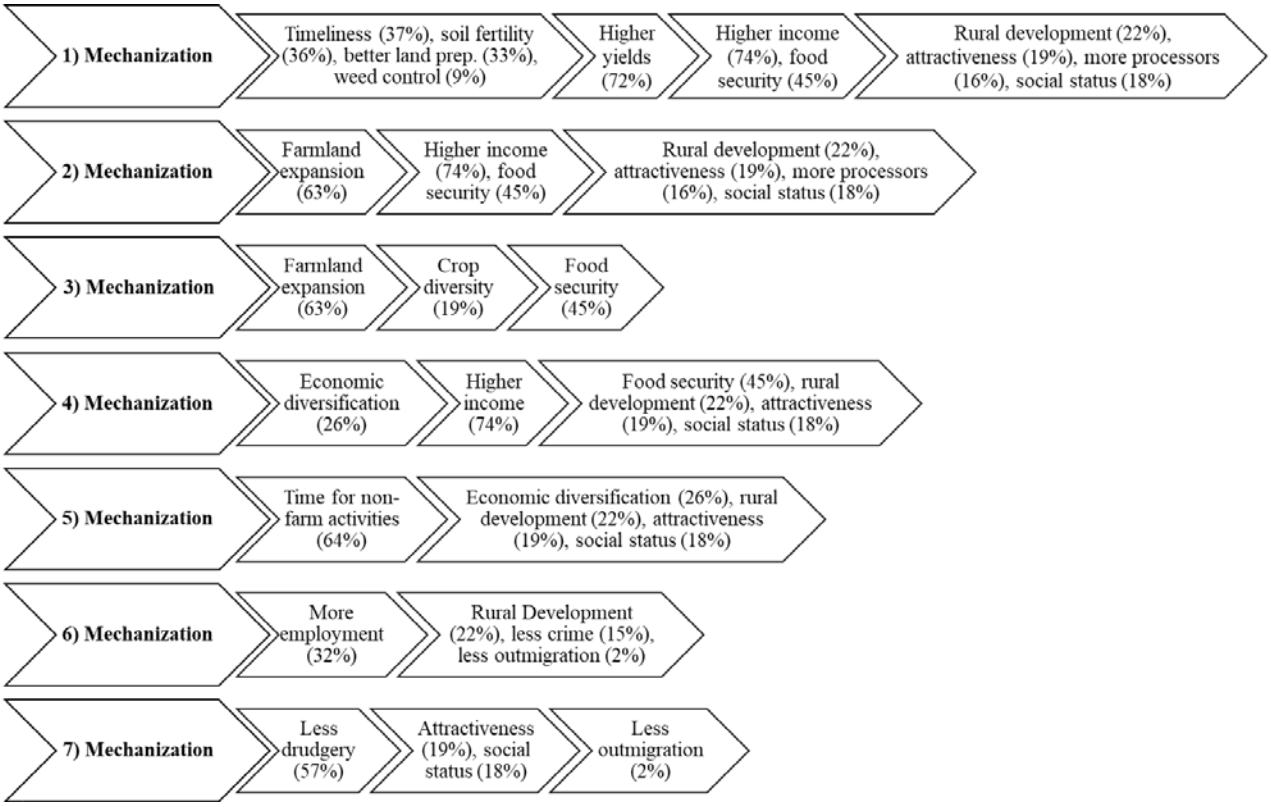
**Table 2. Share of FGDs and individuals identifying positive agronomic and environmental impacts of agricultural mechanization (i.e. the use of tractors).**

| Impacts | Source | Total | | | Total - Mali | | | Benin | | Kenya | | Mali | | Nigeria | | Rationale and comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All | M | F | All | M | F | M | F | M | F | M | F | M | F | |
| Higher yields | *FDG* | 72 | 72 | 73 | 85 | 86 | 76 | 91 | 85 | 100 | 100 | 28 | 42 | 67 | 64 | *Timeliness, better land prep., less weeds* |
| | *Ind* | na | na | na | 79 | 82 | 76 | 91 | 82 | 84 | 84 | na | na | 72 | 63 | |
| Farmland expansion | *FDG* | 63 | 72 | 54 | 63 | 71 | 55 | 87 | 85 | 67 | 50 | 72 | 53 | 60 | 29 | *Less labour & time constraints* |
| | *Ind* | na | na | na | 62 | 73 | 52 | 87 | 84 | 61 | 43 | na | na | 70 | 29 | |
| Increased timeliness | *FDG* | 37 | 43 | 32 | 33 | 36 | 30 | 48 | 45 | 33 | 25 | 62 | 37 | 27 | 21 | *Operations completed at best time* |
| | *Ind* | na | na | na | 31 | 34 | 27 | 48 | 45 | 32 | 20 | na | na | 21 | 17 | |
| Higher soil fertility | *FDG* | 36 | 36 | 35 | 48 | 48 | 47 | 78 | 90 | 67 | 50 | - | - | - | - | *Water retention & soil aeration* |
| | *Ind* | na | na | na | 41 | 39 | 43 | 71 | 83 | 47 | 45 | na | na | - | - | |
| Better land preparation | *FDG* | 33 | 28 | 38 | 41 | 32 | 50 | 39 | 50 | 50 | 100 | 14 | - | 7 | - | *Better depth, spacing & covering* |
| | *Ind* | na | na | na | 32 | 27 | 37 | 38 | 48 | 39 | 63 | na | na | 3 | - | |
| Higher crop diversity | *FDG* | 19 | 30 | 8 | 11 | 19 | 3 | 4 | 10 | 33 | - | 62 | 21 | 20 | - | *More land available for cultivation* |
| | *Ind* | na | na | na | 17 | 10 | 3 | 4 | 10 | 26 | - | na | na | 22 | - | |
| Reduction of bushfires | *FDG* | 19 | 19 | 19 | 25 | 25 | 25 | 74 | 75 | - | - | - | - | - | - | *No fire used for land clearing* |
| | *Ind* | na | na | na | 19 | 19 | 18 | 57 | 54 | - | - | na | na | - | - | |
| Lower weed pressure | *FDG* | 9 | 1 | 17 | 12 | 1 | 22 | 4 | 10 | - | 50 | - | - | - | 7 | *Better burial of weeds* |
| | *Ind* | na | na | na | 11 | 1 | 21 | 4 | 10 | - | 39 | na | na | - | 14 | |
| Guarantee to finish operation | *FDG* | 7 | 6 | 8 | 9 | 7 | 10 | 22 | 30 | - | - | - | - | - | - | *Quick completion of operations & no reliance on labour* |
| | *Ind* | na | na | na | 9 | 7 | 10 | 22 | 30 | - | - | na | na | - | - | |
| Easier sowing /weeding | *FDG* | 6 | 5 | 6 | 7 | 7 | 8 | 13 | 10 | - | - | - | - | 7 | 14 | *Better & uniform land prep.* |
| | *Ind* | na | na | na | 6 | 6 | 6 | 13 | 10 | - | - | na | na | 5 | 9 | |
| Earlier land preparation | *FDG* | 2 | 4 | 1 | 1 | 1 | - | 4 | - | - | - | 10 | 5 | - | 14 | *Mech. tillage can work dry soil* |
| | *Ind* | na | na | na | 1 | 1 | - | 4 | - | - | - | na | na | - | - | |
| Better germination | *FDG* | 2 | 3 | - | 2 | 4 | - | - | - | - | - | - | - | 13 | - | *Since better land prep.* |
| | *Ind* | na | na | na | 2 | 4 | - | - | - | - | - | na | na | 13 | - | |

