__Original Research Article__

TRAJECTORIES FOR SUSTAINABLE MOTORIZEDPILLING IN SUB-SAHARAN AFRICA : ADVANTAGES ANDDISADVANTAGES

ABSTRACT

Four trajectories for motorizedplowingwerecompared on sandyloamysoil in the Benin plateau in order to identify the most effective. We have: Flat plowing (LP), Backing boardplowing (LPA), Splittingboardplowing (LPR) and Alternatingsuperimposedplowing (LAS). A randomizedcomplete block design withthreerepetitionswasexperimentedwith a 60 HP tractorcoupled to a 1 m three-shareplow at a speed of 6 km/h. Fifteenplots of 300 m² eachdividedinto 3 blocks of 5 named plots (S0: control, S1 : LP, S2 : LPA, S3 : LPR and S4 : LAS) wereused to execute the trajectories. Theagroeconomicparametersconsideredare :soil texture, wheel slip, fuel consumption, effective-lost-total plowing time, time efficiency and fieldcapacity. The resultsindicatethat the LAS trajectoryisadvantageous in the case whereplowingiscarried out with a reversibleplow or with a hillerbecauseit has an averageconsumption of 5845.17 g/ha, an averageplowing time of 284 s with an efficiencyaverage of 58.34%. With the simple plow, simultaneously the LPA trajectory (6246.04 g/ha, 270 s and 56.3%) is more economicalthan the LPR trajectory (6593.81 g/ha, 306 s and 54.17%). This workwill help tractoroperators and producersperformeconomicalmotorizedplowing.

Keywords: Soilwork, route, economy, decision, yield.

1. INTRODUCTION

Lplowingis a soilworkingoperationcarried out with a plow; itconsists of opening the earth to a certain depth, turningit over, beforesowing or plantingit(Wikipedia, 2023). It is made mechanizedthanks to the advent of new technologies.

Some of the most important objectives of tillage models are to minimize the number of revolutions and deadspaces but also to maximize the length of tillage cycles. Optimal motorizedplowing not onlyreduces the time spent on non-productive work but also the fuel consumption of the power unit.This optimizationalsodepends on the choice of the plowingtrajectory, thatis to saychoosing an appropriatetrajectorythat can makeit possible to reduce as much as possible the time lostduringplowing, fuel consumption but also to increaseefficiency and the fieldcapacity of the tractor. Lack of understanding of the advantages and disadvantages of trajectories for motorizedplowing by tractor drivers results in difficulties in carrying out economical tillage operations.It iswiththis in mind to increase the efficiency and fieldcapacity of the tractorthat (Zenebe&Chernet, 2016) comparativelyevaluated five designs of alternative plowingmodels in a sugarestate in Metahara in Ethiopia. The resultsindicatedthatThe model for plowingheadlandsfromridgesoffersbetter time efficiency and good effective capacitythan the othermodelsevaluated.Thus the selection of an economicaltrajectory for motorizedplowingmaybenecessary not only to increaseproductivity but also to minimize the cost of production. Fuel consumption and tillage time can beminimized by applying an appropriate tillage pattern during the tillage operation (Sarkar et al., 2016). Also, non-productive passes in the field not only cause excessive soil compaction due to repeatedturningmaneuvers (Ansorge& Godwin, 2007), but alsoincrease fuel consumption, labordemands and the workload of operators (Zhou et al., 2015). In order to enable tractoroperators to carry out economicalmotorizedplowing, we have chosen to carry out the studywhosethemeis “Trajectories for motorizedplowing: advantages and disadvantages”.The objective of thisstudyistodistinguish the mosteconomicaltrajectoryduringmotorizedplowing. The general objective of thisstudyis to distinguish the mosteconomicaltrajectoryduring the execution of motorizedplowing. The areas of work to achieve the general objective are to: specify the differenttrajectories for motorizedplowing; determine the agronomic and economicparameters on each plot; and designate the best trajectory for motorizedplowing.

2. MATERIALS AND METHODS

2.1. Presentation of the study site

The study site islocated in Awai in the district of Kétou, commune of Kétou at the northern end of the Plateau department. The site has geographicalcoordinates: 7°41'30" North and 2°63'08" East. The commune of Kétoucovers an area of 1775 km^2 (RGPH, 2002), or 1.55% of the national territory and 54.38% of the Plateau department. It islimited to the north by the commune of Savè, to the south by the commune of Pobè, to the west by the communes of Zangnanado and Ouinhi and to the east by the Federal Republic of Nigeria.(Directorate of Demographic Studies, 2008).The climateis tropical with a bimodal rainfallregimewithtwoshades (middle Zou and the southeasternplateaus), a long rainyseason: March to July, a short dry season: August, a short rainyseason: September to October and a long dry season: November to February. The annualrainfallaverageisaround 1073 mm in 65 days (ASEGNA, 2023). The two maxima of thisregime are centered on June and September.Thesoils of the commune are essentially of the slightlydesaturatedferralitic type and in places of the well-drained tropical ferruginous type.

