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OVERVIEW OF THE USE OF PRE-HARVEST EQUIPMENT AND TYPOLOGY OF TRACTOR USERS IN BENIN REPUBLIC

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ABSTRACT

Agricultural mechanization level and tractor users groups vary from one country to another. This study aims to assess the status of the use of pre-harvest equipment and tractor users in Benin Republic. A total of 203 respondents were surveyed over the country using a questionaire. The sample size was determined using the normal approximation of binominal distribution sampling method. The data were subjected to a Hierarchical Classification on Main Components carried out through a Factorial Analysis of Mixed Data followed by an Ascending Hierarchical Classification. Fourteen (14) brands of tractors were identified with powers ranged from 30 to 120 horsepowers. The brand Mahindra (42.36 %) was most represented. Tillage equipment (Disc plough (100 %), Disc harrow (6.90 %)) were most used than other (Seeder (1.48 %), Harvester (0.49 %)). Four groups of tractor users were identified. Group 1 (64.52%) of tractor users, consisted mainly of independent contractors with no secondary activity, agronomists, or tractor drivers and to a lesser extent independent contractors farming more than 90 ha/year. Group 2 (15.05 %) of users was made up of independent entrepreneurs who were farmers, fishermen, traders or part-time trainers and sowed less than 90 ha per year. The third group represented 15.59 % and was composed of entrepreneurs who were members of the cooperative. Group G4 (4.84 %) consisted of entrepreneurs who were members of a government agency. The results show the presence of most conventional tillage equipement and call for innovation of new equipment for sustainable agriculture. The variability of groups of machinery users could help decision makers to take action and support each group according to their need.
Key words: Agricultural equipment, farmer, hierarchical clustering, tractor, mechanization.

APERÇU DE L'UTILISATION DES ÉQUIPEMENTS DE PRÉ-RÉCOLTE ET TYPOLOGIE DES UTILISATEURS DE TRACTEURS EN RÉPUBLIQUE DU BÉNIN

RÉSUMÉ

Le niveau de mécanisation agricole et les groupes d'utilisateurs de tracteurs varient d'un pays à l'autre. Cette étude vise à évaluer l'état de l'utilisation des équipements de pré-récolte et des tracteurs en République du Bénin. Au total, 203 personnes ont été interrogées dans tout le pays à l'aide d'un questionnaire. La taille de l'échantillon a été déterminée en utilisant la méthode d'échantillonnage aléatoire par approximation binomiale. Les données ont été soumises à une classification hiérarchique en composantes principales, réalisée à travers une analyse factorielle des données mixtes, suivie d'une classification hiérarchique ascendante. Quatorze (14) marques de tracteurs ont été identifiées avec des puissances allant de 30 à 120 chevaux. La marque Mahindra (42,36 %) était la plus représentée. Les équipements de travail du sol (charrue à disques (100 %), pulvériseur à disques (6,90 %)) étaient plus utilisés que les autres (semoir (1,48 %), moisssonneuse (0,49 %)). Quatre groupes d'utilisateurs de tracteurs ont été identifiés. Le groupe 1 (64,52 %) des utilisateurs de tracteurs, était principalement composé d'entrepreneurs indépendants sans activité secondaire, d'agronomes ou de conducteurs de tracteurs et, dans une moindre mesure, d'entrepreneurs indépendants, exploitant plus de 90 ha/an. Le groupe 2 (15,05 %) des utilisateurs était composé d'entrepreneurs indépendants qui étaient des agriculteurs, des pêcheurs, des commerçants ou des formateurs à temps partiel, et qui emblavaient moins

de 90 ha/an. Le troisième groupe représentait 15,59 % et était composé d'entrepreneurs qui étaient membres de cooperatives agricoles. Le groupe G4 (4,84 %) était composé d'entrepreneurs membres d'une agence gouvernementale. Les résultats montrent la présence de plus d'équipements de travail conventionnel du sol et appellent à l'innovation de nouveaux équipements pour une agriculture durable. La variabilité des groupes d'utilisateurs de matériels agricoles pourrait aider les décideurs à prendre des actions spécifiques et aider chaque groupe en fonction de ses besoins.
Mots-clés: Équipement agricole, agriculteur, classification hiérarchique, tracteur, mécanisation.