***Note: M = Male; F=Female; na = not applicable; Ind = Individuals***

Table 5 shows positive socioeconomic effects related to agricultural mechanization. The most frequently mentioned positive effect perceived was an increase in financial security and income (reported in 74% of all FGDs). The additional income is used to buy more, and more diverse food, as noted in 45% of all FGDs[3] and to pay education expenditures, as reported in 37% of all FGDs. In addition, money is used, for example, for religious activities, travels (such the haj in Nigeria) as well as for obtaining second wives and for "bad leisure" (as visible in the diagram from Kenya, see Figure 1). Some participants reported that the increase in income gives them financial autonomy and the ability to cope with the various risks associated with agricultural production.

### Figure 3. Selected causal chains on the positive impacts of mechanization




***Source: FGDs, authors***

Figure 3 shows some causal chains between mechanization and some positive impacts, as identified in the FGDs. The figure shows that there are different pathways and that small intermediate effects can aggregate into a larger subsequent effect. Regarding income effects, the main drivers are higher yields and area expansion. An additional reason is economic diversification. With mechanization, households have more time to pursue non-agricultural businesses and may have capital to start non-agricultural businesses. Moreover, in 32% of all FGDs, participants perceived that mechanization generates rural employment. One reason is that mechanization can lead to higher yields and cropland expansion, which reportedly leads to a higher labor demand during subsequent farming steps, such as weeding, harvesting and processing. This is illustrated in the following quote:

[3] Others factors explaining the higher food and nutrition security are the higher levels of agricultural production and farm diversity.

*"Indeed, the tractor makes it possible to increase the size of the plantings. This increase generates a higher demand in terms of manpower to carry out operations not yet mechanized" (FGD, Mali)*

Moreover, there are positive spillovers from the overall rising rural wealth on employment. For example, participants reported that many mechanized farmers consume more and start non-agricultural businesses. It was also noted that mechanization creates jobs for tractor operators and technicians. All of these aspects contribute to the perception that mechanization drives rural development, as noted in 22% of FGDs. Employment opportunities and rural development reportedly reduces the incidence of crimes and violence in the villages, as noted in 15% of all FGDs.

*"The possibility of driving a tractor and providing services to earn money is a source of motivation of young people. (…) We are witnessing an increase in the number of tractor drivers, a reduction of the rural exodus by young men, an increase in income, a better social consideration and a reduction of insecurity (e.g., theft,)" (FGD, Benin).*

In 57% of all FGDs, villagers reported that mechanization is associated with a reduction in drudgery, which is reportedly good for health and helps to increase the motivation and attractiveness related to farming (as reported in 19% of all FGDs).

## Table 5. Share of FGDs and individuals identifying positive socioeconomic impacts of mechanization (i.e. the use of tractors)

