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Research article

Analysis of the use of tractors in different poles of agricultural development in Benin Republic

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ABSTRACT

The deep assessment of agricultural mechanization inside developing countries could help for local action-taking. This study investigates the use of tractors between the poles of agricultural development (PAD) in Benin Republic. Using a multi-stage random sampling procedure and a questionnaire, 203 tractor users were surveyed in 43 municipalities distributed across the seven PADs of the country. Kruskal-Wallis tests were carried out to compare the different poles of agricultural development based on the mechanization level and tractor performances. Student-Newman-Keuls tests were used to structure the means of these variables. The results show a significant variation ($P < 0.05$) of the mechanization level between the PADs. Apart PAD1, all the poles use greater than 60 % manual equipment. Animal-drawn is most implemented in the northern part of the country (PAD1; 2 and 3). The use of tractors is lower over the country, and the PAD2 and PAD3 are the most users. From PAD4 to PAD7, the combination of manual tillage with animal power or tractor is not well represented, indicating manual tillage-based agriculture in these poles. In general, 53.20% of the users do not have a tractor parking and the repair center is quasi-absent (97.54 %). PAD2; 4 and 3 are most disc plow users. Mechanical sowing is more observed in PAD2 and 7 and absent in PAD1; 3 and 4. Moreover, the harvester is present in PAD2; 4; 6, and 7. On average, the highest mechanized area was 134.56 ha from PAD3, whereas, the lowest, 12.00 ha was found in PAD7. PAD7 spends more on plowing (47670 FCFA) than the other poles. The mechanized plowing is most slower in PAD7 (3.53 h/ha) while much faster at the PAD2 (1.96 h/ha). These results could help decision-makers for accurate actions taking to advocate for agricultural mechanization sectors in the country based on the weakness of each pole of agricultural development.

1. Introduction

The current population growth coupled with the increase in food demand are the most challenging situations facing some developing countries. For the past decades, there has been an increase in people who are unable to meet their daily food needs, consequently, an increase in humanitarian aids to feed such people have been observed (FSIN, 2019). Besides poverty, food security is the major issue facing many developing countries, especially in sub-Sahara Africa where food production is slowed down by climate change and manual tools used. Thus, it is critical to increase agricultural production. Odey et al. (2008) demonstrated that the efficiency of food security of a nation depends notably on agricultural mechanization. Some developing countries continue to focus on the improvement of land, water, and nutrients efficiency by forgetting farm power. Nevertheless, low farm mechanization is high labor drudgery throughout the production cycle (Bymolt and Zaal, 2015).

FAO and UNIDO, (2008) affirm that the problem of low agricultural productivity in sub-Saharan Africa is attributable to low levels of mechanization. This is due to the lack of economic demand from farmers leading to the collapse of policy reforms on mechanization in some African countries (Sims and Kienzle 2016; Diao et al., 2014).

Benin Republic is a third economy where the increase in agricultural production remains low (FAO and AUC 2018). For many years in Benin, agriculture was dominated by human power (MAEP 2017). Among the

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few numbers of mechanized farms, plowing is the most common mechanized agricultural activity, and others are rare or non-existent. Yet, due to the fact that tractors are difficult and expensive to access, Benin's government has made progress in machinery use by half-funding some tractors given to farmers and cooperatives in the country. Many Cooperatives of agricultural machinery use have been created to supply individual farmers with support services and to make access to agricultural machinery easier and more affordable (Zokpodo et al., 2017). However, despite this effort and the contribution of private sectors with some own business tractor users, many constraints militate against agricultural equipment use. Added to failure and lack of spare parts, these challenges are extended to the lack of qualified personnel and repair and maintenance of equipment, poor training of users, lack of adequate availability of cash and credit when needed; and inefficient use of machinery (Nkakini and Etenero, 2019).

By using efficient machines and equipment, agricultural mechanization improves the utilization efficiency of inputs like fertilizers and agrochemicals and reduces the negative impact on the environment. Many factors such as the size of farms (Rasouli et al., 2009), labor availability, and the types of mechanized operation make the agricultural mechanization variable across the globe. As a result, the level of machinery currently used in farming is considerably different between countries and regions of the world (Rasouli et al., 2009). It is therefore important to look at the local level of agricultural mechanization variability, to carry out the main region favorable for the implementation of new machinery.