INTRODUCTION

The need to feed and adequately nourish an additional two billion people by the end of the subsequent four decades, combined with increasing incomes in the developing world and the growing need for energy, are likely to lead to an increased demand for agricultural products at an unprecedented rate (Mrema *et al.,* 2014). Despite the importance of agricultural sector in Sub-Saharan Africa, most agricultural work and especially manual ploughing takes up 65 percent of the total, with 25 percent ploughed with draught animals and only 10 percent with tractors. To improve that, the number of tractors in these parts of Africa seems to have increased relatively slowly in recent years (FAO, 2006). For several decades, the results of family farming mechanization programs in Sub-Saharan Africa have been mitigated. Possibly, these hand-powered tools were the earliest forms of mechanisation and have continue to exist to date (Blench, 2006).

In Benin Republic, agriculture employs 70 % of the active population and 47 % of the country's employment. But the majority of agricultural operations are done manually. To improve the low productivity of agricultural work, extend the cultivation areas and improve productivity (Beauval and Boquien, 2009), the application of the agricultural modernization plan foresees changes in the cropping system in Benin (MAEP, 2017). However, the current process of agricultural motorization is slowed down by low investment, a lack of qualified personnel, a lack of suitable equipment and spare parts and the import of equipment of highly variable quality (Balse *et al.,* 2015).These challenges have a negative impact on the speed of agricultural activities, limit the extension of areas and the positive effects of agricultural mechanization. It is shown that the higher productivity and greater output are the two major contributions in farm mechanization. Tractors are an integral part of mechanization and have a crucial role to play to enhance agricultural productivity (Mandal and Maity, 2013). For instance, in other countries, land development, tillage and seedbed preparation which earlier used the power of animal driven plough and blade harrow now utilize the power of tractor through tractor driven implements (Singh *et al.,* 2015). Sustainable Agricultural Mechanization Strategy is a planning strategy that contributes to the goal of sustainability across the agri-food value chain, while meeting food self-sufficiency, generating economic development and inclusive growth as well as social benefit (Mrema *et al.*, 2014).

Due to poor management, inadequate equipment and lack of adequate specialists, the expansion in the number of tractors has not been successful. More than 40 percent of tractors currently in use in the fields are more than

15 years old, since tractor imports have not followed suit in some African' countries (FAO, 2006). Thus, a rigorous study must be carried out to support the specific situation in each of the regions of African continent. However, there has been no specific research done in Benin on whether the state of agricultural mechanization. That is why the present study investigated the current statuts of pre-harvest agricultural machinery use and user groups' characteristics in Benin Republic.

MATERIALS AND METHODS

Study area

The area of study is Benin Republic, country of West Africa (Figure 1). The mean annual rainfall distribution of this country is ranged from 900 mm to 1300 mm with an annual temperature of 26 - 28°C. The area situation promotes the growth of maize, cassava, cotton, palm tree, groundnut, beans…