| | | Total | | | Total - Mali | | | Benin | | Kenya | | Mali | | Nigeria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Impacts** | **Source** | **All** | **M** | **F** | **All** | **M** | **F** | **M** | **F** | **M** | **F** | **M** | **F** | **M** | **F** | **Rational and comments** |
| Higher income | FDG | 74 | 72 | 77 | 87 | 87 | 88 | 87 | 100 | 100 | 100 | 28 | 42 | 73 | 64 | *Food, education, health,* |
| | Ind | na | na | na | 83 | 83 | 82 | 87 | 99 | 84 | 86 | na | na | 79 | 62 | *machinery, livestock, religion* |
| Time for non-farm activities | FDG | 64 | 66 | 62 | 71 | 71 | 71 | 91 | 85 | 83 | 100 | 48 | 32 | 40 | 29 | *Rest, off-farm work, family,* |
| | Ind | na | na | na | 69 | 70 | 67 | 91 | 83 | 74 | 92 | na | na | 44 | 27 | *education* |
| Reduction of drudgery | FDG | 57 | 55 | 59 | 57 | 54 | 59 | 57 | 70 | 67 | 50 | 72 | 42 | 73 | 57 | *Less physical heavy work* |
| | Ind | na | na | na | 53 | 50 | 56 | 56 | 68 | 18 | 51 | na | na | 76 | 48 | |
| Food security | FDG | 45 | 44 | 47 | 57 | 58 | 55 | 78 | 80 | 50 | 50 | - | 21 | 47 | 36 | *Due to higher yields & income* |
| | Ind | na | na | na | 54 | 54 | 54 | 78 | 80 | 35 | 49 | na | na | 48 | 32 | |
| Education | FDG | 37 | 41 | 33 | 49 | 54 | 44 | 83 | 90 | 33 | - | - | - | 47 | 43 | *Higher income & more time* |
| | Ind | na | na | na | 41 | 45 | 37 | 60 | 67 | 32 | - | na | na | 43 | 45 | |
| More employment | FDG | 32 | 32 | 32 | 43 | 42 | 43 | 96 | 90 | 17 | 25 | 3 | - | 13 | 14 | *Due land expansion & higher* |
| | Ind | na | na | na | 32 | 30 | 33 | 32 | 30 | 33 | 32 | na | na | 10 | 13 | *yields; rural development* |
| Economic diversification | FDG | 26 | 21 | 32 | 27 | 28 | 26 | 39 | 40 | - | - | - | 47 | 13 | 14 | *Time for work & money for* |
| | Ind | na | na | na | 26 | 26 | 26 | 38 | 38 | 26 | 16 | na | na | 15 | 23 | *business* |
| Lower production costs | FDG | 23 | 18 | 27 | 29 | 22 | 36 | 9 | 25 | 50 | 75 | 7 | - | 7 | 7 | *Due to replacement of* |
| | Ind | na | na | na | 24 | 17 | 31 | 5 | 25 | 42 | 65 | na | na | 5 | 3 | *labourers* |
| Rural development | FDG | 22 | 20 | 25 | 30 | 26 | 33 | 78 | 75 | - | 25 | - | - | - | - | *Spillovers from consumption &* |
| | Ind | na | na | na | 17 | 19 | 14 | 57 | 41 | - | 2 | na | na | - | - | *econ. diversification* |
| Motivation / attractiveness | FDG | 19 | 20 | 17 | 25 | 27 | 23 | 74 | 55 | - | - | - | - | 7 | 14 | *Due to reduction of drudgery &* |
| | Ind | na | na | na | 24 | 25 | 24 | 67 | 50 | - | - | na | na | 7 | 22 | *higher income* |
| Social status / recognition | FDG | 18 | 10 | 26 | 17 | 13 | 20 | 39 | 60 | - | - | - | 42 | - | - | *Use of "modern" tractors, not* |
| | Ind | na | na | na | 15 | 11 | 18 | 32 | 55 | - | - | n | n | - | - | *"backward" manual labour* |
| More processors | FDG | 16 | 15 | 18 | 22 | 20 | 23 | 61 | 70 | - | - | - | - | - | - | *Since increased agricultural* |
| | Ind | na | na | na | 20 | 18 | 22 | 55 | 66 | - | - | na | na | - | - | *production* |
| Less crime /violence | FDG | 15 | 20 | 11 | 20 | 26 | 14 | 65 | 35 | - | - | - | - | 13 | 7 | *More employment & rural* |
| | Ind | na | na | na | 12 | 17 | 8 | 39 | 20 | - | - | - | - | 11 | 3 | *development* |
| Better market access | FDG | 12 | 18 | 5 | 10 | 13 | 7 | - | - | - | - | 31 | - | 40 | 21 | *Tractors are used for* |
| | Ind | na | na | na | 10 | 14 | 6 | - | - | - | - | na | na | 41 | 17 | *transportation* |
| Encourages women to farm | FDG | 3 | - | 5 | 4 | - | 7 | - | - | - | - | - | - | - | 21 | *Labour-intensive steps* |
| | Ind | na | na | na | 4 | - | 9 | - | - | - | - | na | na | - | 26 | *mechanized* |
| Less dependence on male labourers | FDG | 4 | - | 7 | 1 | - | 2 | - | - | - | - | - | 21 | - | 7 | *Since tractors can be used* |
| | Ind | na | na | na | 1 | - | 2 | - | - | - | - | na | na | - | 7 | |
| Less outmigration | FDG | 2 | 3 | 1 | 4 | 4 | 3 | 13 | 10 | - | - | - | - | - | - | *More employment &* |
| | Ind | na | na | na | 2 | 1 | 2 | 4 | 5 | - | - | na | na | - | - | *attractiveness of farming* |

## 3.3. Negative impacts

Participants also mentioned negative effects related to mechanization, comprising both agronomic and environmental effects (see table 6) and socioeconomic effects (see table 7). Figure 4 shows some selected causal chains as identified by respondents themselves explaining these negative outcomes of mechanization. In 58% of all FGDs, participants noted that, while mechanization increases soil fertility in the short-term, it leads to a decline in soil fertility in the long-term, in particular when the disc plough is used (confirming, among others, Adjei et al., 2003; Benin et al., 2013). Relatedly, in 52% of all FGDs, villagers observed that mechanization triggers soil erosion. This was related to the destruction of soil structures and the creation of a hard pan that leaves soils vulnerable to rain and wind erosion. In addition to making soils susceptible to erosion, this hard pan can also cause water-logging and flooding, as noted in Benin:

> *"The introduction of the tractor increases soil compaction given the weight of the tractor and accessories. (…) This is followed by the problems of flooding and erosion, which considerably reduce the fertility of the areas cultivated and consequently the yield" (FGD, Benin).*

These negative aspects of mechanized tillage on soils explain the observation that mechanization can lead to lower yields in the long-term, which was observed in 45% of all FGDs. However, there are additional reasons for lower yields and higher yields risks, including the risk of late or no service delivery, worse land preparation, more irregular rain due to deforestation as well as water-logging and flooding. In Kenya, some farmers also complained that migratory tractor service providers facilitate the spread of weeds across different agro-ecological zones as the following quote illustrates:

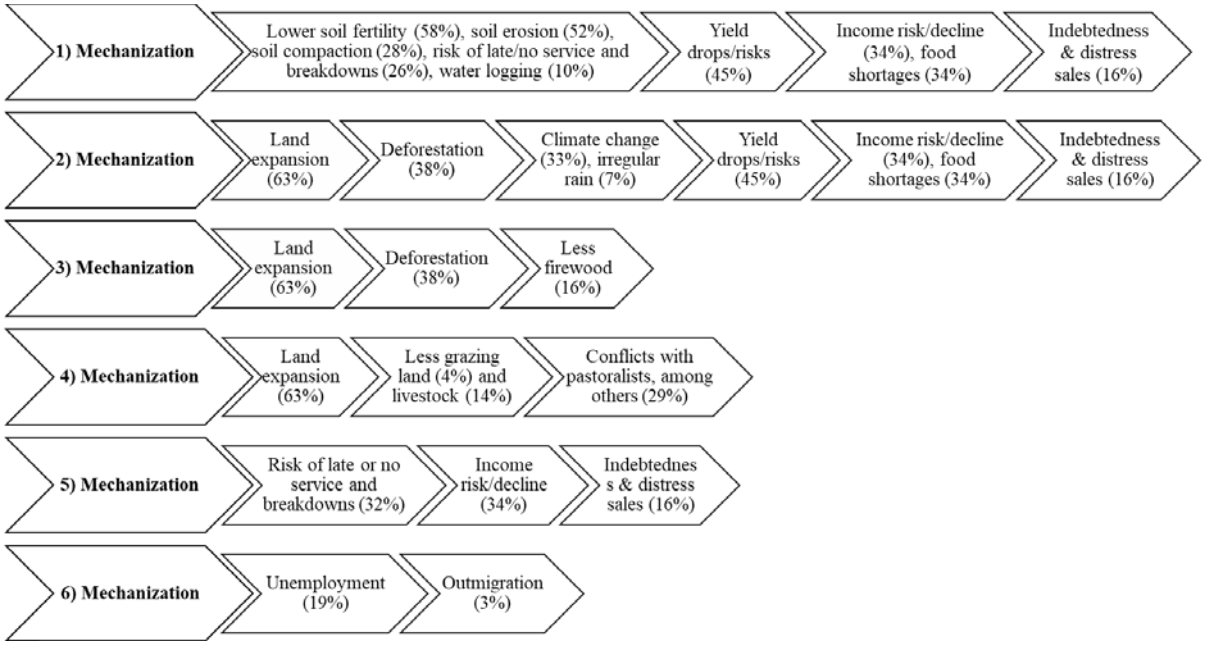
> *"Use of tractors has led to introduction of a new type of weed called 'arap misoi' [Guitaria Abysinica, explanation added], which causes low yields to our wheat crop" (FGD, Kenya).*

