Chapter 12

# EVOLUTION OF AGRICULTURAL MECHANIZATION IN KENYA

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**Abstract:** Agricultural intensification is key to feed the rapidly increasing African population. Although the use of improved varieties has increased substantially over the last 20 years, the use of land- and labor-saving technologies, such as mechanization, has lagged behind. This study reviews existing literature and uses four household surveys conducted between 1992 and 2012 to analyze the evolution of agricultural mechanization in Kenya. The results show persistently low levels of mechanization in Kenya; in 2012, most farm households still used only hand tools. More than a quarter of farmers (28 percent) had a plow, but very few (2 percent) had a tractor. From 1992 to 2012, the percentage of farmers with oxen increased from 17 percent to 33 percent, but those with tractors decreased from 5 percent to 2 percent. Tractors were most important in the highlands, whereas animal traction was most important in the dry areas and moist mid-altitude zone. Adoption of tractors increased with income, acreage, and age. Adoption of animal traction increased with absentee husbands, age, sales of maize, livestock, family size, and access to extension; it decreased with land, fertilizer use, and income. Mechanization in Kenya is likely to continue to depend on animal traction, which is not linked to farm size, complements labor, helps to reduce fertilizer use, increases commercial maize production, and has room to grow—particularly in the highlands. Agricultural extension, development projects, and research should consider the opportunities in animal traction and provide training and research on appropriate technologies in areas with sufficient land area.

## Introduction

Despite recent economic growth in Africa, poverty levels in the continent remain alarmingly high, especially in rural areas. Most people still live and depend on rural land, while the population, along with demand for food and fuel, is increasing fast. To feed this rapidly growing population and avoid deforestation and land degradation from the new pressures on land, agricultural intensification is urgently needed.

Other continents have experienced a Green Revolution of dramatic increases in agricultural production and reduction in food prices (Evenson and Gollin 2003), driven by technology and structural transformation; but this has not happened in Africa. Whereas the use of improved varieties has increased substantially, the use of other land-saving technologies (such as fertilizers and irrigation) and labor-saving technologies (mechanization) remains limited. Development and agricultural economists are struggling to explain what is restraining the Green Revolution in Africa. It is therefore important to study the processes of agricultural intensification in Africa. Although many studies have covered the adoption of improved varieties and fertilizer (Doss 2006; Jayne et al. 2003; Smale and Jayne 2003), recent studies on agricultural mechanization in Africa are lacking.

The topic of agricultural mechanization drew attention in the 1980s, when several influential studies argued that African countries were not yet ready for widespread agricultural mechanization (Binswanger 1986; Pingali, Bigot, and Binswanger 1987). Since then, the topic has not received much interest, though animal traction in West Africa's cotton belt spread quickly during the 1980s and 1990s (Tefft 2010). More recently, the Food and Agriculture Organization of the United Nations has been trying to revive interest in agricultural mechanization (FAO and UNIDO 2008). Recent studies in Ghana did not provide support for the classic government-run program of tractor services provision (Diao et al. 2014; Houssou et al. 2013). In Burkina Faso, however, animal traction was shown to increase both labor productivity and land productivity (Savadogo, Reardon, and Pietola 1998). As an alternative to expensive tractors, some have also argued for the use of small, multipurpose, inexpensive power sources such as two-wheel tractors (2WTs) (Baudron et al. 2015).

To add to the discussion on the role of agricultural mechanization in the intensification of agricultural production in Africa, this study provides a review of the relevant literature. This is followed by a quantitative analysis of the evolution of farm mechanization in Kenya over a recent 20-year period, based on four consecutive representative household surveys covering the major agricultural zones of the country.

## Background

### History of Mechanization in Kenya

The demand for farming system intensification, and potential demand for mechanization, started rising in Kenya in a few pockets of areas favorable for

intensification. It has been argued that an increasing population and greater food demand motivate an increase in effective mechanization, in particular with regard to draft animals in areas where tractors are not appropriate or have failed (O'Neill and Kemp 1989). Migration to more favorable areas leads to more intensive production with a shorter fallow period. An example is Nyanza province, described as early as the 1940s (Humphrey 1947). Similarly, immigration occurred into the high altitudes, which had historically enjoyed a better climate and lower incidence of disease (including malaria and sleeping sickness), such as the North Kavirondo district (Wagner 1949) and the Kikuyu highlands (Humphrey 1945). Mechanization was more substantially stimulated by such farming intensification than by other factors. For example, the spread of the plow from settlers to smallholders had been a relatively minor channel of diffusion, because such transfers had often been inhibited by a number of discriminatory practices (Pingali, Bigot, and Binswanger 1987).

Infrastructure development also led to farming system intensification and increased use of more modern mechanization methods. Intensive production of maize in more fertile parts of Kenya was directly induced by the railways built by the colonial government, and commercial production of maize along the railways has been concentrated in the areas with high potential for production (Pingali, Bigot, and Binswanger 1987). Favorable areas with a good railway network, such as Nyanza province, started seeing the use of animal-drawn moldboard plows as early as the 1920s and the 1930s, for the production of maize and cotton (Pingali, Bigot, and Binswanger 1987).[1]

By the mid-1980s, the use of mechanization (motorized transport) had spread gradually for various transport operations in areas including most of the highlands, Embu and Machakos districts, and areas around Nairobi; it had also spread, though to a lesser extent, for plowing activities in areas including Embu and Machakos districts (Pingali, Bigot, and Binswanger 1987). In these areas, the use of animal-drawn plows had also started spreading by the mid-1980s. Also by that time, private-sector contract-hire operations with tractors

1 The use of animal traction in Africa started around 6000 BCE, as shown in depictions of oxen and plows in Egyptian and early Mesopotamian civilizations, some of the earliest records in the world. In North Africa and Ethiopia, animal traction has been a core part of farming and transportation for over 2,000 years. In South Africa, European travelers observed the Khoi-Khoi riding cattle and used them as pack animals in the 15th century (Joubert 1995). In West Africa, the use of horses, donkeys, and camels for riding and as pack animals has been popular for centuries, especially in sem-iarid areas (Starkey 2000). However, in many eastern and southern African regions, including many parts of Kenya, manual labor is still the main source of power in agriculture and draft animals are a relatively recent introduction (Lawrence and Pearson 2002).

had also been observed in various locations within Kenya, including Nakuru and Narok districts (Pingali, Bigot, and Binswanger 1987).