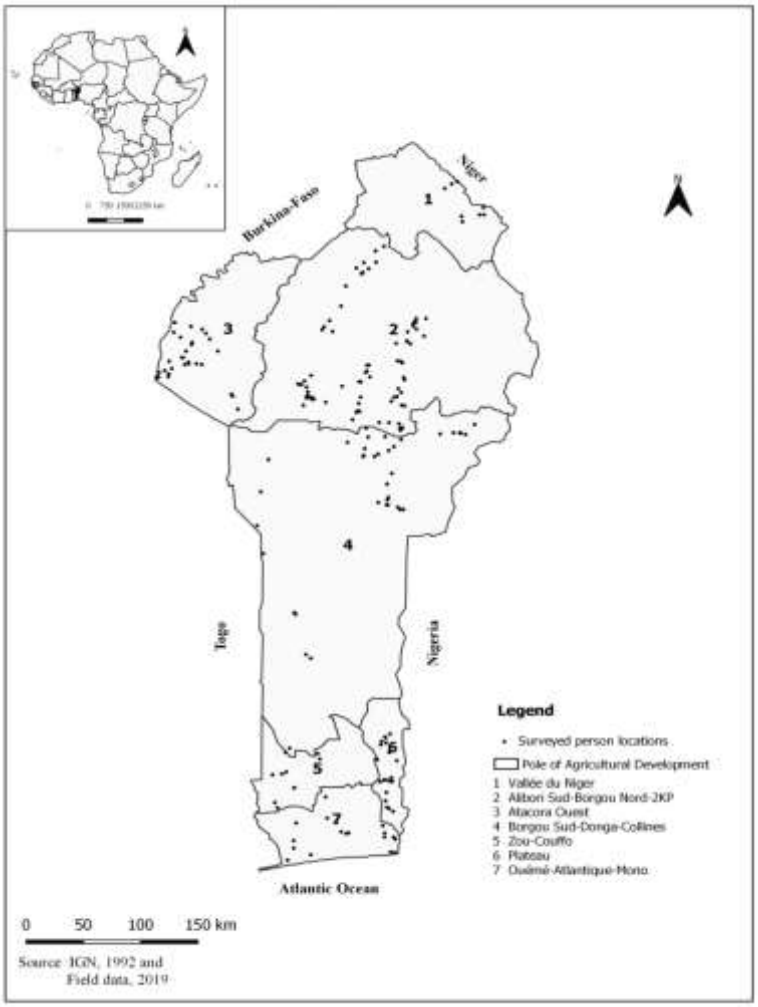

Figure 1. Study area showing the location of tractors and equipment users surveyed

Sampling

The number of persons surveyed is based on data from the latest Benin General Population and Housing Census (RGPH4) of the National Institute of Applied Statistics and Economy (INSAE, 2016) and data from the report of the Programme of Agricultural Mechanization Development of the Ministry of Agriculture, Livestock and Fishery of Benin (MAEP, 2016). These data provided information on the proportion of households using mechanical equipment in agriculture by department and municipality, and the approximate number of tractors available in Benin. A survey was then carried out in all the country's departments, selected municipalities and pole of agricultural development. The sampling method consisted to determine the sample size in the country using the normal approximation of binominal distribution of Dagnélie (1998):

$$n = U_{1-\alpha/2}^{2} \frac{p(1-p)}{d^{2}}$$

With U the normal distribution value $U_{1-\alpha/2}$=1.96 (≈ 2) for a confidence level α = 5 %, n = the minimum number of persons investigated, P = percentage of households using tractors p ≥ 1/10 and d is the maximum permissible error set at 5%, 1 % ≤ d ≤ 15 %.

The number of people surveyed per department was estimated using the relationship:

$$E_d = n \times p_d$$

With E_d the minimum number of persons surveyed per department and percentage of tractor used in each department in relation to the whole of Benin.

The number of respondents surveyed per municipality was determined by considering the percentage of tractor used in each municipality to the total proportion of the department. In addition, the representativity of the municipality within the pole of agricultural development of each zone was taken in account. Finally, a total of 203 persons were investigated.

Data collection and analysis

The researcher interviewed each respondent personally using a structured questionaires, photographic and recording device for data collection. In absence of formal tractor user identified based on existing data, the Sampling Snowball method were used. This technique is a sequential targeted sampling method that can be used in a multi-criteria decision-making process in which the researcher, after identifying the individuals introduced by an user, asks them to introduce one or more other tractor users in the municipality.

Data obtained from the study were analysed using descriptive statistics such as tables and charts. The Hierarchical Classification on Main Components (CHCP) were carried out with the FactoMineR package, consisted of a Factorial Analysis of Mixed Data (FAMD) carried out on both quantitative and qualitative variables followed by an Ascending Hierarchical

Classification (AHC) on the main components resulting from the FAMD. Chi-2 independence tests and Kruskal-Wallis tests were carried out on the qualitative and quantitative variables respectively in order to identify the characteristics of the tractors and their users and to discriminate between the different user groups. Recursive partitioning (Breiman, 1984) was carried out with the rpart package (Therneau and Atkinson, 2019) in order to describe briefly the groups of tractor users. Correspondence factor analysis was also performed with the FactoMineR package to visualize the distribution of tractor user groups by development pole. All analyses were performed using R (R Core Team, 2019) and the significance level of the statistical tests was set at 5 %.

RESULTS AND DISCUSSION

Characterisation of tractors and their use

Table 1 shows the different brands of tractors, their powers and the frequence of users in the country.