Consequently, participants in 45% of all FGDs reported that mechanization can lead to sudden yield and income drops. The higher risk associated with mechanization becomes problematic in combination with one other effect: in 50% of all FGDs, participants mentioned that mechanization increases the production costs of farming.[4] As the production costs of farming increases with mechanization, both the likelihood and severity of negative effects also increases, which has led to cases of indebtedness and distress sales of livestock, machinery and land. Risks not only affect service receivers but also tractor owners who suffer

[4] On the other hand, others noted that mechanization can contribute to decrease the risks, since it enhances the timeliness of farming and helps households to build up capital for bad times, to diversify crop production and to pursue income-generating activities.

economically from frequent tractor breakdowns. In 34% of all FGDs, participants discussed that the different risks associated with mechanization can lead to food shortages. Yet, while this aspect was reported across many FGDs, the share of individuals identifying this aspect is much lower (see Table 7).

### Figure 4. Selected causal chains on the negative impacts of mechanization




***Source: FGDs, authors***

While some effects are only affecting individual farms, others have more far-reaching effects. The results suggest that mechanization is associated with area expansion, as reported in 38% of all FGDs, which was seen as positive by the respondents, since it helps to increase agricultural production and income. However, it is also concerning from an environmental perspective, since it is associated with large-scale deforestation, as also noted by the respondents, in particular in Mali and Nigeria where forest covers are still relatively high, albeit declining fast (see Table 1). Moreover, 43% of all male farmers in Benin noted that deforestation leads to more irregular rainfall, which increases yield risks and has reportedly triggered desertification in some areas. Mechanization not only reportedly leads to deforestation but also causes the clearing of trees from the fields, which reportedly reduces biodiversity and makes the soil more susceptible to rain and wind erosion, as the following quote illustrates:

> *"Tractor plowing requires land without obstacles. Therefore, trees are destroyed to enable the tractor to work comfortably. This exposes the land." (FGD, Mali)*

This can have negative agronomic and environmental effects, as well as nutritional consequences when farmers destroy fruit trees to ensure mechanization (see also Kansanga et al., 2019, for Ghana).

**Table 3. Share of FGDs and individuals identifying negative agronomic and environmental impacts of mechanization (i.e. the use of tractors).**

| | | Total | | | Total - Mali | | | Benin | | Kenya | | Mali | | Nigeria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Impacts | Source | All | M | F | All | M | F | M | F | M | F | M | F | M | F | Rationale and Comments |
| Lower soil fertility | *FGD* | 58 | 67 | 48 | 65 | 66 | 64 | 78 | 80 | 83 | 75 | 69 | - | 33 | 43 | *Due to soil erosion* |
| | *Ind* | na | na | na | 51 | 56 | 47 | 75 | 60 | 61 | 75 | na | na | 31 | 38 | |
| Soil erosion | *FGD* | 52 | 55 | 50 | 63 | 64 | 62 | 43 | 55 | 83 | 75 | 28 | 11 | 67 | 57 | *Tillage destroys soil structure & creates hard pan* |
| | *Ind* | na | na | na | 48 | 53 | 42 | 25 | 32 | 70 | 75 | na | na | 64 | 54 | |
| Yield risks & drops | *FGD* | 45 | 52 | 38 | 55 | 59 | 51 | 65 | 70 | 100 | 75 | 31 | - | 13 | 7 | *Erosion, fert. decline, late service, logging, flooding, irreg. rain* |
| | *Ind* | na | na | na | 41 | 48 | 35 | 62 | 50 | 67 | 75 | na | na | 14 | 3 | |
| Deforestation / farm tree removal | *FGD* | 38 | 41 | 34 | 48 | 51 | 45 | 100 | 100 | 17 | - | 21 | - | 27 | 36 | *Land expansion, easier operation* |
| | *Ind* | na | na | na | 37 | 30 | 43 | 90 | 89 | - | 50 | na | na | 23 | 36 | |
| More agro-chemicals | *FGD* | 37 | 41 | 34 | 47 | 48 | 45 | 70 | 65 | 50 | 50 | 10 | - | 33 | 21 | *Area expansion & response to fert. decline* |
| | *Ind* | na | na | na | 40 | 39 | 42 | 55 | 51 | 4 | - | na | na | 34 | 26 | |
| Climate change / pollution | *FGD* | 33 | 37 | 28 | 40 | 43 | 37 | 90 | 91 | 17 | - | 21 | - | 20 | 21 | *Due to exhausts & deforestation* |
| | *Ind* | na | na | na | 33 | 33 | 33 | 85 | 84 | 4 | - | na | na | 11 | 14 | |
| Soil compaction | *FGD* | 28 | 31 | 24 | 32 | 32 | 32 | 26 | 25 | 50 | 50 | 28 | - | 20 | 21 | *Use of heavy machinery* |
| | *Ind* | na | na | na | 25 | 22 | 28 | 17 | 19 | 39 | 50 | na | na | 11 | 16 | |
| Worse land preparation | *FGD* | 20 | 24 | 16 | 26 | 31 | 22 | 9 | 15 | 83 | 50 | 3 | - | - | - | *Wrong ploughing depth, bad burial of weeds* |
| | *Ind* | na | na | na | 20 | 21 | 20 | 8 | 15 | 54 | 50 | na | na | - | - | |
| Less livestock | *FGD* | 14 | 13 | 14 | 19 | 19 | 18 | 57 | 55 | - | - | - | - | - | - | *To buy machinery & repairs* |
| | *Ind* | na | na | na | 13 | 14 | 13 | 41 | 38 | - | - | na | na | - | - | |
| Next steps more difficult / labour intense | *FGD* | 12 | 6 | 18 | 13 | 3 | 23 | 9 | 20 | - | 50 | 14 | - | - | - | *Sowing, weeding and harvesting* |
| | *Ind* | na | na | na | 12 | 2 | 21 | 7 | 18 | - | 45 | na | na | - | - | |
| Water logging / flooding | *FGD* | 10 | 13 | 6 | 13 | 13 | 14 | 22 | 25 | 17 | - | 14 | - | - | - | *Due to hard pan* |
| | *Ind* | na | na | na | 7 | 9 | 5 | 14 | 16 | 14 | - | na | na | - | - | |
| Irregular rain | *FGD* | 7 | 11 | 4 | 10 | 14 | 5 | 43 | 15 | - | - | - | - | - | - | *Due to deforestation* |
| | *Ind* | na | na | na | 10 | 14 | 5 | 43 | 15 | - | - | na | na | - | - | |
| Less grazing land / cattle routes | *FGD* | 4 | 3 | 8 | 6 | 4 | 7 | - | - | - | - | - | - | 13 | 21 | *Cropland expansion* |
| | *Ind* | na | na | na | 7 | 6 | 8 | - | - | - | - | na | na | 17 | 23 | |
| Spreading of noxious weeds | *FGD* | 4 | 8 | - | 6 | 11 | - | - | - | 33 | - | - | - | - | - | *Service providers moving across agro-ecological zones* |
| | *Ind* | na | na | na | 4 | 8 | - | - | - | 25 | - | na | na | - | - | |