This paper analyses the variability of tractors and equipment used in different poles of agricultural development and describes the distribution of users in Benin Republic. It highlights the level of mechanization, the variations of mechanized factors, and the distribution of tractor user groups according to the poles of agricultural development in the country.

2. Material and methods

2.1. Study area

The study covers the Republic of Benin (West Africa). With a total area of 114,763 km^2, it accounts for 77 Municipalities and 7 Poles of Agricultural Development administered by Territorial Agencies of Agricultural Development (ATDA). The pole of agricultural development is the framework for the operational implementation of agricultural development policies, programmes, and projects. It represents a development territory organized on a limited number of priority sectors, driving the economic development of a group of municipalities, in a perspective of intercommunal. The mean annual rainfall distribution of Benin ranges from 900 mm to 1300 mm with an annual temperature of 26–28 °C. The main crops are maize, cassava, cotton, palm tree, groundnut, and beans (see Figure 1).

2.2. Sampling and data collection

Data from the last General Population and Housing Census conducted in Benin in 2013 were obtained from the National Institute of Applied Statistics and Economy (INSAE 2016), added to data from the Ministry of Agriculture, Livestock, and Fishery of Benin (MAEP 2016, 2017). These data provided information on the total number of agricultural workers, the level of mechanization, the proportion of households using mechanical equipment in agriculture by department and municipality, and the number of tractors and equipment distributed in Benin (1040 as total estimated) by the Promotion of Agricultural Mechanization Program (PPMA). Based on these data, the sampling focused on a comparative study between the poles of agricultural development. The survey was carried out in all the departments, selected municipalities, and pole of agricultural development across the country. A multi-stage random sampling procedure was used. It consisted of determining the sample size in the country using the normal approximation of binomial distribution by the relationship (1) of Dagnélie (1998):

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

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

The number of people surveyed per department was estimated using the relationship (2):

$$E_d = n \times p_d \quad (2)$$

With E_d the number of employees by department and percentage of tractor use in each department in relation to the whole of Benin.

The number of people surveyed per municipality was determined by considering the percentage of the use of tractors in each municipality in the total proportion of the department. Moreover, the representativeness of the municipality within the pole of agricultural development of each zone was taken into account. Finally, a total of 203 tractor users were surveyed in 43 municipalities out of 77 municipalities of the country.

2.3. Data analysis

Kruskal-Wallis tests were carried out to compare the different poles of agricultural development based on the average area tilled and the average performance of the tractors (number of hours required to plow one hectare, the amount of fuel necessary for plowing one hectare, year of acquisition of tractors). Student-Newman-Keuls tests were performed with the agricolae package (Felipe de Mendiburu 2019) for structuring the means of these variables from the poles. Fisher's exact tests were used to assess the link between the poles of agricultural development on the one hand, and the mode of land access and the type of organic fertilizer used on the other. Correspondence factor analysis was done with the FactoMineR package to visualize the distribution of tractor user groups per pole of agricultural development. All analyzes were performed in the R programming language (R Core Team 2019) and the level of significance of the statistical tests was set at 5%.

3. Results and discussion

3.1. Level of mechanization and the frequency of agricultural machinery use frequency

Table 1 shows the level of mechanization in Benin.

The results in Table 1 show a significant variation ($P < 0.05$) of mechanization level between the different poles of agricultural development. Considering the manual tool used in agriculture, aside from PAD1, all the poles used more than 60 % manual equipment, particularly in PAD4; 5; 6, and 7, which perform more than 95% manual tillage-based agriculture. Oxen and horse are most used for animal traction in the northern PADs of the country (PAD1; 2 and 3) where the animal power used in agriculture is most implemented. Although they are less used, only oxen are involved in the Central and southern PADs. In northern PADs, the association of manual tools with animal-drawn is the highest as well as the mixed-use of manual and tractor. The finding is in line with the study of Takeshima and Lawal (2018) who reported that in Northern Nigeria, 50% of farm households used animal tractions but few use animal traction in the Southern part because of heavy soils, tsetse flies and root/tree crops. Tractors are less used to perform mechanical tillage across the country. PAD2 and PAD3 were found to be the most tractor users, whereas no difference was observed among the other five poles. From PAD 4 to PAD 7, the combination of manual tillage with animal power or tractor is not well represented, confirming their agriculture most based on manual tillage only. The variability between the PADS could be due to the pattern of farmers' agricultural mechanization experience. In fact, the first tractors, especially in Cooperatives of