Animal power has the potential to enhance a farmer's ability to adopt and use renewable practices such as animal manure, crop rotation, and ridging. It allows the cultivation of larger areas, increases household production and food security, and enhances the likelihood of a marketable surplus (Bishop-Sambrook 2005). In the late 1990s, it was estimated that 65 percent of the cultivated area in Africa south of the Sahara (SSA) was prepared by hand, 25 percent by draft animals, and 10 percent by tractors (FAO and UNIDO 2008). In Kenya, the main draft animals are oxen and donkeys, which are well distributed throughout the country. The use of animal traction had also benefited from the breeding of larger cattle with greater tractive power. Kenya was one of the successful examples of such activities, where the use of breeding activities originally aimed at producing suitable beef and dairy cattle had been applied to breeding cattle for tractive purposes (Jaetzold and Schmidt 1982).

Tractors were introduced in Kenya shortly after World War II, and in the two decades following the nation's 1963 independence, the government promoted motorized mechanization to smallholders through state-sponsored tractor hiring and tractor credit schemes, with the aim of increasing the production of crops (Guthiga, Karugia, and Nyikal 2007). The adoption of tractors in SSA went through various phases between 1945 and 1981, each phase being significant in increasing the number of tractors in use (Pingali 2007). Kenya was among the first generation of tractor users in SSA, with the introduction of a substantial number of tractors in 1945–1955, and adoption spread from settler farmers to farms owned by native Africans. In early years, tractors were used in public irrigation schemes such as the Mwea Irrigation Settlement Scheme, where tractor hiring through leasing companies started in 1960 (Pingali, Bigot, and Binswanger 1987, Table 5.6).

In 1966/1967, government tractor hiring service was initiated in Kenya when 50 tractors were introduced to provide cultivation services, primarily for areas under the Masai Wheat Scheme (Pingali, Bigot, and Binswanger 1987). Although these 50 tractors achieved about 770 productive hours per machine in 1967/1968, and remained relatively productive in early years, once the total number of tractors increased to 150 in 1980, the number of productive hours per tractor decreased substantially, to 167 a year in 1980 (Pingali, Bigot, and Binswanger 1987), which was considerably lower than the rate of about 1,000 hours recorded in the private sector in Kenya in 1981 (Seager and Fieldson 1984). Whereas such low performance of public-sector hiring services was similar to the experience of other African countries, in the case of Kenya, the

public-sector hiring service operations were also restricted to their respective jurisdictions and not allowed to operate outside them. Similar to many other SSA countries, Kenya saw a decline in mechanization in the 1980s, especially in the use of tractors and tractor hiring services for farming (Pingali 2007). In Kenya, similar to other SSA countries, most farmers could not individually afford tractors, and the organization of cooperatives or farmer groups to access credit and obtain tractors was rare (Lamidi and Akande 2013).

Large-scale farming, in contrast to small-scale farming, has seen higher levels of mechanization at all stages of production. For example, irrigation schemes for sugarcane production in Kenya, similar to those in Sudan and Tanzania, have been highly mechanized. The major mechanized operations include land preparation, cane loading, and cane transport to the factory (Kienzle, Ashburner, and Sims 2013). Another example is large-scale wheat farming in Kenya, which uses tractors for cultivation and planting, spraying equipment, and combine harvesters; most of this machinery is owned rather than hired (Longmire and Lugogo 1989). However, these types of farmers have remained small in terms of share in Kenya.

After the collapse of tractor projects, attention was given to draft animal power as a more sustainable option. In Kenya, a program to support draft animal power was established in 1970, covering the selection and training of draft animals, the development of the collar harnesses and oxen yokes, farmer training, and development of specialized equipment (Onyango 1988). These efforts have produced mixed results. For maize production, the promotion of mechanization projects saw a relative success in Kenya, but to a limited extent compared with other countries in East Africa, such as Tanzania (Anthony 1988).

## Recommendations from the Literature

This literature review indicates that both the government and the private sector have clear, but distinct, roles to play in sustainable mechanization. The role of government lies in education and training; in the creation, funding, and management of institutions responsible for the research; and in the distribution of information on agricultural mechanization. The government should also facilitate trade relationships with new suppliers of technology or equipment and help in maintaining standards (FAO and UNIDO 2008).

The private sector, on the other hand, is better equipped to look after the day-to-day provision of farm inputs, including farm machinery and the associated support services. In the developed world, once economic conditions produced effective demand for machinery, private firms were able to respond rapidly (Binswanger 1986). Decisions on the operations to be performed,

prices to be charged, and so on, are better made by individual contractors, rather than by the government. The private sector has clear incentives for the mechanization of agriculture—more mechanization implies a higher demand for their services and higher revenues (Pingali, Bigot, and Binswanger 1987). Governments, as in Ghana, can impede this progress by crowding out or otherwise preventing private-sector importation of appropriate and affordable machinery for use in hiring services (Diao et al. 2014).

The economic costs of using tractors, animals, or human labor are determined by the relative costs of labor and capital, the interest rate, capacity utilization, farm size, the availability of fodder, the comparative maintenance costs of animals and tractors, and the difficulty of obtaining spare parts, fuel, and repair services for the tractors, or veterinary services for the animals (Pingali, Bigot, and Binswanger 1987). Therefore, the farmers must calculate and compare the costs and benefits of alternative options and find those best suited to their needs. However, draft animal power, tractor power, and human power should be taken as complementary sources of power for agriculture production and not as mutually exclusive. In Burkina Faso, for example, nonfarm income was a major factor that allowed farmers to invest in animal traction (Savadogo, Reardon, and Pietola 1998).