Table 1. Brands of tractor and horse powers

Tractor brands	Horse powers		Number of tractors	% of users
	Minimum	Maximum		
Mahindra	60	60	86	42.36
Massey Ferguson	30	120	42	20.69
Farmtrac	60	90	42	20.69
Sonalika	30	75	39	19.21
SF554B	30	55	7	3.45
YTO	30	30	6	2.96
John Deere	90	90	4	1.97
SWT904	45	45	2	0.99
Fiat	60	60	2	0.99
Jinma	30	30	2	0.99
OUQI	45	45	1	0.49
Landini	75	75	1	0.49
Foton	60	60	1	0.49
Ford	90	90	1	0.49

There are 14 brands of tractor identified. Several users have more than one tractor brand. There is a variation of tractor brands among users. The tractor powers were ranged from 30 horse powers (HP) to 120 HP. Side, (2013) noticed similar results by ranking the tractor in Sub-Sahara Africa from 35 HP to more than 100 HP. This variation of tractor power is may be due to the need of each farmer and the machiney price according to the power. In general, in Sub-Sahara Africa, farmers use manual force three times as much comparing to North Africa farmers, and tractor power in North America is six times higher (World Bank, 2014).

The number of tractors per brand varies from one (01) to 86. The Mahindra brand was the most used (42.36 %) followed by Massey Ferguson and Farmtrac (20.69 %). Some brands were less represented (OUQI, Landini, Foton, Ford (0.49 %)). It confirms that there is a lot of tractor brands in some countries of Africa but the users preferred some brands than other due to their availability and the subvention on the purchase price by the government, especially the Mahindra and Farmtrac brands. This subvention to facilitate the farmers' access to agricultural machinery could contribute to the increasing of agricultural production and fight against poverty. According to FAO and UNIDO, (2008) the countries that improve the investment rates per agricultural worker are those which best contribute for reducing hunger.

Table 2 shows the significance of use of main types of implements.

Table 2. Implements used by farmers

Implements	Number of users	% of users
Rotary cutter	4	1.97
Disc plough	203	100.00
Moldboard	6	2.96
Disc harrow	14	6.90
Seeder	3	1.48
Sprayer	1	0.49
Harvester	1	0.49
Trailer	52	26.62

Several users have more than one implement. Except for the trailer, the total number of the pre-harvest equipment was seven (07) throughout the country. The number of users varies based on the operations. High number of users preferred soil preparation equipment. The disc plow was used by all the surveyed persons (100 %) followed by disc harrow (6.9 %). In contrast, the sowing (1.48 %), the spraying (0.49 %) and the harvesting (0.49 %) were practically not mechanized. The same results were found by Mrema *et al.* (2018) who concluded that only the tillage is the most mechanized in some regions of Africa and developing country. The earliest developmental stage of mechanization focused on the substitution of the use of animate power with mechanical power in performing energy-intensive such as primary land tillage. For Lal, (2004) land preparation was the most energy-demanding farming operation in rainfed agriculture. According to Houmy *et al.* (2013), for example in some cases in Niger, only land preparation and transportation are carried out by tractors. But the most important implements used in mechanized farms are the disc plow, disc harrow and trailer (FAO and AUC, 2018). Thus, ploughing is most performed using a disc plows, and transport with trailers as reported by Sims and Kienzle (2006). Other operations such as seeding and harvesting are still mostly carried out manually. This is due to a lack of knowledge by farmers about suitable equipment and lack of skills in operating such equipment.It can also depend of the price of equipment, the poverty of the farmers and the fact that only the tractor with disc plow added to the trailer are sometime the most subventionned equipment sent to the farmers. The presence of obstacles (tree stumps, stones) preventing the

realization of the other operations must not be neglected. Also, for the present, the population prefers to use family labour for sowing, weeding, spraying and harvesting operations.

The characteristic of tractor use and its implication on area tilled and the cost are showed in Table 3.