Agricultural Machinery Use, were introduced in the northern PADs of the country. In addition to the animal-drawn used experience in the past, it could motivate the ambition of each PAD based on their knowledge of the importance of agricultural mechanization and their financial capacity. In general, in Sub-Saharan, farmers use manual force as much as three times compared to North Africa farmers, and tractor power in North America is six times higher (World Bank 2014). The same trend was observed in Nigeria where 90% of agricultural work is done with hand tools, 7% with animal-drawn tools and only 3% with engine powered technology, compromising the self-sufficiency in food (Asoegwu and Asoegwu 2007; Onwualu and Pawa 2004). It is necessary to improve the level of mechanization according to the need of each pole. That could improve the living standards of several farmers because farmers who use mechanization services had a notably higher total farm income (Adu--Baffour et al., 2019).

Table 2 shows the tractors' state and the significance of the use of main equipment in the seven Poles of Agricultural Development.

The results from Table 2 show that more farmers have their tractors operational and currently in use in PAD2; 4 and 3 respectively unlike a few farmers in PAD1 and 5. It was noted that all operational tractors are not in use because of the lack of tractor drivers, the stumps and stones in the fields which can easily damage tractors (Diao et al., 2018). Generally, 53.20 % of users do not have tractor parking, it is only in some areas of PAD2 had a small percentage, about 18.23 % of peoples have tractor parking. Additionally, repair centers are almost absent in all of the poles of agricultural development (97.54 %). The highest frequency of repair