The development and modernization of Africa's agriculture will depend to a large extent on the transformation of agricultural policies. Agricultural mechanization policy ought to be seen within the context of an overall agricultural growth strategy (Pingali 2007). It is imperative for African leaders and policymakers to understand the importance of mechanization for Africa's future. There should be concerted efforts by all stakeholders to accelerate the rate of mechanization adoption by farmers in SSA, whether through draft animals or tractors. These efforts to accelerate mechanization will require substantial long-term political and financial commitments, which ought to address the critical problems in the agriculture sector and help to improve the prospects for African agriculture and farmers (Mrema, Baker, and Kahan 2008). In the meantime, it is important to look at available information to guide policies, as we do in the next section.

## Methods

### Conceptual Framework

Intensification of agriculture is generally driven by an increasing population, which requires communities to produce increasing amounts of food on a fixed

land area (Boserup 1965). Technology development tends to follow the direction of the scarcest resources, a process called *induced innovation* (Ruttan and Hayami 1984). Mechanization, the replacement of human labor by machinery, therefore tends to occur where land is abundant or labor is scarce, as in many settler communities such as North America or in large-scale settler farms such as those in eastern and southern Africa in the first half of the 20th century. However, when the population grows rapidly, as is the current case in Africa, land becomes scarce and labor becomes abundant. These conditions are likely to remain until there is a structural transformation in the form of movement of large groups from rural to urban areas, driven by economic development and the creation of job opportunities in cities. Only when rural labor moves to the cities, and the economy is sufficiently strong to absorb them and pay increasing wages, will labor become scarce in rural areas.

Animal traction has some benefits other than replacing labor: draft animals provide manure to replace expensive mineral fertilizer, and they provide transport of inputs and produce within the farm as well as to and from local market centers. It reduces drudgery and offers an increase in agricultural production above family needs.

## Empirical Framework

In this chapter, we take advantage of household survey data available from four surveys conducted over a recent 20-year period to analyze agricultural mechanization in Kenya. We first examine the use of farm implements by rural households in the most recent survey (2012) and the geographical distribution of the different technologies. Because different surveys used different questions and variables, it was not easy to pool the data. We therefore limit the analysis of the evolution of mechanization by charting the proportion of farmers who over the years have adopted tractors, plows, and oxen, and the distribution of adoption patterns over different agroecological zones. Finally, we use the most recent survey to run a logistic regression analyzing the factors that affect the adoption of these three factors. We hypothesize that characteristics of the household head (including age, education, and gender) and of the household itself (including available land, labor, and livestock), as well as access to the markets and rural services (including agricultural extension and microcredit) all play a role in adoption.

## Data Sources

The data were collected during rural household surveys conducted in Kenya over a recent 20-year period—1992, 2002, 2010, and 2012 (De Groote,

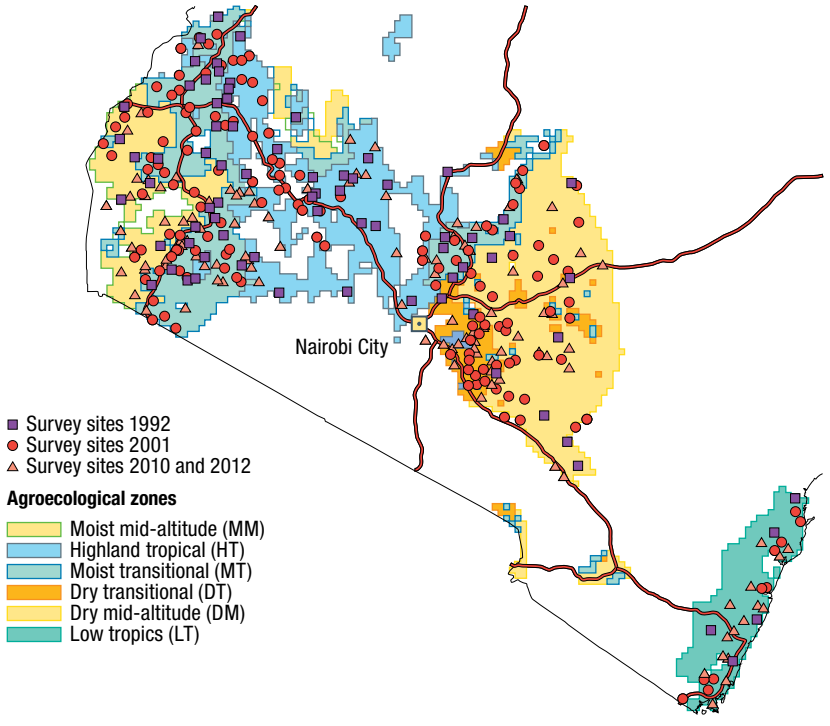
Marangu, and Gitonga 2018). The first three surveys were cross-sections, whereas for the last survey the households from the 2010 round were revisited, with a rotation of 20 percent of the sample. Each survey was representative of all major maize-growing areas of the country, where most rural households are located, and each used a stratified two-stage design, with agroecological zones as strata, sublocations as primary sampling units, and households as the second stage. Each survey covered more than 1,300 households (Figure 12.1, Table 12.1).

The first survey was conducted in 1992 by the International Maize and Wheat Improvement Center and the Kenya Agricultural Research Institute in the major agroecological zones of Kenya (Hassan, Lynam, and Okoth 1998). This study redefined these zones into six major agroecological zones for maize production (Figure 12.1). From the coast inland, we encounter the lowland tropics, followed by the dry mid-altitude and the dry transitional zones. These three zones are characterized by low yields, less than 1.5 tons[2] per hectare. Although these zones cover 29 percent of Kenya's maize area, their maize production is just 11 percent of the country's total production. Central and western Kenya are dominated by the highland tropics, which are bordered at the west and east by the moist transitional zone that is transitional between the mid-altitude zone and the highlands. These zones have high yields (more than 2.5 tons per hectare) and produce 80 percent of Kenya's maize on 30 percent of Kenya's maize area.