A major concern related to mechanization is that it may create unemployment. This was mentioned in 19% of all FGDs. However, numbers vary starkly across the countries. In Benin, where mechanization is associated with area expansion, unemployment effects were reported in none of the FGDs; in densely populated Nigeria they were reported by on average 48%. Unemployment effects are illustrated in the following quote:

*"With the tractor many laborers remain unemployed and move to urban areas" (FGD, Mali)*

Unemployment effects are in particular related to the land preparation period since mainly tillage is mechanized (see table 1). In some areas, mechanization is mostly associated with a shift in labor demand from the beginning towards the end of the farming season. Reportedly, this is problematic in cases where rural laborers need the income from wage labor at the beginning of the season to purchase inputs for their own fields.

Across the four countries, participants felt that mechanization leads to social tensions, conflicts and crime, aspects noted in 29% of all FGDs. One reason for conflicts is a clash between farmers and tractor owners if service provision is done too late, too badly or not at all, all of which can lead to large yield drops. Conflict also occur between different crop farmers over who has access to mechanization services and between tractor owners over the fuel needed to run the tractors. These conflicts can be violent, in particular if they are related to land issues. Land conflicts are increasingly common due to the farmland expansion effects of mechanization. Such conflicts can also pitch crop farmers against pastoralists whose grazing lands are increasingly encroached upon, as observed in 4% of all FGD (but 17% in Nigeria). Social conflicts also spark over accidents injuring tractor operators or villagers and may require expensive health care.

As with most new technologies, mechanization leads to benefits for some but not for others. The role of rural labor has been discussed above. In addition, the rise of tractors has led to less demand for providers of animal draught services, although the number of FGDs reporting this is surprisingly low (3%). While other studies have found that smallholder farmers often have worse access to mechanization (Daum & Birner, 2017 for Ghana), this aspect was also surprisingly absent from many FGDs – with 15% of all FGDs indicating this negative consequence. Overall, mechanization is less accessible for women compared to men, which may exacerbate existing gender inequalities. Less access for women was reported in 29% of all female FGDs - as compared to 0% of the male FGDs. Reason for lesser access of female farmers to mechanization are social norms as well as the fact that they often have smaller and more scattered plots compared to men. Such plots are less lucrative to service providers, as illustrated by the following quote from Benin:

*"Service providers tend to prioritize men and large producers for the purpose of providing services. Thus, women and smallholders are often marginalized" (FGD, Benin).*

In addition, women, who are mostly responsible for cooking, face disadvantages as mechanization destroys forests and reduces the amount of firewood available. Therefore, women need to spend more time and travel longer distances to fetch firewood. This was reported in 26% of all female FGDs as compared to 7% of all male FGDs. Other effects mostly affect men, however. Yield risks associated with mechanization were reported in 52% of all male FGDs, but only 38% of all female FGDs, perhaps because a higher share of male crops are mechanized. Accidents were reported in 13% of all male FGDs (compared to 4% of female FGDs) and unemployment effects were reported in 26% of all male FGDs (compared to 13% of female FGDs), potentially because most tractor operators and wage laborers are male. In 18% of all female FGDs, as compared to 6% of all male FGDs, respondents complained that mechanized land preparation raises the workload for not yet mechanized activities such as weeding and harvesting and processing. Differences in gender roles may explain why this effect is mainly felt by women. This contradicts Daum et al. (2019b) and also Baudron et al. (2019) who found that mechanized tillage reduces women's labor burden since it can suppress weed growth. Interestingly, if female farmers have access to mechanization it can greatly empower them as mechanized households enjoy a higher social status, a fact that was reported in particular by women (in 27% of all female FGDs as compared to 10% of all male FGDs).

## Table 6. Share of FGDs and individuals identifying negative socioeconomic impacts of mechanization (i.e. the use of tractors).