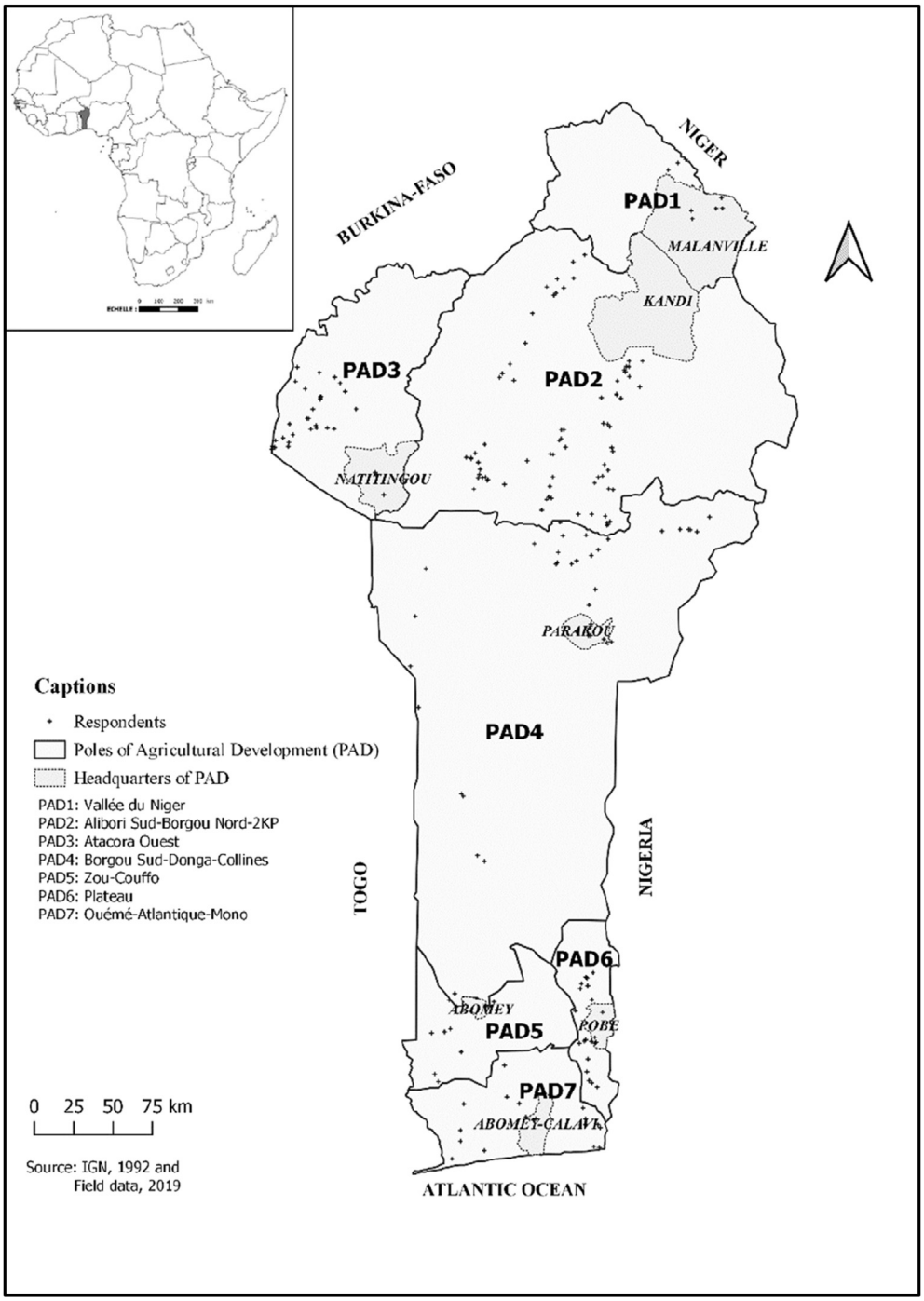

Figure 1. Location of the study area.

Table 1. Level of mechanization per Pole of Agricultural Development.

PAD*	% of equipment used for tillage				
	Manual	Animal-drawn	Tractor	Manual and animal-drawn	Manual and tractor
PAD1	31.35 (12.80)^{d}	7.45 (3.52)^{b}	0.25 (0.06)^{b}	55.90 (18.01)^{a}	5.10 (4.81)^{a}
PAD2	60.29 (19.77)^{c}	13.10 (7.19)^{a}	1.77 (1.53)^{a}	18.10 (15.65)^{b}	4.40 (3.32)^{ab}
PAD3	72.88 (26.57)^{b}	6.42 (6.79)^{b}	1.30 (1.43)^{ab}	17.03 (19.41)^{b}	2.40 (1.67)^{abc}
PAD4	95.89 (6.18)^{a}	0.84 (1.51)^{c}	0.42 (0.69)^{b}	1.61 (2.61)^{c}	1.23 (2.25)^{bc}
PAD5	98.83 (1.19)^{a}	0.11 (0.12)^{c}	0.16 (0.20)^{b}	0.18 (0.16)^{c}	0.72 (0.99)^{c}
PAD6	97.36 (2.61)^{a}	0.16 (0.11)^{c}	0.46 (0.44)^{b}	0.30 (0.32)^{c}	1.68 (1.92)^{bc}
PAD7	98.36 (2.17)^{a}	0.36 (0.78)^{c}	0.32 (0.51)^{b}	0.52 (0.99)^{c}	1.13 (1.62)^{bc}

Each value is an average (standard deviation). Numbers with different letters in the same column are significantly different at 5% threshold according to the Student Newman-Keuls test.

* PAD = Pole of Agricultural Development.

Source: Adapted from INSAE 2016.

centers in PAD7 despite its lower frequency of tractors is explained by the presence of Secondary Agricultural School repair centers and private mechanical experts of Diesel machines who served or helped in the past in some governmental mechanization agencies majority implemented in this pole. Since 2006, there is a trend of tractor use increasing in Benin. Given the lack of spare parts and repair centers which can notably reduce the life of a tractor (Diao et al., 2018), some tractors are now parked and farmers go back for power tiller and animal traction uses, as it was observed in all municipalities of PAD 1 and some municipalities of PAD 2. In regards to the equipment used, PAD6 and 7 use more rotary cutter, while Poles 2; 4, and 3 are more disc plow users. The moldboard and the harrow are less used across the country, but most used in PAD2 (1.48 %); and PAD6 (5.42 %). Mechanical sowing was more observed in Poles 2 and 7 than in poles 5 and 6; while absent in PAD1; 3 and 4. Moreover, only 0.49 % of respondents use sprayers and whose users are found in PAD2. Despite the low use of harvesters, it was however present in PAD2; 4; 6, and 7 (0.49 %). Despite the low use, trailers were found in some poles with the highest in PAD2 (10.84%). In general, some agricultural mechanization implements were almost absent. It was observed that the disc plow was more used than other implements, showing that tillage was the most mechanized operation in each PAD. This finding is in line with the results from Adu-Baffour et al. (2019) who suggested that the main income effect from accessing tractor services may be due to the increase in cultivated land area, which is made possible by mechanizing soil preparation. There is also an imbalance between the number of tractors available and the number of agricultural mechanization implements within a PAD and between PADs. It could be due to the determination of farmers of some PADs wishing to maintain their high production based on their experience in agricultural mechanization on one hand, and the wake up of the remaining PADs in this sector on the other hand. This imbalance, particularly between regions, has already been observed in Tanzania where six regions alone own nearly 70% of the tractor fleet out of 21 regions, with a ratio of one (01) plow for 1.5 tractors, the number of harrows lower, as well as trailers (Mrema 2016).