The first survey was conducted in 1992 and covered 79 clusters, selected from the sampling frame of the Central Bureau of Statistics, and 1,407 farmers (Hassan, Lynam, and Okoth 1998). The second survey covered 185 sublocations, randomly selected from the 1999 census report (Kenya, CBS 2001), and 1,800 farmers (Table 12.1). The third survey was conducted in 2010; it covered 120 sublocations in the first stage, and 1,344 farmers in total. The fourth survey, conducted in 2012, revisited the same sublocations of the 2010 survey and visited the same households, except for a randomly selected replacement of 20 percent of the households. This survey therefore had the same number of sublocations (120) and the same number of households (1,344) as the previous survey.

2 "Tons" refers to metric tons throughout the chapter.

**FIGURE 12.1** Map with primary sampling units of different surveys, Kenya, 1992–2012




**Source:** De Groote, Marangu, and Gitonga (2018).

**TABLE 12.1** Sampling design of the four surveys, Kenya, 1992–2012

| | 1992 | | | 2002 | | | 2010 | | | 2012 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agroecological zone | PSUs | HHs /PSU | HHs | PSUs | HHs /PSU | HHs | PSUs | HHs /PSU | HHs | PSUs | HHs /PSU | HHs |
| Low tropics | 5 | 20 | 100 | 20 | 15 | 300 | 15 | 6 | 90 | 15 | 6 | 90 |
| Dry mid-altitude | 10 | 18 | 181 | 25 | 8 | 200 | 18 | 12 | 217 | 18 | 12 | 216 |
| Dry transitional | 4 | 20 | 80 | 20 | 5 | 100 | 17 | 12 | 203 | 17 | 12 | 204 |
| Moist mid-altitude | 9 | 20 | 183 | 25 | 10 | 250 | 20 | 12 | 240 | 20 | 12 | 240 |
| Moist transitional | 23 | 18 | 412 | 55 | 10 | 550 | 30 | 12 | 354 | 30 | 12 | 354 |
| High tropics | 28 | 16 | 451 | 40 | 10 | 400 | 20 | 12 | 240 | 20 | 12 | 240 |
| **Total** | **79** | **n.a.** | **1,407** | **185** | **n.a.** | **1,800** | **120** | **n.a.** | **1,344** | **120** | **n.a.** | **1,344** |

**Source:** De Groote, Marangu, and Gitonga (2018).

**Note:** HH = number of households in the survey; n.a. = not applicable; PSU = primary sampling unit (clusters in 1992, sublocations in the other years).

## Survey Results

### Farm Implements Used

The proportion of farmers who used different implements in 2012 reveals the very limited extent of agricultural mechanization in Kenya (Figure 12.2). The majority of farm implements used were hand tools, and most households owned at least some *pangas* (machetes), hoes, axes, spades, or shovels. More than half of the households owned a fork hoe or a slasher. The most popular mechanical device was the bicycle, owned by slightly less than half of the households (48 percent). The most popular modern farm implements were the backpack sprayer (owned by 46 percent of respondents) and the wheelbarrow (45 percent). As for mechanization, more than a quarter of farmers owned an ox plow (28 percent), but few had an oxen or donkey cart (8 percent), and even fewer had a push cart (2 percent). Tractors were rare, with only 2 percent of farmers in the survey owning them.

Devices to generate electricity were more popular than tractors—17 percent of respondents had solar panels and 6 percent had a generator. For transport, apart from the bicycle, only a few farmers owned vehicles and a few households had a motorbike (10 percent) or a car (5 percent).

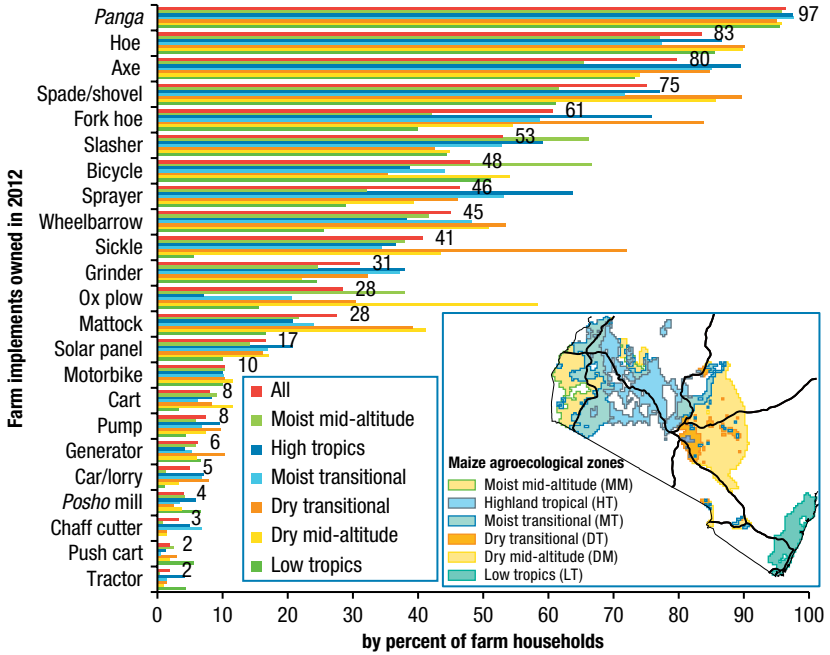
### Evolution of Agricultural Mechanization

Plotting the evolution of agricultural mechanization in Kenya over the last 20 years shows that levels of adoption have been consistently low (Figure 12.3). Oxen were introduced in the early 20th century by European and South African settlers, who switched to the use of tractors when these became available. After independence, the large settler farms and their equipment were purchased by African farmers and the upcoming elite. However, these farmers never had many tractors, and the proportion of farms with tractors is decreasing. In 1992, only 4 percent of respondents to the survey owned tractors, and in 2012 it was less than 2 percent.