Table 3. Global characteristics of tractor used

Variables	Minimum	Maximum	Mean	Standard deviation
Mechanized area (ha)	2	280	89.79	66.33
Tillage cost (US $/ha)	40	120	65.80	12.39
Harrowing cost (US $/ha)	27	70	42.43	16.47
Number of tractor per user	1	5	1.24	0.6397
Power of tractor (HP)	30	120	60.42	12.10
Year of acquisition	2006	2019	-	-
Acquisition price (US $)	4000	32000	12285.22	6566.26
Number of the year of use	1	12	4.30	2.82
Number of hour for 1ha tilled	1	5	2.48	0.91
Number of ha tilled per year	2	300	92.73	64.27
Fuel quantity per ha (l/ha)	3	20	10.71	2.95

The areas mechanized varied from two (02) to 280 ha, with the average area 89.79 ha in Benin. Sometimes the areas tilled were greater than their mechanized area showing their service delivery. This system needs to be encouraged to move forward commercial farming with medium-scale farms (10–200 ha) and should to provide mechanization services to the majority of small-scale farmers (Mrema *et al.,* 2018). The tractors were relatively new from one (01) year to 14 years of acquisition with most of purchased 6 years ago. It is an improvement comparing over the last decade, where more than 40 percent of tractors in use were more than 15 years old in some African countries (FAO, 2006). A similar result (1-14 years as tractor age) was obtained by Al-Suhaibani and Wahby, (2017) when assessing the farm tractors' breakdown classification in Saudi Arabia. However, in that country, tractor power varied from 70 to 325 HP against 30 to 120 HP in Benin Republic. A pilot study of the World Bank showed that in most African countries, tractors are predominantly small- and medium-range (30 to 70 horsepower) for more than 70 % (World Bank, 2014).

The average cost of plowing per hectare was $60.85 which is lower than a regional cost of tractor rental (pilot average $82) reported by World Bank in 2014. This disparity in cost can be attributed mainly to the quickness of tillage. In fact, the user in general till within less than 3 hours. It is good for time and fuel-saving according to some of them. However, it conducts to bad tillage operation which will impact the crop growth and final yield.

Classification of tractor users

The 30 first axes of the Factorial Analysis of Mixed Data (FAMD) retained 90.34 % of the initial information of the characteristics of the tractors and their users for the Hierarchical Classification. Four groups of tractor users

were identified (Figure 2). The qualitative variables that significantly discriminated between these four groups of tractor users (Table 4 ; $P \leq 0.05$) were mainly individual characteristics of the producer such as membership of a cooperative, access to land, type of acquisition, main and secondary activities and level of education (χ^2 >100). As for the quantitative discriminating variables, they were mainly the total area tilled per year, the mechanized area, the number of planters, the number of tractors, the number of harrowing discs, the cost of tillage and the number of harvesters ($\chi^2 > 40$).
The results of recursive partitioning indicates that Group 1 (G1) had 64.52 % of tractor users, consisting mainly of independent contractors with no secondary activity, agronomists, or tractor drivers (92.50 %); and to a lesser extent independent contractors farming 90 ha or more per year (7.50 %). The second group (G2) representing 15.05 % of tractor users was made up of independent entrepreneurs who were farmers, fishermen, traders, or part-time trainers and sowed less than 90 ha per year (7.50 %). The third group (G3) represented 15.59 % of tractor users and was made up of entrepreneurs who were members of the Cooperative of Agricultural Machinery Use (CUMA). The fourth group (G4) of tractor users (4.84%) consisted of entrepreneurs who were members of a government agency. There was a gradual decline in tractor rental services, whether public or private, which may also reflect a general decline in the profitability of agriculture (Bishop-Sambrook, 2003). However, Sims and Kienzle, (2006) reported that private tractor rental services may be viable in areas of high population density and high agricultural production, for example for tea and / or high-yielding varieties of corn. Then, the use of higher levels of mechanization combined with the use of other inputs such as improved seeds and fertilizers will lead to higher productivity and generate higher yields according to Houmy *et al.* (2013).