3.2. Variations of mechanized parameters between the poles of agricultural development

Table 3 shows the comparison of different parameters between different poles of agricultural development (PAD).

The results of the Kruskal Wallis tests (Table 3) show that the power of the tractor, 60.51 ± 0.51 horsepower, does not vary significantly ($P > 0.05$) between development poles. In contrast, the mechanized areas, the plowing costs, the purchase price of the tractors, the number of years of use of the tractors, the number of hours of plowing per ha, the number of hectares plowed per year, and the amount of fuel consumed per ha vary significantly from one development pole to another (Table 3; $P \leq 0.05$). Thus, the PAD3 and PAD2 poles have mechanized average areas (134.56 ± 10.04 ha and 114.45 ± 5.63 ha respectively) higher than the other poles; while the PAD7 has the lowest average mechanized area (12.00 ± 2.90 ha) but spend more money on plowing (47.67 ± 1.68 thousand FCFA) than the other poles. The variability between the PADS could be due to the usual farm size, the availability of cultivation areas, and the contribution of each PAD in national production. These mechanized areas per farmer are higher compared to the general average in other systems in sub-Saharan Africa where arable land is less than 0.3ha per

Table 2. Frequency of tractors and equipment users per Pole of Agricultural Development (%).

Equipment	No/Absent	PAD1	PAD2	PAD3	PAD4	PAD5	PAD6	PAD7
Tractors' state								
Still operational	23.65	2.96	30.54	12.32	13.30	2.96	7.88	6.40
Currently used	27.09	2.46	30.05	11.82	12.81	2.96	6.90	5.91
Presence of parking	53.20	1.48	18.23	6.90	7.88	2.96	4.93	4.43
Repair center	97.54	0.00	0.49	0.00	0.00	0.00	0.49	1.48
Equipment								
Rotary cutter	95.07	0.00	0.49	0.00	0.00	0.99	1.97	1.48
Disc plow	0.00	3.94	36.45	15.76	18.72	5.42	10.84	8.87
Moldboard	97.04	0.00	1.48	0.49	0.00	0.49	0.49	0.00
Harrow	87.19	0.49	1.97	0.99	0.49	1.48	5.42	1.97
Seeder	96.06	0.00	1.48	0.00	0.00	0.49	0.49	1.48
Sprayer	99.51	0.00	0.49	0.00	0.00	0.00	0.00	0.00
Harvester	98.03	0.00	0.49	0.00	0.49	0.00	0.49	0.49
Trailer	74.88	1.97	10.84	6.40	3.94	0.49	0.00	1.48

Table 3. Variation of mechanized parameters and tractor performances: results from Kruskal Wallis test.