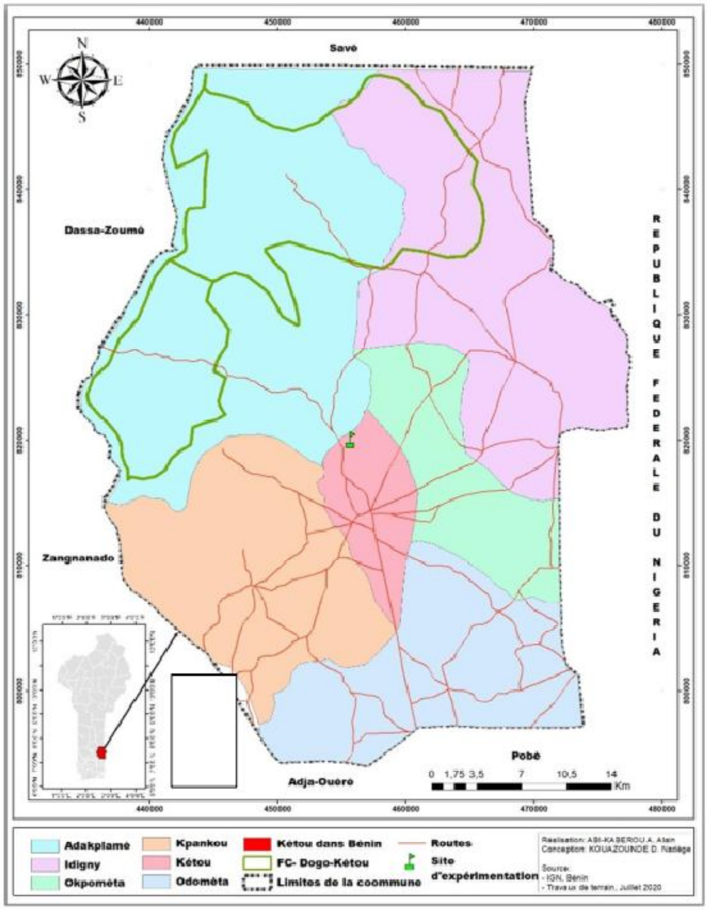


Figure1: Geographical location map of the Commune

2.2. Specification of differenttrajectories for motorizedplowing

In thisstudy, the trajectories for motorizedplowing to betested are as follows:

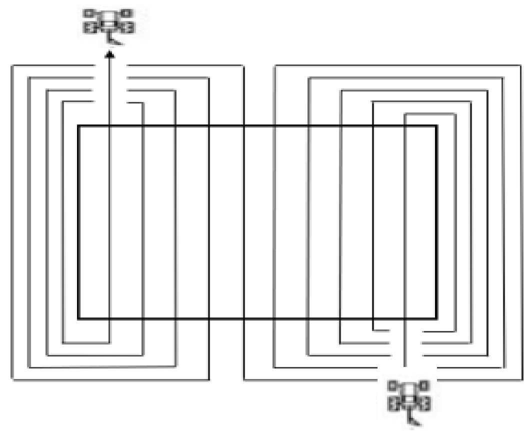


Figure2: Trajectory for flat plowing (LP)

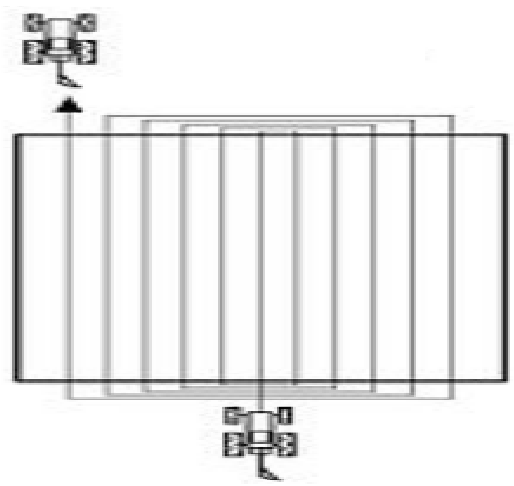


Figure3: Trajectory for back-to-back plowing (LPA)

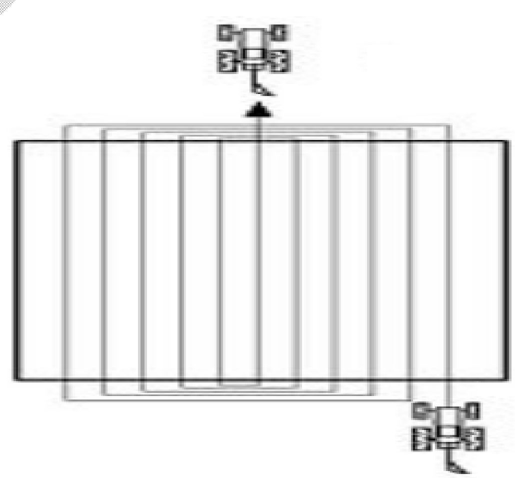


Figure4: Trajectory for splittingboardplowing (LPR)