During this same study period, however, there were many more farmers with plows than with tractors, indicating the relative importance of animal traction. The proportion of farmers who own plows steadily increased over the study period, from 12 percent to 28 percent. Similarly, the proportion of farmers owning oxen steadily increased, from 17 percent to 33 percent, over the 20-year period. There was a dip in oxen ownership in the 2010 survey, likely because of a serious drought just before the year of the survey.

Plotting the results separately for each year and by zone shows the large differences in mechanization levels, both for tractors and animal traction,

**FIGURE 12.2** Farm implements used, by agroecological zone, farm households, Kenya, 2014

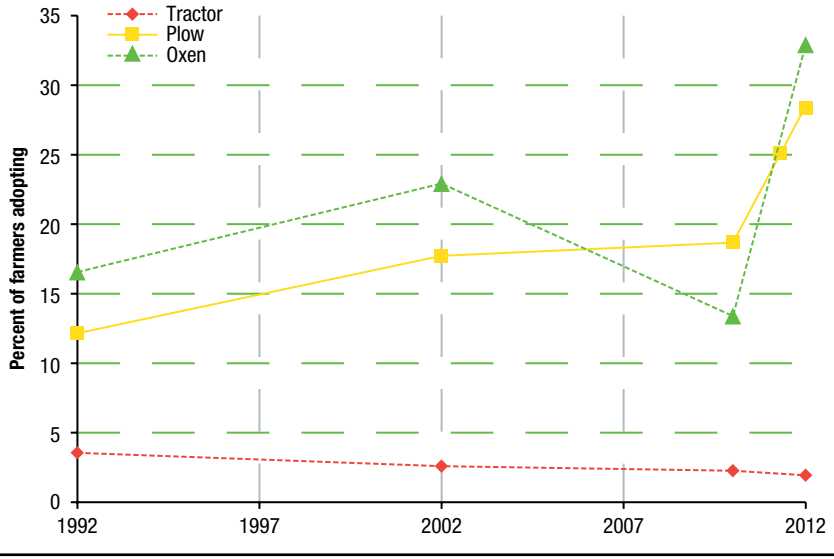



**Source:** De Groote, Marangu, and Gitonga (2018).
**Note:** A *panga* is a machete; *posho* is maize flour.

between the agroecological zones in Kenya (Figure 12.4). The results show that the relative importance of tractors and animal traction over the different zones has not changed over the years. Tractors have always been most important in the highlands, whereas oxen and oxen plows were most popular in the dry mid-altitude zones, followed by the moist mid-altitude zones. Most tractors were found in the highlands, with only a few in other zones. Only in the last survey did tractors show up in the coastal lowlands. Likely, the presence of tractors in the highlands is influenced by colonial history, which favored large-scale, capital-intensive, commercial farming.

Ownership of plows is, understandably, strongly correlated with ownership of oxen. Especially in the dry zones, many farmers have oxen and plows. The popularity of oxen in the dry areas likely is affected by the lower population density, because farms have larger land areas for both farming and pasture, and they have more cattle from which to draw oxen. Similarly, farmers in the moist mid-altitude zones tend to have more cattle, a fact that has likely

**FIGURE 12.3** Evolution of farm mechanization in Kenya from 1992 to 2012



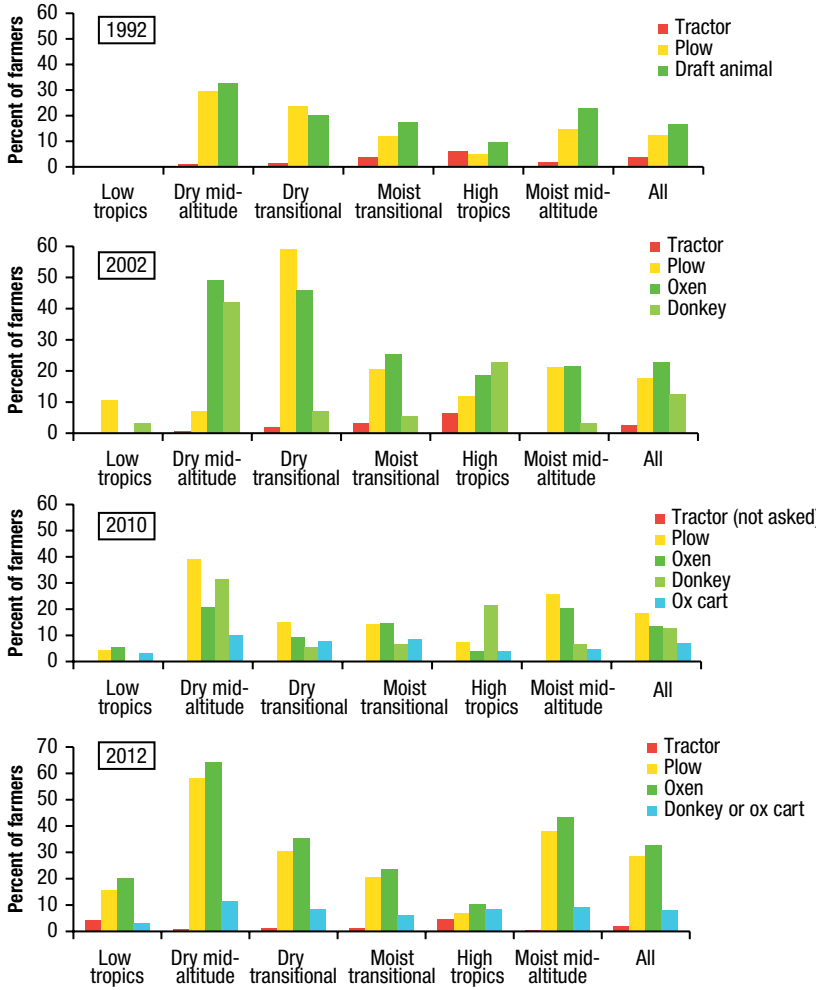

**Source:** De Groote, Marangu, and Gitonga (2018).

affected the adoption rates for animal traction. The high tropics, on the other hand, have the lowest levels of animal traction, despite the zone's high potential and large available land areas. This might be affected by the historic preference for tractors in the zone and the resulting presence of tractors for hire. The highlands tend to have only one long rainy season, so plowing is needed only once per year, as compared with the other zones, which tend to have two rainy seasons and therefore need to prepare land and plow twice per year.