| Impacts | Source | Total | | | Total - Mali | | | Benin | | Kenya | | Mali | | Nigeria | | Rationale and comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All | M | F | All | M | F | M | F | M | F | M | F | M | F | |
| Higher production costs | FGD | 51 | 52 | 49 | 46 | 43 | 48 | 70 | 80 | 33 | 50 | 79 | 53 | 27 | 14 | *For mechanization services & other inputs* |
| | Ind | na | na | na | 43 | 43 | 42 | 62 | 72 | 32 | 39 | na | na | 34 | 16 | |
| Income risks & decline | FGD | 34 | 35 | 33 | 44 | 44 | 44 | 48 | 25 | 83 | 100 | 10 | - | - | 7 | *Yield risks & drops (see Table 5)* |
| | Ind | na | na | na | 37 | 45 | 29 | 48 | 24 | 86 | 55 | na | na | - | 7 | |
| Food shortages | FGD | 34 | 31 | 36 | 45 | 41 | 48 | 91 | 95 | 33 | 50 | - | - | - | - | *Yield risks & drops (see Table 5)* |
| | Ind | na | na | na | 29 | 23 | 34 | 47 | 52 | 23 | 49 | na | na | - | - | |
| Conflicts, tensions & crime | FGD | 29 | 35 | 23 | 37 | 45 | 29 | 70 | 45 | 17 | - | 7 | 5 | 47 | 43 | *Expansion (into pastures), over service/fuel access, unemployment* |
| | Ind | na | na | na | 29 | 35 | 23 | 47 | 33 | 12 | - | na | na | 46 | 36 | |
| Late/no service, breakdowns & dependence on providers | FGD | 26 | 23 | 29 | 24 | 22 | 26 | 35 | 40 | 17 | 25 | 28 | 37 | 13 | 14 | *Breakdowns & low bargaining power for female/small farmers* |
| | Ind | na | na | na | 21 | 21 | 21 | 32 | 36 | 18 | 20 | na | na | 12 | 6 | |
| Unemployment | FGD | 19 | 26 | 13 | 22 | 31 | 12 | - | - | 33 | - | 10 | 16 | 60 | 36 | *Lower demand for agricultural workers* |
| | Ind | na | na | na | | 17 | 25 | 8 | - | - | 18 | na | na | 56 | 25 | |
| Indebtedness & distress sales | FGD | 16 | 21 | 11 | 21 | 28 | 15 | 83 | 45 | - | - | - | - | - | - | *Income risk/decline, breakdowns, sales of land/ machinery/livestock* |
| | Ind | na | na | na | 18 | 25 | 11 | 74 | 34 | - | - | na | na | - | - | |
| Less firewood | FGD | 16 | 7 | 26 | 22 | 9 | 35 | 13 | 90 | - | - | - | - | 13 | 14 | *Due to deforestation* |
| | Ind | na | na | na | 16 | 5 | 26 | 10 | 66 | 16 | - | na | na | 6 | 12 | |
| Limited access for female & marginalized farmers | FGD | 15 | - | 29 | 6 | - | 12 | - | 5 | - | 25 | - | 79 | - | 7 | *Due to social norms* |
| | Ind | na | na | na | 7 | - | 14 | - | 4 | - | 29 | na | na | - | 10 | |
| Accidents | FGD | 9 | 13 | 4 | 6 | 7 | 5 | 22 | 15 | - | - | 31 | - | - | - | *Lack of tractor and operator safety* |
| | Ind | na | na | na | 5 | 7 | 4 | 20 | 12 | - | - | na | na | - | - | |
| Road destruction | FGD | 6 | 5 | 7 | 8 | 7 | 10 | - | - | - | - | - | - | 20 | 29 | *Heavy tractors driving in rainy season* |
| | Ind | na | na | na | 8 | 6 | 11 | - | - | - | - | na | na | 18 | 32 | |
| Social disapproval | FGD | 4 | - | 8 | - | - | - | - | - | - | - | - | 32 | - | - | *Due to social norms* |
| | Ind | na | na | na | - | - | - | - | - | - | - | na | na | - | - | |
| Laziness or bad behaviour | FGD | 4 | 6 | 2 | 5 | 8 | 2 | - | - | 17 | - | - | - | 7 | 7 | *Money for "bad leisure" & unemployment* |
| | Ind | na | na | na | 4 | 6 | 2 | - | - | 11 | - | na | na | 6 | 7 | |
| Less demand for animal draught | FGD | 3 | 4 | 1 | 1 | - | 2 | - | 5 | - | - | 17 | - | - | - | *Since tractors are used* |
| | Ind | na | na | na | 1 | - | 2 | - | 5 | - | - | na | na | - | - | |
| Outmigration | FGD | 3 | 1 | 4 | 2 | 1 | 2 | 4 | 5 | - | - | - | 11 | - | - | *Due to unemployment* |
| | Ind | na | na | na | 2 | 1 | 2 | 4 | 5 | - | - | na | na | - | - | |

### 3.4. Implications and limitations

The results suggest that mechanization has more far-reaching agronomic, environmental and socioeconomic consequences than commonly assumed. So far, empirical research on mechanization has focused on yield and labor effects. The results suggest mixed effects regarding yields and labor, suggesting that local factors shape both. Regarding yields, this reflects the current literature, which is characterized by some studies finding positive yield effects (Adu-Baffour et al., 2019; Yukichi et al., 2017), while others found mixed or no effects (Houssou & Chapoto, 2015; Kirui, 2019).

Yield effects likely depend on agro-ecological conditions such as soil types and rainfall patterns, the use of complementary agronomic practices and the availability of labor. Moreover, they may change over time: farmers reported that yields rise at first as mechanization helps to improve the timeliness and quality of land preparation. Furthermore, as some farmers start to cultivate previously uncultivated and thus fertile land, yields may be initially high. Yet, yields then often drop after some years as current mechanization practices, in particular the use of the disc plough, lead to soil erosion and a decline in soil fertility (see also Adjei et al., 2003; Benin et al., 2013). Conservation agriculture, which minimizes soil disturbance by replacing the plough with rippers or direct planters - as well as protects soils by having a continuous soil cover and builds soil fertility with crop residues and crop rotation using leguminous plants - is likely to be a way forward here (as suggested by Baudron et al., 2015 and Jaleta et al., 2019).

Mechanization has mixed effects on employment, again confirming the literature (Adu-Baffour et al., 2019; Cossar, 2019; Houssou & Chapoto, 2015; Kirui, 2019; Yukichi et al., 2017). In some areas, mechanization reduces the demand for labor, including both family labor, which is positive but also hired labor, which can be problematic. However, in areas where farmers reported cropland expansion, mechanization seems to create rather than destroy rural jobs (similar to Adu-Baffour et al., 2019). In Benin, which has the highest share of respondents from all countries reporting land expansion, none reported unemployment effects.

The results reveal that mechanization has more far-reaching effects, other than on yield and labor. Regarding agronomic and environmental effects, mechanization is associated with the above discussed soil fertility and erosion problems but also soil compaction and water logging. Moreover, mechanization contributes to the cutting of farm trees, which can have negative agronomic and environmental effects and has nutritional consequences when farmers destroy fruit trees (similar to Kansanga et al., 2019). Another concern is that mechanization leads to monocultures of easy to mechanize crops, with negative effects for

nature and human nutrition (Berhane et al., 2017; Kansanga et al., 2018). The results suggest that this is not the case. Respondents even reported that mechanization enhances crop diversity, mostly since farmers have more space for additional crops.