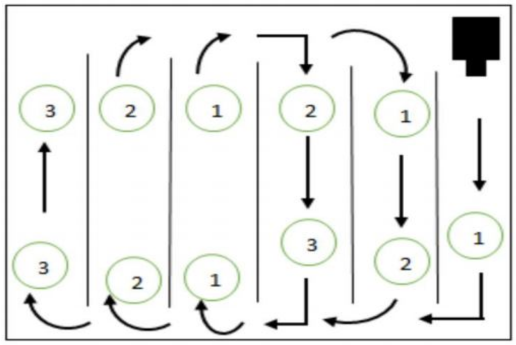


Figure5: Trajectory for superimposedalternatingplowing (LAS)

2.3. Description of the experimentalprotocol

The experimentconsists of executing the four trajectories for motorizedplowingmentionedabove at a speed of 6 km/h. Thesetrajectories for motorizedplowing are carried out successively on 15 plots of surface area 300 m² eachdividedinto 3 blocks of 5 plots, separated by 5 m alleys to facilitate the passage of the tractor and delimited by stakes. The plots are designated S0, S1, S2, S3 and S4. The S0 plot served as a control and the others are characterizedrespectively by the LP, LPA, LPR and LAS trajectories.The experimental plan adoptedis a randomizedcomplete block design withthree (03) repetitions (figure 6).For the experimentation of the differenttrajectories for plowing, weused a MAHINDRA 605 DI tractorwith an engine speed of 1100 rpmwith the second gear at the fast range 6km/h.

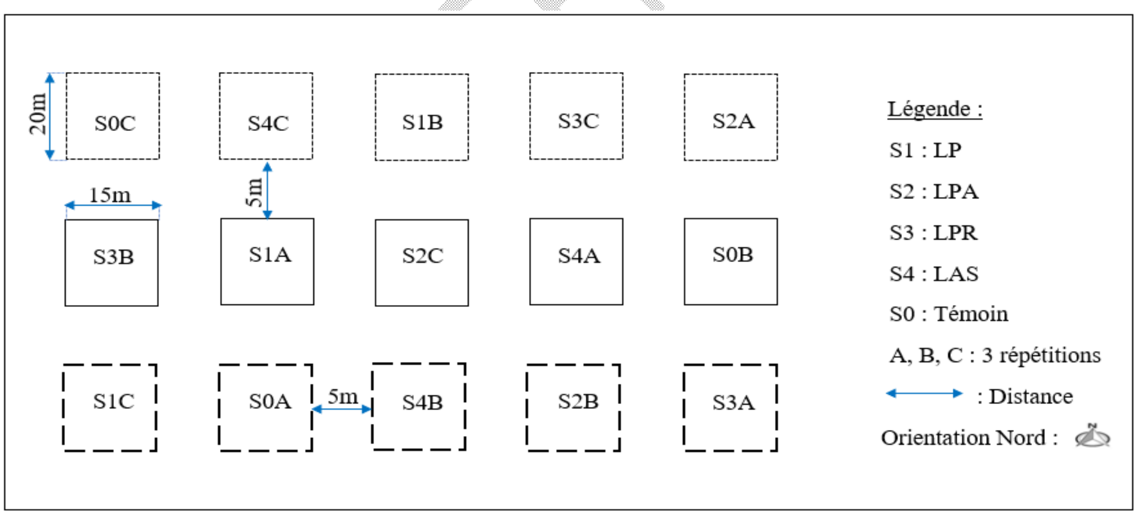


Figure6: Randomizedcomplete block experimental design

2.4. Sample collection method

A soil profile wascarried out on the experimental site. This cultural profile of 1m width, 1m length and 1m depthwasinstalled in order to measure the depth of the Arab layer whichis 20 cm;thisallowed us to maintain a plowingdepth of 15 cm. For the particle size analysiswhichallowed us to determine the texture and structure of the soil, disturbedsoilsamplesweretakenusing a manualaugerfrom the control plots (S0) following the diagonal of the plots in three points, startingfromboth ends of the diagonal to end in the right middle. Thesesamplestakenfrom the control plots were mixed to have a representativesample.

2.5. Particle size analysis

The particle size analysis of a sedimentconsists of determining the proportion of the variousparticle size classes: sand, silt, clay, etc.(Quebec Center of Expertise in Environmental Analysis, 2003). This analysiswascarried out according to standard NF EN ISO 17892-4:2018(NF EN ISO 17892-4, 2018).