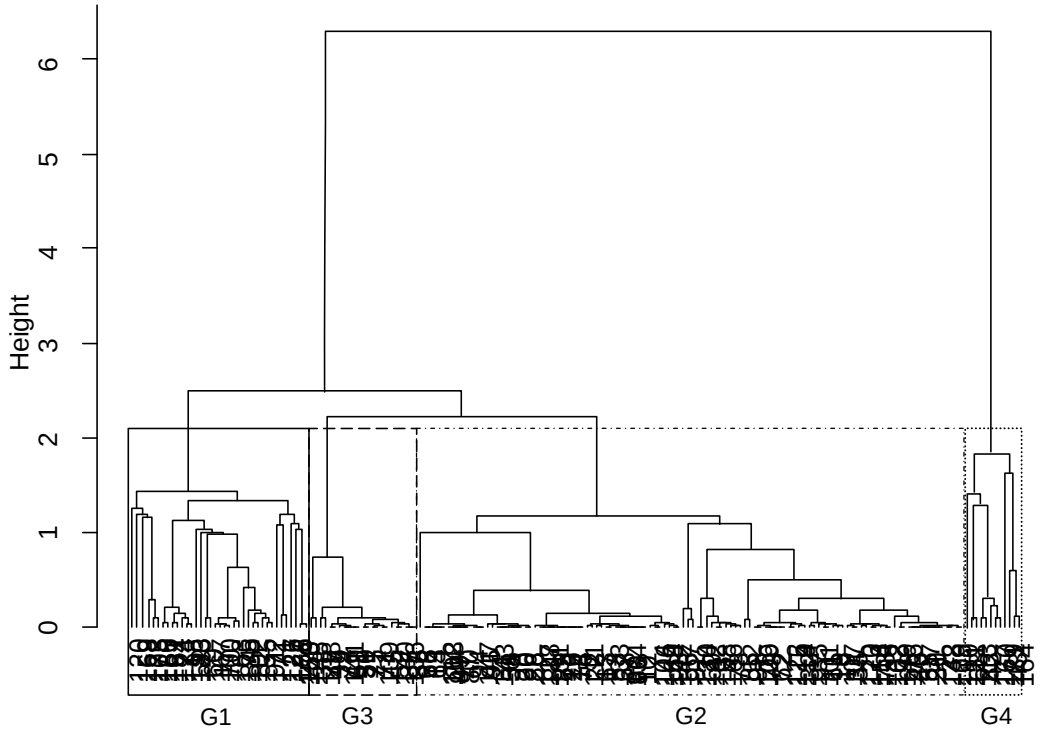

Figure 2. Dendrogram of tractor users

Table 4. Qualitatives and quantitatives variables discriminating the forth groups of tractor users identified

Qualitatives variables	df	χ^2	Prob	Quantitative variables (df=3)	χ^2	Prob
Part of a cooperative	6	315.07	<0.001	Area (ha/year)	75.50	<0.001
Land access	6	210.76	<0.001	Mechanized area	72.82	<0.001
Type of acquisition	6	204.77	<0.001	Nb. planters	61.47	<0.001
Main Activity	45	226.58	<0.001	Nb. tractors	53.16	<0.001
Secondary activity	21	163.73	<0.001	Nb. disc harrows	52.33	<0.001
School level	9	121.99	<0.001	Tillage cost	47.76	<0.001
Owner of the centre	3	59.27	<0.001	Nb. harvesters	43.98	<0.001
Repair centre	3	47.11	<0.001	Nb. rotary cutters	31.10	<0.001
Type of parking	6	49.22	<0.001	Price	30.03	<0.001
Mechanized Harrowing	3	33.99	<0.001	Nb. years of use	28.67	<0.001
SF554R	3	75.80	<0.001	Age (years)	14.03	0.003
TM Mahindra	3	32.72	<0.001			
TM YTO	3	31.96	<0.001			
TM Massey Ferguson	3	20.50	<0.001			
TM John Deree	3	13.86	0.003			

Legends : TM = Tractor Brand ; df = degree of freedom ; χ^2 = Chi-2 test; Prob = probability ; Nb. = Number of ; F-value = statistical test of Fisher (df = 3 over 187)

CONCLUSION

This study on assessment of the status of pre-harvest equipment use of tractor users in Benin Republic has identified 14 brands of tractor with power from 30 to 120 HP as in some Sub-Sahara Africa countries. The number of users varies according to tractor brands with some brands less used than other. It showed that there is a lot of tractor brand but the users preferred some brands than other due to their availability and the subvention on purchase price by the government. The number of users also varies as function of the type of equipment. High number of users prefered soil preparation equipment, especially tillage with disc plow, which is the most energy-demanding. Other operations such as seeding, spraying and harvesting are still mostly carried out manually. Sometime the areas tilled are greater than their own mechanized area but they use also the tractor for service delivery. Four groups of tractor users were identified. The current tractors used have at latest 14 years of use. It is an improvement comparing to last decade where more than 40 percent of tractors in use are more than 15 years old in some African countries. The user in general tills within less than 3 hours.This study is a contribution for understanding the current level of agricultural machinery and their users for sustainable agricultural mechanization policy decision making.

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