PAD	Variables	Mean (SD)	χ^2 (df = 6)	P	Variables	Mean (SD)	χ^2 (df = 6)	P
PAD1	Mechanized area (ha)	79.75 (12.15)^{b}	89.91	<0.001	Years of use	3.25 (0.65)^{ab}	20.50	0.002
PAD2		114.45 (5.63)^{a}				4.62 (0.36)^{a}		
PAD3		134.56 (10.04)^{a}				2.75 (0.45)^{b}		
PAD4		98.97 (11.96)^{b}				5.05 (0.41)^{a}		
PAD5		26.38 (11.92)^{c}				5.00 (0.91)^{a}		
PAD6		26.38 (9.24)^{c}				4.14 (0.50)^{a}		
PAD7		12.00 (2.90)^{c}				4.39 (0.57)^{a}		
PAD1	Tillage cost (thousands of FCFA)	25.00 (0.89)^{e}	118.34	<0.001	Number of hours for 1ha tilled	2.88 (0.36)^{ab}	75.77	<0.001
PAD2		30.27 (0.14)^{d}				1.96 (0.07)^{c}		
PAD3		31.08 (0.46)^{d}				2.19 (0.13)^{c}		
PAD4		32.04 (0.52)^{c}				2.46 (0.10)^{b}		
PAD5		36.67 (1.82)^{b}				3.09 (0.19)^{a}		
PAD6		37.36 (1.53)^{b}				3.39 (0.20)^{a}		
PAD7		47.67 (1.68)^{a}				3.53 (0.23)^{a}		
PAD1	Power of tractor (HP)	57.5 (1.89)^{a}	1.94	0. 924	Hectares tilled per year	80.00 (11.69)^{c}	105.27	<0.001
PAD2		60.74 (0.79)^{a}				114.66 (4.89)^{b}		
PAD3		58.12 (1.91)^{a}				141.56 (9.04)^{a}		
PAD4		63.42 (3.10)^{a}				105.13 (11.58)^{c}		
PAD5		56.81 (3.89)^{a}				30.18 (12.20)^{d}		
PAD6		61.14 (1.98)^{a}				29.34 (9.25)^{d}		
PAD7		59.44 (4.94)^{a}				10.89 (2.00)^{d}		
PAD1	Tractor price (millions of FCFA)	4.65 (1.42)^{bcd}	48.77	<0.001	Fuel used per ha (L)	10.31 (1.47)^{abc}	15.91	0.014
PAD2		7.57 (0.25)^{a}				10.20 (0.29)^{bc}		
PAD3		6.91 (0.47)^{ab}				10.14 (0.49)^{bc}		
PAD4		6.09 (0.51)^{bc}				10.43 (0.36)^{bc}		
PAD5		4.59 (1.21)^{cd}				11.64 (0.69)^{ab}		
PAD6		3.00 (0.71)^{d}				10.33 (0.90)^{c}		
PAD7		4.50 (1.18)^{d}				12.86 (0.98)^{a}		

SD = standard deviation; χ^2 = Statistic of Chi-2; df = degree of freedom; P = probability; the means followed by the same letters are not significantly different at 5%.

person (Olasehinde-Williams et al., 2020). That illustrates the contribution of mechanization in cultivated land extension and confirms the studies of Diao et al. (2016) and Block (2010) which related the positive impact of agricultural mechanization on total factor productivity, and by extension, economic growth. The expansion of the land size that farm households cultivate was also revealed as a major positive effect of the use of tractors by Daum et al. (2020) because using tractors, more land can be cultivated, which together with the increase in yields, helps farmers to increase agricultural production. However, these acceptable areas in some PADs are sometimes too small in other PADs since even up to 60 ha per year, they will always be less than the area needed to reach the break-even point for the investment in tractors, even with the subsidized price (Houssou et al., 2013). PAD1 is the pole that spends the least on plowing (25.00 ± 0.89 thousand FCFA). Olaoye and Rotimi (2010) reported in southwest Nigeria, an average plowing labor of 10, 000 Naira/ha (around 18,000 FCFA/ha) which is lower than of Benin republic. The tillage cost becomes higher when there is more than one passage by the tractor. But in Benin, some farmers prefer tillage with one passage as soil preparation based on the cultivated crops, as reported by Kansanga et al. (2018), farmers focus more on crops that are easy to mechanize. Tractors purchased in PAD2 pole are the most expensive (7.5 ± 0.25 million FCFA) while those purchased in PAD6 (3.00 ± 0.71 million FCFA) and PAD7 (4.50 ± 1.18 million FCFA) are the least expensive. The tractors in PAD4 (5.05 ± 0.41 years) to PAD7 (4.39 ± 0.57 years) have the longest service lives while those used in PAD3 (2.75 ± 0, 45 years) have a shorter duration of use. Mechanized plowing time is relatively slower in the PAD5 (3.09 ± 0.19 h/ha), PAD6 (3.39 ± 0.20 h/ha) and PAD7 (3.53 ± 0.23 h/ha) while it is much faster in PAD2 (1.96 ± 0.07 h/ha) and PAD3 (2.19 ± 0.13 h/ha) poles. The amount of fuel required for plowing varies from 10.14 ± 0.49 l/ha in PAD3 to (12.86 ± 0.98 l/ha) in PAD7.