2.6. Method for determiningtractor slip on the ground

The slip rate isdeterminedbased on the distance traveled by the tractorwhileplowing and thattraveledwith the implementraised. For thiswemarked a reference point where one of the rearwheelswas in contact with the ground. We made 5 turns of the wheelwhileplowing, thenwemarked the finishing point on the ground. This distance wasmeasured and denoted by A. Thenwerepeated the previousstepswith the toolraised. The new distance traveledwith the toolraisedwasalsomeasured and designated by B. The slip rate iscalculatedusing the equationfrom (Leghari et al., 2016):

$$\%\ de\ glissement = \frac{B-A}{B}\ x\ 100 \qquad (1)$$

2.7. Fuel measurementmethod

Fuel consumptionismeasured in liters but wasevaluated in g in the remainder of the study. For thisfact, weconsidered the density of diesel ρ diesel = 0.840 Kg/l(Innovation, Science and Economic Development Canada, 2008). The measurementprocedureinvolvescompletelyfilling the fuel tank at the start of eachplowingoperation. At the end of the plowingoperation of a plot, the quantity of fuel required for the supplementismeasured and thisallowed us to know the fuel consumptionduring the plowing of said plot.

2.8. Method for measuring time parameters

The different times, namely: the actualplowing time, the time lostduringplowing and the total plowing time wererecordedwith a stopwatch. Four people wereused to record the different times. Two people recorded the actualplowing time and the othertworecorded the time lostduringplowing. The recording of actualplowing time and time lostduringplowingwascarried out by two people in order to minimizemeasurementerrors. The accumulation of thesetworecorded times gives us the total plowing time.

2.9. Determination of time efficiency in the field

According to(Hunt, 2008), time efficiencyis a percentage of the ratio between the actual operating time of a machine and the total time the machine isspent in operation. Anytime the machine doesn'tactually process the field, itcounts as wasted time.

The time efficiency in the field (Ef) of eachtrajectory for motorizedplowingwascalculatedusing the 1st formula of(Zenebe & Chernet, 2016):

$$(Ef)\% = \frac{Temps\ effectif\ de\ labour\ (s)}{Temps\ total\ de\ labour\ (s)} x100 \qquad (2)$$

2.10. Effective fieldcapacity

This is the actual area covered by the toolbased on its total time consumed and itswidth(E-Agri, 2023). It isdefined by the second formula of(Zenebe & Chernet, 2016).

$$C = \frac{VW}{10} Ef \quad (3)$$

With :
VS: the effective fieldcapacity (ha/h); V: plowing speed (Km/h); W: the workingwidth of the tool (m) and Ef: the time efficiency in the field of the tractor in decimal.

2.11. Data analysis and processing

Excel software wasused to create the databases. The R 4.2.2 software (2022-10-31) wasused for the statisticalanalysis of the data of the differentparametersrecorded and the statisticalsignificancewas set at 10%. We first checked the normality of the data for the differentparametersusing the Shapiro-Wilk test.The statisticalanalysiswasbased on the ANOVA 1 methodfollowed by the Tukey test for pairwisecomparison in order to structure the means in the case where the data follow a normal distribution. If applicable, the Kruskal-Wallis test followed by theMann-Whitneyisdone. After the analyses, interpretations are made and theseallowed us to designate the best trajectory for motorizedplowing.Boxplots and histogramswerealsoproducedwiththis software.

RESULTS AND DISCUSSIONS

3.1. Particle size analysis

Table 1 presents the resultsfrom the particle size analysis of the representativesampletakenfrom the plots.

Table 1: Result of the particle size analysis

Samples	LG	Lf	HAS	SF	Sg
	%				
Awai 0-20cm	8.5	10.4	8.6	24.93	47.06

Lg = Coarse silts, Lf = Fine silts, A = Clays, Sf = Fine sands, Sg = Coarsesands.

Table 2 gives us indications of the texture of the soil on whichwecarried out ourexperiment.

Table 2: Summary of the result

Sample	Texture	Interpretation
Awai 0-20cm	SL to LA	Sandy Silty on the surface (0-15 cm) rangingfromSilty-Clayy at depth (15 – 20 cm)

According to the results in tables 1 and 2, wewillsaythatcoarsesands are predominantthancoarse silts; whichgivesit the type of sandyloamysoil. Thus, the soil of Awai has a lumpy structure. This willallowsoilorganisms to have a primary action in the soil, such as earthworms, by digginggalleries, creating a real aeration network thuspromoting the deep circulation of air and water.

3.2. Determination of slip on each plot

The slip values on the plots are around 7%. According to(Firestone, 2021), the slip values must bebelow 15%. In our case, the slip values calculated on the different plots of the experiment are lessthan 15%, sothey are acceptable. Consequently, the physical state of the soil and the state of the tractor tires did not then influence the plowing of the plots following the differenttrajectories.The data collectedduring the experiment for the evaluation of agroeconomicparameters are recorded in Table 3 below and theirstatisticalanalysisissummarized in Tables 4 and 5 above.