The analysis further shows that few people have carts, either for donkeys or oxen—the rate of ownership is just 12 percent in the dry mid-altitude zones and less than 10 percent in all other zones. The proportion of farmers with carts does not seem to have increased much over the years.

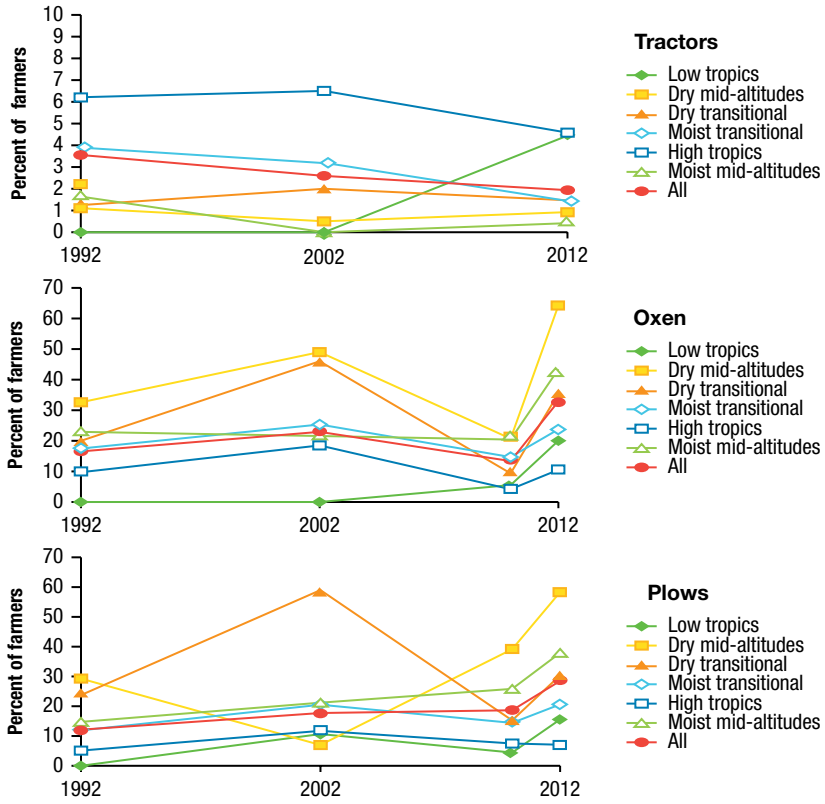
Plotting the evolution of the use of different implements in each zone shows the similarity of the trajectories across the different zones (Figure 12.5). With few exceptions, the proportion of farmers who own tractors has been declining, whereas the number of oxen and plows is increasing. One exception is the coast, where several farmers obtained tractors between 2010 and 2012. Another exception is the reduction in the proportion of farmers with oxen or plows in the dry transitional zone; there was a strong increase in 2001, followed by a decrease in 2010, and then finally an increase leading up to 2012.

**FIGURE 12.4** Evolution of farm mechanization in Kenya from 1992 to 2012, by agroecological zone and year




**Source:** De Groote, Marangu, and Gitonga (2018).

**FIGURE 12.5** Evolution of farm mechanization in Kenya from 1992 to 2012, by year and by agroecological zone




**Source:** De Groote, Marangu, and Gitonga (2018).

## Factors Affecting the Adoption of Farm Mechanization

A logistic model was estimated to analyze the factors affecting the adoption of agricultural mechanization. Three different dependent variables were used for the analysis—the adoption of tractors, of trained oxen, and of plows, all expressed as binary variables (yes = 1, no = 0).

Specifically, the following model is estimated:

$$y_i = \begin{cases} 1 \text{ with probability } P_i \\ 0 \text{ with probability } 1 - P_i' \end{cases} \quad (1)$$

in which $y_i$ denotes the three dependent binary variables described above and $P_i = P(Y_i = 1|x_i)$ is the probability that $y_i = 1$ given the set of exogenous

variables $x_i$. Under the assumption that $P_i$ can be approximated by the cumulative logistic distribution based on the linear prediction of the function of independent variable $x_i$ so that

$$P_i = \frac{\exp(\mathrm{x}_i'\beta)}{1+\exp(x_i'\beta)} = F(\mathrm{x}_i'\beta), \tag{2}$$

where $F(\cdot)$ denotes the cumulative logistic distribution function, coefficients $\beta$ can be estimated by maximizing the log maximum likelihood function

$$\ln L = \sum_{\mathrm{i}=1}^{\mathrm{N}}[y_i \ln F(\mathrm{x}_i'\beta) + (1-y_i)\ln(1-F(\mathrm{x}_i'\beta))] \tag{3}$$

over the relevant samples i = 1,...,$N$.

The results, displayed in Table 12.2, show that the model parameters for tractors are very different from the other two, whereas the models for oxen and plows are more similar to each other. Only two factors significantly affect both the tractor and the oxen/plow models: age of the household head and household income are both positively associated with adoption of implements. Total available land per household affects the adoption of both tractors and oxen but in different ways—it increases the likelihood of adopting tractors but decreases ownership of trained oxen. Similarly, the agroecological zones matter: whereas the highlands have more tractors and fewer oxen, the dry and the moist transitional zones have more oxen and fewer tractors.