3.3. Tractor user groups and distribution according to the poles of agricultural development

Table 4 summarizes some socio-demographic characteristics of tractor users per pole of agricultural development.

It was found that tractor user ages vary between PADs and range from an average of 47.5–49.4 years old, and in some cases like in PAD5, the age goes up to 57.3 years (Table 4). The respondents are mostly males (83.3–100%) showing the gender imbalance among tractor users. Education level varies between PADs but most respondents attended at least primary school classes. More than 75% of tractors were half-funded or donated to users and cooperatives, except for some personal purchases. This important role of the government in tractor purchase for farmers was recognized by Daum and Birner (2020) especially for the smallholder farmers because they are a key in agricultural development.

The results of the correspondence analysis show that 99.62% of the information in the contingency table between the groups of tractor users and the development poles is summarized on the first two factorial axes. Group 1 (G1), which comprises 64.52% (120/186) of tractor users, consists mainly of independent contractors with no secondary activity, agronomists, or tractor drivers (92.50%; 111/120); and to a lesser extent independent contractors sowing 90 ha or more per year (7.50%; 9/120). The second group (G2) representing 15.05% (28/186) of tractor users is made up of independent entrepreneurs who are farmers, fishermen, traders, or part-time trainers and sowed less than 90 ha per year (7.50%; 9/120). The third group (G3) represents 15.59% (29/186) of tractor

Table 4. Socio-demographic characteristics of tractor users per pole of agricultural development.

		PAD1	PAD2	PAD3	PAD4	PAD5	PAD6	PAD7
Age (years)	Mean	48.1	49.1	48.4	49.2	57.3	47.5	49.4
	SD	4.7	5.3	7.4	6.7	9.3	6.5	11.1
Sex (%)	Female	12.5	1.4	3.1	0.0	0.0	9.1	16.7
	Male	87.5	98.6	96.9	100	100	90.9	83.3
Education (%)	No formal	25.0	44.6	25.0	28.9	27.3	13.6	5.5
	Primary	62.5	31.1	46.9	21.1	0.0	13.6	16.7
	Secondary	12.5	18.9	18.7	39.5	18.2	41.0	38.9
	Tertiary	0.0	5.4	9.4	10.5	54.5	31.8	38.9
Tractor's acquisition (%)	Personal	25.0	9.5	18.75	18.4	9.1	18.2	22.2
	Funded*	75.0	90.5	81.25	81.6	90.9	81.8	77.8

SD = standard deviation; * = donated or half-funded by the Government.

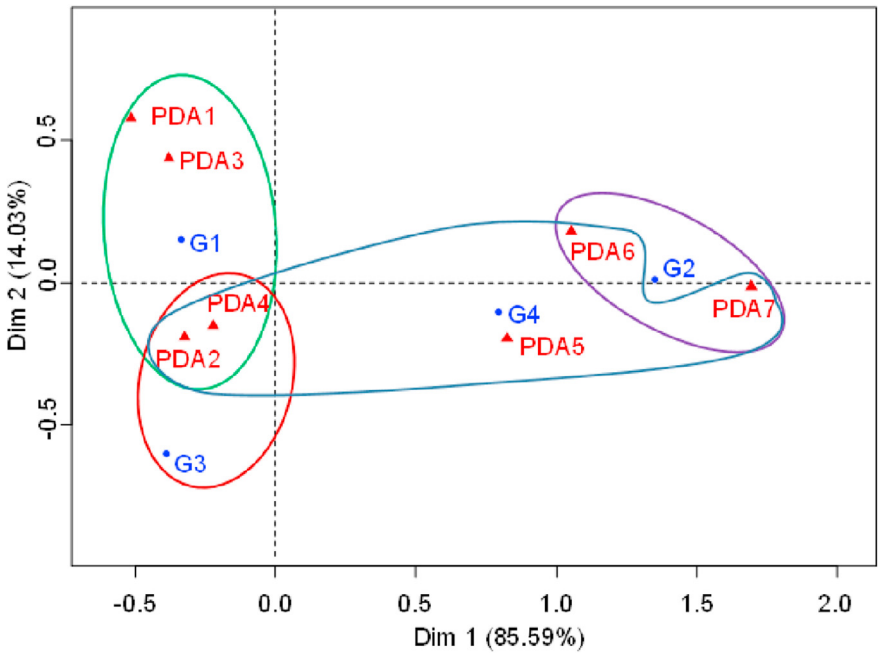

Figure 2. Factor analysis results of correspondences: joint projection of tractor user groups and development Poles (PAD) in the main plane.