Table 3: Data recorded on experimental plots for motorizedplowingtrajectories

PLOTS	AGRONOMIC AND ECONOMIC PARAMETERS							
	Fuel consumption (g)	Effective plowing time (s)	Time lostduringplowing (s)	Total plowing time (s)	Time efficiency in the field (%)	Effective fieldcapacity (ha/h)	Theoreticalfieldcapacity (ha/h)	Fuel consumption per hectare (g/ha)
S1A	189	104	226	330	31.52	0.19	0.6	10903.85
S1B	252	151	276	427	35.36	0.21	0.6	10013.25
S1C	294	192	319	511	37.57	0.23	0.6	9187.5
S2A	180.6	177	131	308	57.47	0.34	0.6	6122.03
S2B	147	145	102	247	58.70	0.35	0.6	6082.76
S2C	147	135	121	256	52.73	0.32	0.6	6533.33
S3A	168	165	123	288	57.29	0.34	0.6	6109.09
S3B	147	140	113	253	55.34	0.33	0.6	6300
S3C	231	188	189	377	49.87	0.30	0.6	7372.34
S4A	168	156	130	286	54.55	0.33	0.6	6461.54
S4B	147	163	108	271	60.15	0.36	0.6	5411.04
S4C	168	178	117	295	60.34	0.36	0.6	5662.92

Table 4 presents the statisticalresultsfrom the statisticalanalyzes of the differentparameters.

<u>Painting4</u>*: One-way ANOVA results*

Parcels_Trajectories for motorizedplowing	Settings	Mean ± Standard deviation	Mann-Whitney	Kruskal-Wallis chi-squared F	Pr
S1_LP	Fuel consumption	245 ± 52.84	b	6.0527	0.109
S2_LPA		158 ± 19.39	a		
S3_LPR		182 ± 43.71	b		
S4_LAS		161 ±12.12	a		
S1_LP	Fuel consumption per hectare	10034.86± 858.37	b	7,307	0.06271*
S2_LPA		6246.04± 249.57	a		
S3_LPR		6593.81± 680.95	a		
S4_LAS		5845.16 ± 548.44	a		
S1_LP	Time lostduringplowing	273.66 ± 46.54	vs	6,589	0.086*
S2_LPA		118 ± 14.73	a		
S3_LPR		141.66 ± 41.29	ab		
S4_LAS		118.33 ±11.06	a		
S1_LP	Time efficiency in the field	34.82 ± 3.06	a	7,513	0.057*
S2_LPA		56.3±3.15	b		
S3_LPR		54.16 ± 3.84	b		
S4_LAS		58.34 ±3.29	b		
S1_LP	Field capacity	0.21± 0.018	a	7.5128	0.05723*
S2_LPA		0.33 ± 0.018	b		
S3_LPR		0.325 ± 0.023	b		
S4_LAS		0.35 ± 0.019	b		

Table 5:Results of the Kruskal-Wallis test

Types of plowing	Settings	Mean ± Standard deviation	Tukey	F	F and Pr
S1_LP	Effective plowing time	149 ± 24	a	0.27	0.844
S2_LPA		152.33 ± 21.94	a		
S3_LPR		164.33 ± 44.03	a		
S4_LAS		165.66 ±11.23	a		
S1_LP	Total plowing time	422.66 ± 90.57	a	4.28	0.044*
S2_LPA		270.33± 32.92	b		
S3_LPR		306 ± 63.92	ab		
S4_LAS		284 ±12.12	b		

3.3. Fuel consumption (g) of trajectories for motorizedplowing

The boxplot (

) shows the variation in fuel consumption for each type of trajectory for motorized plowing.