While some effects only affect individual farms, others have more far-reaching effects. The results suggest that mechanization is associated with area expansion, which was seen as positive by the respondents, since it helps to increase agricultural production and income. However, it is concerning from an environmental perspective since it is associated with large-scale deforestation. Area expansion effects are confirmed across Africa (Adu-Baffour et al., 2019; Houssou & Chapoto, 2015; Kirui, 2019; Takeshima et al., 2013). The conversion of forests and savannah to farmland can change the local climate, affect biodiversity and lead to large greenhouse gas emissions (Searchinger et al., 2015). To minimize these effects, which are not inherent to mechanization as such, it is essential to carefully plan and monitor land-use changes, for example, by protecting land that is particularly valuable for climate change mitigation, biodiversity and wildlife. In addition, applied research seeking mechanization implementation as part of more sustainable integrated crop-livestock-forestry systems is needed (as suggested by Alves et al. 2017). When trying to minimize the negative effects of mechanization, there is no environmental benefit in preventing small-scale farms (as in this study) from mechanizing if large scale farms expand cultivation instead (Sulieman, 2015).

While mechanization has various positive socioeconomic effects, there are also negative effects, many of which have been neglected. Risk is of particular importance here. On the one hand, mechanization contributes to decrease the risks, since it enhances the timeliness of farming and helps households to build up capital for bad times, to diversify crop production and to pursue income-generating activities. On the other hand, it increases risks by causing soil fertility declines and erosion as well as water logging, all of which can lead to large yield drops. Moreover, many mechanized farmers rely on tractor service providers, who do not always show up or come too late. In particular, women complained about the dependence on tractor owners. As the production costs of farming increases with mechanization, the severity of negative effects increases, which has led to cases of indebtedness due to mechanization. Safeguards are needed to mitigate some of the avoidable negative effects, e.g. to ensure that service providers stick to agreements. Since late and no service delivery is often related to tractor breakdowns, building the knowledge and skills of tractors operators and technicians can help to reduce risks (Daum & Birner, 2017).

As with most new technologies, mechanization leads to benefits for some but not for others. The role of rural labor has been discussed above. In addition, since mechanized farmers

cultivate more land, grazing land is increasingly encroached upon, leading to conflicts between crop farmers and pastoralists. While other studies found that smallholder farmers often have worse access to mechanization (see Daum & Birner, 2017 for Ghana), this aspect was surprisingly absent from many FGDs. Gender inequalities are stark in some areas echoing studies from other countries, for example, Daum & Birner (2017) in Ghana; Fischer et al. (2018) in Tanzania; and Kirui (2019) in twelve African countries. Accompanying efforts are needed to mitigate conflicts, in particular regarding land rights and land use planning, and to ensure that women and marginalized groups can also reap the benefits from mechanization.

While the qualitative approach of this study has helped to unravel new perspectives on the effects of mechanization and, uniquely, to provide a better understanding on causal impact chains, the approach has limitations as well. For example, while it gives an indication of how often certain impacts are observed, it provides no information on the magnitude of the impacts. Future studies may ask participants of FGDs to rank effects or to distribute, for example, checker pieces to create “magnitude towers” on the severity of effects. Moreover, while the approach helps to explore the perceived impacts of mechanization, thus giving respondents a voice, such an approach may underestimate aspects that are not felt by respondents. For example, while many women reported a decline in available firewood, men did not, potentially because they do not feel this effect due to a gender division of labor. Similarly, other aspects, which are not directly experienced, may be neglected. For example, while respondents highlighted the negative effects of deforestation, Savannah conversion was not mentioned, although it can equally cause greenhouse gas emissions and threaten wildlife (Searchinger et al., 2015). In addition, slowly shifting gender roles due to mechanization (as observed by Kansanga et al., 2019) may be neglected, and more abstract concepts such as rural development and land inequality, which are difficult to observe, may not be reported or attributed to mechanization.

While some aspects may have been neglected, others may have been exaggerated or attributed wrongly to mechanization. Some effects that respondents ascribed to mechanization may actually be caused by factors that unfold simultaneously alongside mechanization but are independent of it. For example, yield decline in the long-term may, to some extent, also occur without mechanization in the absence of soil fertility management. Similarly, the narrative of mechanization leading to deforestation and, subsequently, more irregular rainfall may reflect participant’s views on a phenomenon they are trying to make meaning of but may not be true – although deforestation can indeed change local climates (Searchinger et al., 2015). Thus, regarding some of the identified impacts, it remains a challenge to distinguish between experienced and “real” impacts of

mechanization and respondent's views on mechanization. Importantly, many quantitative economic approaches such as household surveys and subsequent analyses cannot solve these attribution problems and establish causal chains as well. Thus, mechanization research on the interface between social and natural science is needed. Thus, we present this paper as a first explorative study of potential effects which can guide future research from different scientific disciplines concerned with agricultural, rural and environmental development in Africa.

## 4. Conclusion

Despite having the potential to change the face of African farming and rural areas fundamentally, the effects of agricultural mechanization have not been studied comprehensively. Drawing on qualitative evidence from 130 focus groups discussions in 87 villages in four African countries, this study is the first to take a holistic view on the effects of mechanization. The results suggest that mechanization has more far-reaching agronomic, environmental and socioeconomic consequences than commonly assumed. The results suggest that many of the changes related to mechanization will be positive. However, some can be negative in the absence of complementary research efforts and policy measures. As highlighted by the FAO (2013), agricultural mechanization strategies are therefore needed for each African country, that provide "a framework for making decisions on how to allocate resources, how to address current challenges, and how to take advantage of opportunities that arise" (p.xii). As noted by the FAO and emphasized by the findings from this study, such mechanization strategies have to consider all three pillars of sustainability. This will help to ensure that mechanization contributes to an African agricultural transformation that is sustainable from a social, economic and environmental perspective.

## 5. References


Adu-Baffour, F., Daum, T., & Birner, R. (2019). Can small farms benefit from big companies' initiatives to promote mechanization in Africa? A case study from Zambia. Food Policy, 84, 133-145.

Alves, B. J., Madari, B. E., & Boddey, R. M. (2017). Integrated crop–livestock–forestry systems: prospects for a sustainable agricultural intensification. Nutrient Cycling in Agroecosystems, 108(1), 1–4.

Baudron, F., Misiko, M., Getnet, B., Nazare, R., Sariah, J., & Kaumbutho, P. (2019). A farm-level assessment of labor and mechanization in Eastern and Southern Africa. Agronomy for Sustainable Development, 39(2), 17.

Baudron, F., Sims, B., Justice, S., Kahan, D. G., Rose, R., Mkomwa, S., ... & Gérard, B. (2015). Re-examining appropriate mechanization in Eastern and Southern Africa: two-wheel tractors, conservation agriculture, and private sector involvement. Food Security, 7(4), 889-904.