users and is made up of entrepreneurs who are members of the cooperative. The fourth group (G4) of tractor users (4.84%; 9/186) consists of entrepreneurs who are members of a government agency. This classification is important for action-taking based on the characteristics of each group of tractor users. Cousins (2010) advised against treating smallholder farmers as one homogeneous group, as they may have differences in ownership of agricultural assets and are subject to different constraints. Based on the difference between tractor user groups, appropriate mechanization must be implemented for improved efforts in rural farm mechanization (López Gómez and Van Loon, 2018).

Fisher's exact test results show that the mode of access to the land and the type of organic fertilizer are not independent of the development pole ($P < 0.001$). Thus, no user of PAD1 and PAD2 tractors acquire the land by purchase, while 41.18% of PAD7 users buy land. Besides, the proportion of tractor users who use organic matter reached 44.44% (8/18) in the PAD7 pole while it is zero in the PAD1. The results of the Kruskal-Wallis test indicate that the tractor acquisition period varies significantly between poles ($p^2 = 18.94$; $df = 6$; $P = 0.004$). The acquisition of tractors is indeed more recent at the PAD1-3 (2015–2016) poles than at the PAD5 (2012), PAD4 and PAD7 (2013), and PAD6 (2014) poles.

Figure 2 shows the results from the factor analysis of correspondences of tractor user groups and development centers.

The joint projection of tractor user groups and development poles in the main plane (Figure 2) indicates that tractor users of group G1 were mainly distributed between the PAD 2 development poles (41.38%), PAD 3 (24.14%), and PAD 4 (19.83%), whereas the tractor users in group G2 were mainly in the PAD 7 (33.33%) and PAD 6 (30.00%) poles. Group G3 consisted mainly of tractor users in PAD 2 (64.29%) and PAD 4 (28.57%). Group G4 was made up of tractor users mainly in the poles PAD 2 (25.00%), PAD 7 (25.00%), PAD 4 (16.67%), and PAD 6 (16.67%). The Government should continue to follow up on each of the groups for improvement of the mechanization services for more agricultural production because many farmers cannot alone purchase equipment and financial support through funding programs is limited (Van Loon et al., 2020). According to Agboola and Balcilar (2012), agricultural mechanization plays a key role in the actualization of sustainable economic development, especially in sub-Saharan Africa which is plagued by food insecurity. The findings of Olasehinde-Williams et al. (2020) indicated that a one-percent increase in mechanization can increase productivity by 0.004%.

4. Conclusion and recommendations

This study highlights the use of tractors between the poles of agricultural development (PAD) in Benin Republic. It revealed a variation of

tractor use parameters across the country. Despite the introduction of tractors, hand tools are most frequently used, followed by animal-drawn. Agricultural machinery use is most developed in the northern PADs of the country where the cultivable lands are most available, while manual tillage is well represented in the southern PADs. Soil preparation activities (plowing and harrowing) are the common mechanized operations by farmers in all the PADs. The mechanized areas per PAD vary from 12.00 ha to 134.56 ha. Tillage cost is higher in some agricultural poles than other poles. The tillage takes two to 4 h depending on the ability of the tractor driver, and influence the fuel consumption and other inputs in the machines used. Apart the lack of spare parts, several tractor users do not have tractor parking and repair centers. There is a need to improve the agricultural mechanization policy. This policy must take into account the different performances of each pole of agricultural development. For the complete mechanization of agriculture, besides the plow, the use of other equipment must be dynamized and encouraged. There is then the need to train support staff for producers. Some repair centers and spare parts stores must be implemented in each pole. Given the expensiveness of the machinery, the existing Cooperatives of Agricultural Machinery Use must be supported and the creation of new agricultural cooperatives encouraged. The award for the best-mechanized farm can be initiated. The local equipment fabrication must be re-engineered to supply the lack of adequate and adapted equipment for the success of the agricultural mechanization in Benin Republic.

Declarations

Author contribution statement

Dayou E. D.; Zokpodo K. L. B.: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Atidegla C. S.; Dahou M. N.: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Ajav E. A.; Bamgboye A. I.: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Glèlè Kakaï L. R.: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

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Data included in article/supplementary material/referenced in article.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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