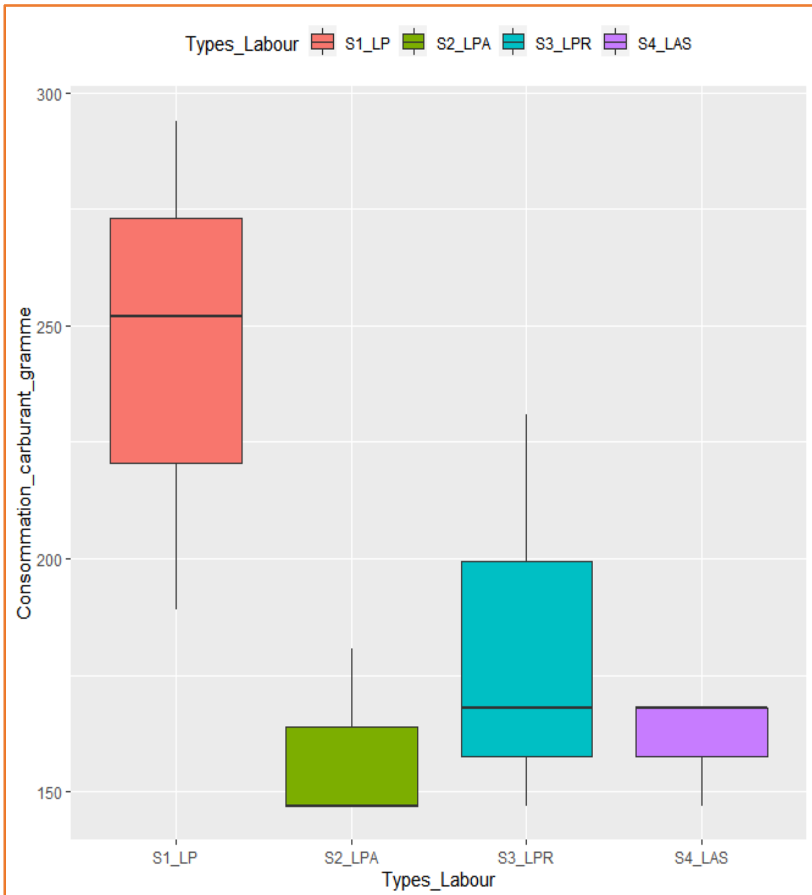


Figure7: Boxplot of fuel consumption (g) of trajectories for motorizedplowing

The analysis of theseboxplotsinitiallyindicatesthatthereis a large variation in the volume of fuel used for each type of trajectory for motorizedplowing, particularly for LP compared to the otherthreetrajectories for motorizedplowing. With an extremum of 189 g and 294 g, the fuel consumptionrequired for LP isgreaterthanthat of the others, especiallycompared to LAS whichpresented an extremum rangingfrom 147 g to 168 g.

Indeed, as shown in the bar histogramproduced, on average 245 g of fuel wereconsumed for the establishment of the plots on which LP wascarried out compared to respectively 158 g, 161 g and 182 g for the plots havingsheltered LPA, LAS and LPR.