Berhane, G., Dereje, M., Minten, B., & Tamru, S. (2017). The rapid–but from a low base–uptake of agricultural mechanization in Ethiopia: Patterns, implications and challenges. Ethiopia Strategy Support Program Working Paper 105. International Food Policy Research Institute. Washington.
Benin, S. (2015). Impact of Ghana's agricultural mechanization services center program. Agricultural Economics, 46(S1), 103-117.
Bitsch, V. (2005). Qualitative research: A grounded theory example and evaluation criteria. Journal of Agribusiness, 23(1), 75–91.
Daum & Birner (2019). Agricultural mechanization in Africa: Myths, realities and an emerging research agenda. Gobal Food Security. In Press.
Daum, T., Capezzone, F., Birner, R. (2019b). Of trackers and tractors. Using a smartphone app and compositional data analysis to explore the link between mechanization and intra-household allocation of time in Zambia. ZEF Discussion Papers on Development Policy 278. Center for Development Research.
Daum, T., & Birner, R. (2017). The neglected governance challenges of agricultural mechanisation in Africa–insights from Ghana. Food Security, 9(5), 959-979.
De Groote, H., Marangu, C., & Gitonga, Z. (2018). Trends in agricultural mechanization in Kenya's maize production areas from 1992-2012. Agricultural Mechanization in Asia, 49(4), 20-32.
Diao, X., Cossar, F., Houssou, N., & Kolavalli, S. (2014). Mechanization in Ghana: Emerging demand, and the search for alternative supply models. Food Policy, 48, 168-181.
Dixon, J. A., Gibbon, D. P., & Gulliver, A. (2001). Farming systems and poverty: improving farmers' livelihoods in a changing world. Food & Agriculture Org..
Douthwaite, B., Schulz, S., Olanrewaju, A. and Ellis-Jones, J. (2007). Impact pathway evaluation of an integrated Striga hermonthicacontrol project in northern Nigeria. Agricultural Systems 92: 201-222.
Doss, C. R. (2001). Designing agricultural technology for African women farmers: Lessons from 25 years of experience. World Development, 29(12), 2075-2092.
FAO (2013). Agricultural Mechanization in Sub Saharan Africa: Guidelines for preparing a strategy. Integrated Crop Management Vol. 22.
Fischer, G., Wittich, S., Malima, G., Sikumba, G., Lukuyu, B., Ngunga, D., & Rugalabam, J. (2018). Gender and mechanization: Exploring the sustainability of mechanized forage chopping in Tanzania. Journal of Rural Studies, 64, 112-122.
Garbarino, S., & Holland, J. (2009). Quantitative and qualitative methods in impact evaluation and measuring results.
Houssou, N. & Chapoto, A. (2015). Adoption of farm mechanization, cropland expansion, and intensification in Ghana. Agriculture in an Interconnected World, 29.
Jaleta, M., Baudron, F., Krivokapic-Skoko, B., & Erenstein, O. (2019). Agricultural mechanization and reduced tillage: antagonism or synergy?. International Journal of Agricultural Sustainability, 17(3), 219-230.
Jansen, A. J. (1969). Social implications of farm mechanization: final report on a cross-national research. Sociologia Ruralis, 9(4), 340-407.
Malabo Montpellier Panel (2018.) Mechanized: Transforming Africa's agriculture value chains. Dakar, Senegal: International Food Policy Research Institute (IFPRI) and Malabo Montpellier Panel.
Kariuki, J., & Njuki, J. (2013). Using participatory impact diagrams to evaluate a community development project in Kenya. Development in Practice, 23(1), 90-106.
Kate, S. (2009). Agro-ecological Zones of Africa, https://doi.org/10.7910/DVN/HJYYTI, Harvard Dataverse, V2
Kansanga, M. M., Mkandawire, P., Kuuire, V., & Luginaah, I. (2019). Agricultural mechanization, environmental degradation and gendered livelihood implications in northern Ghana. Land Degradation & Development.
Kansanga, M., Andersen, P., Kpienbaareh, D., Mason-Renton, S., Atuoye, K., Sano, Y., ... & Luginaah, I. (2018). Traditional agriculture in transition: examining the impacts of agricultural modernization on smallholder farming in Ghana under the new Green Revolution. International Journal of Sustainable Development & World Ecology, 26(1), 11-24.
Kirui, O. (2019). The Agricultural mechanization in Africa: micro-level analysis of state drivers and effects. ZEF-Discussion Papers on Development Policy 272.
PPMA (2015). Evaluation de la production vivrière 2015 et des perspectives alimentaire pour 2016 au Bénin. Rapport Général 1 . PPMA MAEAP ONASA DSVSA SSA
Searchinger, T. D., Estes, L., Thornton, P. K., Beringer, T., Notenbaert, A., Rubenstein, D., ... & Herrero, M. (2015). High carbon and biodiversity costs from converting Africa's wet savannahs to cropland. Nature Climate Change, 5(5), 481.

Sims, B.G. Hilmi, M. Kienzle, J. (2016). Agricultural mechanization: a key input for sub-Saharan Africa smallholders. Integrated Crop Management 23. FAO, Rome.
Sulieman, H. M. (2015). Grabbing of communal rangelands in Sudan: The case of large-scale mechanized rain-fed agriculture. Land Use Policy, 47, 439-447.
Takeshima, H., & Lawal, A. (2018). Overview of the evolution of agricultural mechanization in Nigeria (Vol. 1750). Intl Food Policy Res Inst.
Takeshima, H., Edeh, H. O., Lawal, A. O., & Isiaka, M. A. (2015). Characteristics of Private-Sector Tractor Service Provisions: Insights from Nigeria. The Developing Economies, 53(3), 188-217.
Wang, X., Yamauchi, F., & Huang, J. (2016). Rising wages, mechanization, and the substitution between capital and labor: evidence from small scale farm system in China. Agricultural Economics, 47(3), 309-317.
World Bank (2017). https://data.worldbank.org/indicator/AG.YLD.CREL.KG
Yukichi Y. & Mano Yukichi Y. & Takahashi K. & Otsuka K. (2017). Contract Farming, Farm Mechanization, and Agricultural Intensification: The Case of Rice Farming in Cote d'Ivoire. Working Papers 157. JICA Research Institute.

**Social and Institutional Change in Agricultural Development**
**Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute)**
**Universität Hohenheim**
Wollgrasweg 43 | 70599 Stuttgart | Deutschland
**T** +49 (0)711-459-23517 | **F** +49 (0)711-459-23812
**E** regina.birner@uni-hohenheim.de | https://490c.uni-hohenheim.de/en