Clearly, the adoption of tractors and of oxen and plows follow different mechanisms. The adoption of tractors is affected by age, with older farmers more likely to have tractors. This is consistent with the observed decline in tractor ownership. Furthermore, tractor ownership increases with available land and capital, which is also understandable—tractors need sufficient land to justify their use, and they require a substantial amount of capital. After considering these factors, there are still regional differences: the high tropics, as well as the low tropics, have significantly higher proportions of farmers with tractors than the other zones. The higher adoption of tractors in the highlands clearly originates from the area's colonial history.

For the adoption of oxen, household composition matters. Households in which the husband is away are more likely to have oxen. This might be because of remittances from the husband or because the household is short of labor. However, neither argument is supported by the regression results; income actually decreases the probability of adopting oxen, and available labor increases the probability of adopting oxen. The latter indicates that oxen power complements labor rather than substitutes for it. A greater number of tropical livestock units in a household improves the probability of adopting oxen and plows. It most likely helps the household to have more cattle from

**TABLE 12.2** Factors affecting the adoption of farm mechanization, Kenya, farm household survey of 2012

| | | Tractor | | | Trained oxen | | | Ox plow | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dependent variable | | Coef. | SE | Sign. | Coef. | SE | Sign. | Coef. | SE | Sign. |
| Head | Constant | –7.29 | 1.98 | *** | –4.55 | 0.83 | *** | –4.21 | 0.74 | *** |
| | Age of household head (years) | 0.04 | 0.02 | * | 0.00 | 0.01 | n.a. | 0.02 | 0.01 | *** |
| | Household head is male | –0.37 | 1.05 | n.a. | 0.54 | 0.45 | n.a. | –0.25 | 0.39 | n.a. |
| | Head education (years) | 0.04 | 0.04 | n.a. | 0.01 | 0.02 | n.a. | 0.03 | 0.02 | * |
| Marital status | Married but spouse away | 0.59 | 0.91 | n.a. | 0.88 | 0.32 | *** | 0.45 | 0.30 | n.a. |
| | Divorced/separated | 0.00 | n.a. | n.a. | 0.18 | 0.80 | n.a. | –1.00 | 0.78 | n.a. |
| | Widow/widower | 0.38 | 1.06 | n.a. | 0.50 | 0.46 | n.a. | –0.34 | 0.41 | n.a. |
| Household | Adult equivalents | 0.14 | 0.090 | n.a. | 0.15 | 0.04 | *** | 0.15 | 0.04 | *** |
| | Tropical livestock units | 0.00 | 0.018 | n.a. | 0.16 | 0.02 | *** | 0.11 | 0.02 | *** |
| | Total land (acres) | 0.03 | 0.014 | ** | –0.02 | 0.01 | *** | 0.00 | 0.01 | n.a. |
| | Number of extension contacts | 0.00 | 0.014 | n.a. | 0.01 | 0.00 | *** | 0.01 | 0.00 | *** |
| | Total income (KES) | 0.81 | 0.334 | ** | –2.18 | 0.48 | *** | –1.41 | –2.18 | *** |
| | Percentage of land owned | 0.56 | 1.012 | n.a. | 0.34 | 0.40 | n.a. | 0.53 | 0.35 | n.a. |

which the oxen can be pulled. More land to cultivate, on the other hand, decreases the probability of having oxen but does not affect plows. This is counterintuitive; we would have expected larger farms to have more oxen.

The number of extension contacts is an important factor in the adoption of mechanization—an increase of 1 extension contact over the last year increases the probability of adopting oxen or plows by 1 percent. Landownership (in terms of the percentage of land a household cultivates that it owns) does not seem to make a difference in mechanization. The use of fertilizer, for at least the top dressing, is negatively correlated with the adoption of animal traction—it is likely that when a household has oxen there is less need for fertilizer. Increased marketing of maize, on the other hand, increases the adoption of animal traction. Commercially oriented maize producers are more likely to invest in animal traction. After considering the above factors, agroecological zones are still important factors in the adoption of animal traction. Compared with the base (the low tropics), the dry areas and the

| Dependent variable | | Tractor | | | Trained oxen | | | Ox plow | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Coef. | SE | Sign. | Coef. | SE | Sign. | Coef. | SE | Sign. |
| Household (continued) | Basal fertilizer (1 = yes; 0 = no) | 0.16 | 0.731 | n.a. | 0.10 | 0.25 | n.a. | 0.10 | 0.22 | n.a. |
| | Top dressing (0 = no; 1 = yes) | 0.98 | 0.676 | n.a. | –0.70 | 0.24 | *** | –0.56 | 0.21 | *** |
| Agroecological zone | Dry mid-altitude | –1.95 | 0.97 | ** | 1.58 | 0.46 | *** | 2.19 | 0.39 | *** |
| | Dry transitional | –2.25 | 1.01 | ** | 0.80 | 0.49 | n.a. | 1.11 | 0.41 | *** |
| | Moist transitional | –2.51 | 0.89 | *** | 0.34 | 0.47 | n.a. | 0.40 | 0.40 | n.a. |
| | High tropics | –1.07 | 0.76 | n.a. | –1.69 | 0.58 | *** | –1.75 | 0.51 | *** |
| | Moist mid-altitudes | –2.54 | 1.17 | ** | 1.07 | 0.46 | ** | 0.90 | 0.39 | ** |
| Marketing | Distance to main market (km) | 0.02 | 0.02 | n.a. | 0.00 | 0.01 | n.a. | –0.01 | 0.01 | n.a. |
| | Percentage of own maize sold | 1.03 | 0.80 | n.a. | 1.64 | 0.32 | *** | 1.51 | 0.29 | *** |
| Model | Number of observations | 1,111 | n.a. | n.a. | 1,128 | n.a. | n.a. | 1,128 | n.a. | n.a. |
| | Pseudo $R^2$ | 0.255 | n.a. | n.a. | 0.2576 | n.a. | n.a. | 0.24 | n.a. | n.a. |
| | Log likelihood | –80.48 | n.a. | n.a. | –427.58 | n.a. | n.a. | –512.80 | n.a. | n.a. |

**Source:** Authors' estimations based on data from De Groote, Marangu, and Gitonga (2018).
**Note:** KES = Kenya shillings; SE = standard error. n.a. = not applicable. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

moist mid-altitude zones have higher levels of adoption, likely because they are affected by large amounts of cattle and low population densities. The high tropics have lower levels of animal traction, likely because they are affected by the historic use of tractors.