Kruskal-Wallis chi-squared = 6.0527; Pr = 0.109*

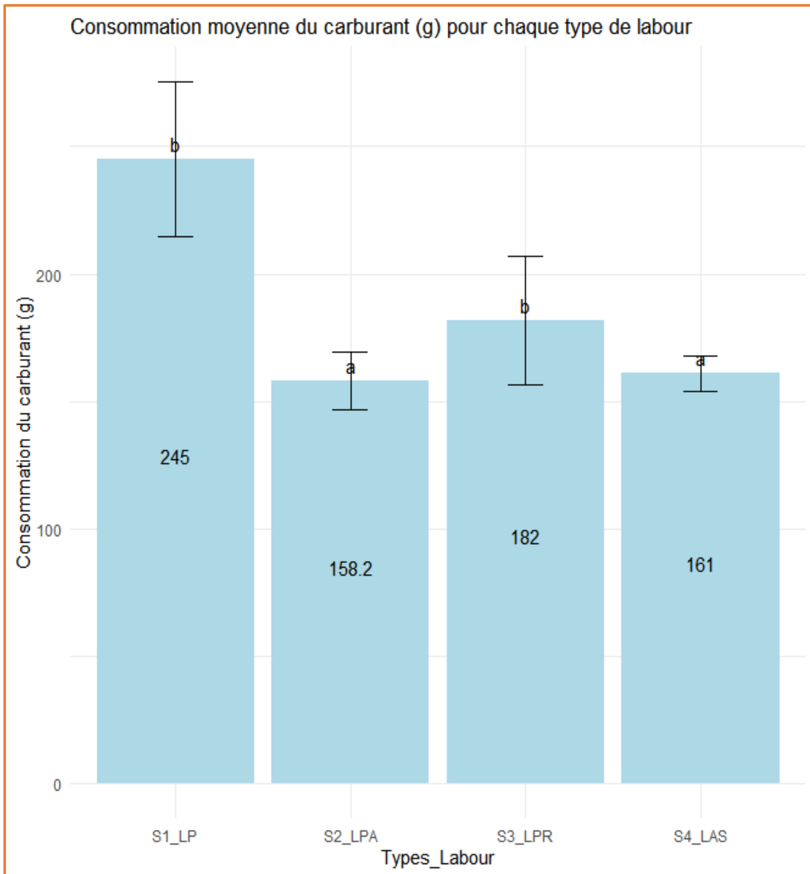


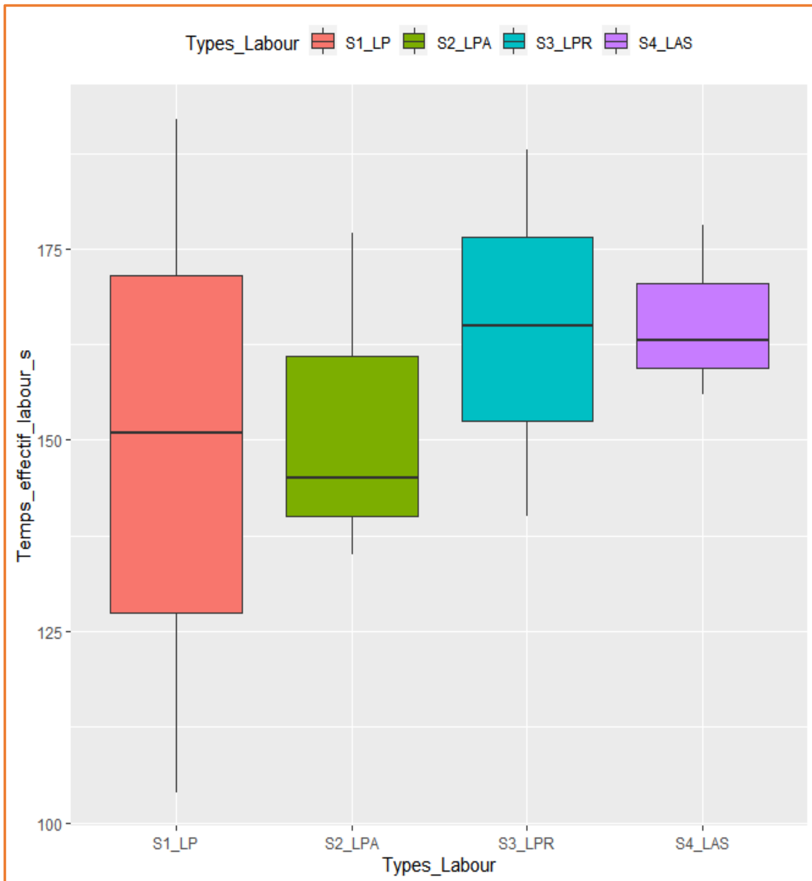
Figure8: Comparison of fuel consumption (g) of trajectories for motorizedplowing

Furthermore, the assessment of normalitythrough the Shapiro-Wilk test showedthat fuel consumptiondoes not follow a normal distribution. The use of non-parametric tests (Kruskal-Wallis) to compare theseaverageconsumptionsshowed, however, thatthereis no significantdifference at the 10% threshold. Whichmeansthatregardless of the trajectory for motorizedplowing, the fuel consumptionis not statisticallydifferentalthough LP consumed more fuel than the others.

However, the pairwisecomparisonresultingfrom the Mann-Whitney analysis shows a structuring of two groups withsimilarconsumption of LP and LPR (group b) while the twoothertrajectories for motorizedplowingpresent fuel consumptionwhichisequivalent (group a).

3.4. Effective time (s) for eachtrajectory for motorizedplowing

In order to appreciate the level of complexity of eachtrajectory for motorizedplowing, otherparameterssuch as "the time" taken to executeeachtrajectory for motorizedplowingwereexplored. Indeed, in terms of effective time, thatis to say the time duringwhich the plowingoperatorwasactivelyengaged in the execution of eachplowingtrajectory, withouttakingintoaccount interruptions, pauses or non-working times. Productive; thisis the time actuallyused to executeeach type of trajectory.

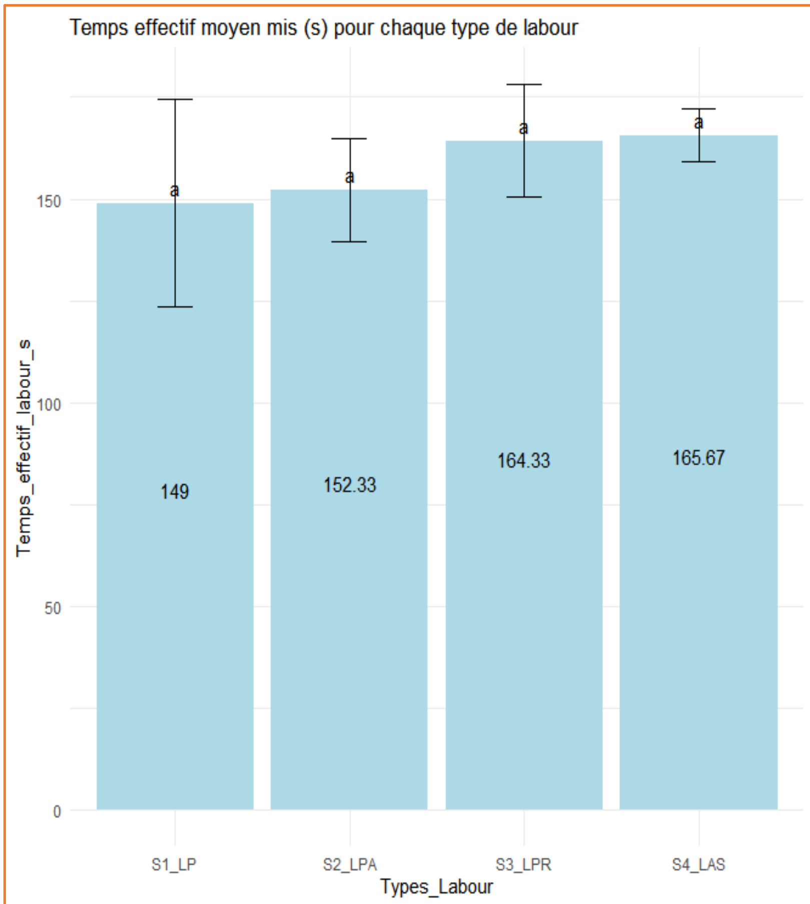


<u>Figure9</u>: Boxplots of the effective time (s) according to the differenttrajectories for motorizedplowing