## Discussion

This study examines the low adoption levels of agricultural mechanization in Kenya. In 2012, most farm households used only hand tools; slightly less than half owned a bicycle, a backpack sprayer, or a wheelbarrow. Slightly more than a quarter of farmers (28 percent) had a plow, whereas very few (2 percent) had a tractor. None of the interviewed farmers owned 2WTs. From 1992 to 2012, the proportion of farmers with trained oxen increased from 17 percent to 33 percent, whereas the proportion with tractors decreased from 5 percent to 2 percent. Tractors were most important in the highlands, and animal

traction was most popular in the dry areas and moist mid-altitude zones (around Lake Victoria). Relative differences between zones have persisted over the years, although all zones have followed the same general trend of increased animal traction and decreased adoption of tractors. The factors that affect mechanization differ for tractors and animal traction. The adoption of tractors increases with household income, acreage, and age of the household head. The adoption of animal traction also increases with income and age of the household head but decreases with land area. Furthermore, adoption of animal traction is higher in households where the husband is away, and increases with sales of maize, ownership of livestock, family size, and access to extension services. Finally, adoption of animal traction is negatively correlated with the top dressing of fertilizer.

The four different household surveys over a 20-year period offer good insights into the evolution of agricultural mechanization in the different zones of Kenya, despite the independent cross-sectional designs of the first three surveys. Another big issue was the fact that the different surveys did not use the same tools and definitions; however, this chapter shows how these shortcomings can be improved in future surveys. In particular, a distinction should be made between ownership of, access to, and use of (the latter two through ownership or hiring services) the different farm implements and draft animals involved in agricultural mechanization. Furthermore, within the different implements a distinction should be made between ox plows and tractor plows, and between different types of carts (oxen, donkey, or hand cart). Ownership and use of weeding implements—to be used with draft animals—and shelling equipment should also be included. Finally, a distinction should be made between oxen and trained oxen, and ownership of donkeys should be included.

Household surveys typically ask about implements and draft animals, but that leaves out other types of mechanization. For example, most households have moved from manual to mechanical milling, but mills are typically owned by small businesses in the towns and do not frequently show up in household surveys (just 4 percent of households reported using a mill in 2012). The presence of such services could be picked up by a community survey, and the use of those services could then be picked up in the household survey. Similarly ignored services include availability of electricity and irrigation.

Our results show that agricultural mechanization is slowly making progress in Kenya through animal traction rather than tractors, and this trend is likely to continue for many years. Promoting tractors does not seem well-advised, at least not for maize cultivation. Tractors are expensive (they were

not developed for low-cost maize production in areas with low labor costs), and fuel prices are steadily increasing. Furthermore, the population in Kenya is growing rapidly and most are still living in rural areas, reducing the availability of agricultural land per person and therefore farm size, and suppressing rural wages. As a result, the proportion of farmers owning tractors is decreasing and is likely to decrease further. Whereas 2WTs are substantially cheaper than larger tractors, the arguments against their efficacy are similar and the profitability of these implements needs to be carefully assessed against the potential of animal traction and manual labor.

These results from Kenya align with the conclusions of earlier studies (Pingali, Bigot, and Binswanger 1987) and suggest that the farming system in Africa has not yet reached the intensification levels suitable for investment in tractors. Similarly, they confirm the results from West Africa (Blench 2015) that African farming systems, or at least some of them, are more suited for animal traction than for tractors. Despite the increased interest from farmers, animal traction has been receiving little attention from rural development projects and extension agencies. In our analysis, animal traction has the following advantages: it is not linked to farm size; it does not reduce labor, and instead complements it; it helps reduce the use of chemical fertilizer; and it helps farmers to engage in commercial maize production. Moreover, there is still large potential for expanding animal traction, in particular in the highlands. Whereas tractors were popular in this zone, likely for historical reasons, animal traction should be given more attention because large land areas are still available for both crop production and pasture, population density is low, and commercial maize production is important. Contact with extension services increases the probability of technology adoption, so continued training of trainers, as well as research and dissemination of locally adapted implements, should be encouraged. Animal traction is not common, however, in areas with high population density, with low land area per household, and with low availability of pasture, which includes most of the moist transitional zone.

We conclude that, despite the seemingly more advanced nature and attractiveness of tractors for rural development, the short- to medium-term future of agricultural mechanization in Kenya lies in the promotion of animal traction in areas with sufficient land area.

Nevertheless, some recommendations laid out in the Asian chapters apply to Kenya. First, more research is needed to understand whether the limited substitution of animal traction with tractors reflects the low overall demand for mechanical power for land preparation (and thus less intensive tillage). Many Asian chapters suggest, for example, that the role of research and development

in developing complementary technologies such as high-yielding varieties can be critical in raising the demand for greater farm power use beyond the level that animals alone can provide, so that the demand for stronger sources of power such as tractors starts to emerge. Second, as described in the introduction to this volume, Kenya's importation of tractors has been seemingly restrictive, and only four-wheel tractors of greater than 100 hp have commonly been imported. Reducing import restrictions, as was done in many Asian countries, could increase the importation of smaller tractors and power tillers, which could be more affordable and lead to increased adoption in certain areas.

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