The analysis of the boxplotslinked to thisparameteralsoindicates a variation in the extreme duration taken for each type of plowingoperation, in particular for LP compared to the threeother types of trajectory. As with the volume of fuel consumption, the trajectory for flat plowing (LP) has a widerinterval, i.e. an effective time rangingfromapproximately 104 seconds to more than 192 s. Thencomes the trajectory for splittingboardplowing (LPR) with extremums rangingfrom at least 140 s to 188 s at most.

Indeed, as shown in the histogram, on average the effective times range from 149 s (LP) to approximately 165 s (LAS) or between 2 min 29 s (LP) and 2 min 45 s (LAS).

Anova: F = 0.27; Pr = 0.844



<u>Figure10</u>: Comparison of the average effective time (s) spent on plowingwith the differenttrajectories

The assessment of normalitythrough Shapiro showedthatthisparameterfollows a normal distribution in general. This made it possible to carry out a one-wayanalysis of variance (ANOVA 1) thusshowing a non-significantdifference at the 10% threshold in terms of effective time taken for each type of trajectory for motorizedplowing. Whichmeansthatwhatever the trajectory, the time actuallyspentcarrying out theseoperations per plot does not varystatistically. This isalsowhatisreflected in the pairwisecomparisonresultingfromTukey'sanalysiswhich shows an identical structure (samegroup: a) for all the trajectories for motorizedplowing; nevertheless LPR and LAS took longer than the others. Furthermore, the results of the study of(Zenebe & Chernet, 2016), show that back-to-back plank plowing (LPA) has an effective time of 5257 s compared to a time of 5558.3 s for splitting plank plowing (LPR) but these results are not based on any statistical analysis as this was done in our case.

3.5. Time lostduringmotorizedplowingoperations

The assessment of time alsotakesintoconsideration the “lost time” aspect, referringmainly to the seconds or minutes necessary for the operatorbeforerepositioning for a new start for plowing.

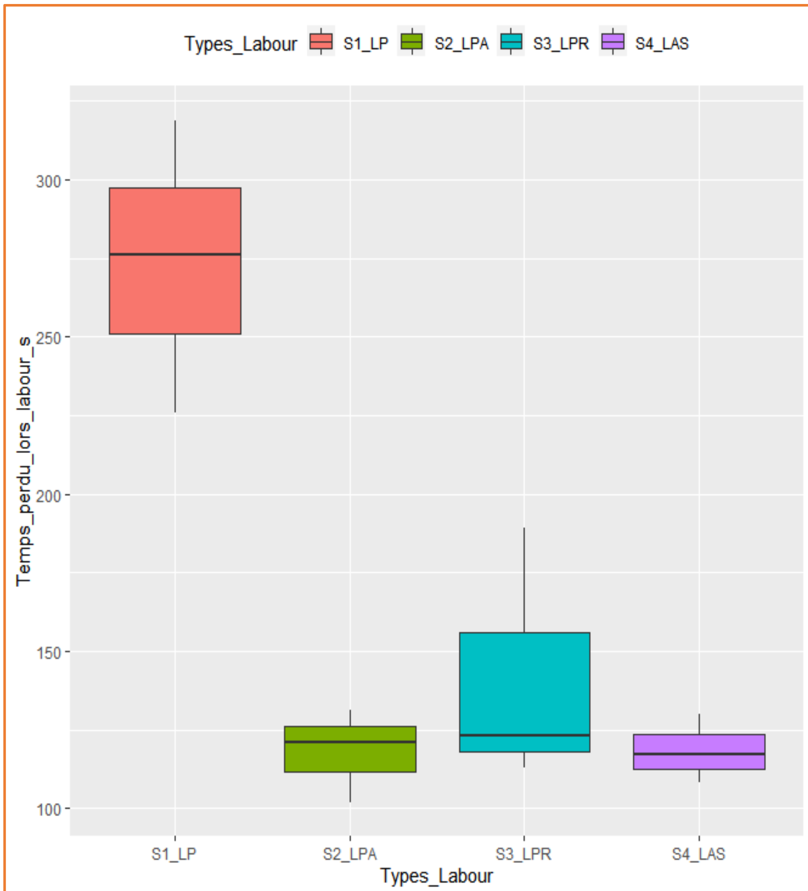


Figure11: Boxplot of time lost (s) duringplowing

The analysis of the boxplotslinked to thisparameterclearlyindicatestwodifferent groups in terms of evaluation of time lost for the realization of the differenttrajectories for motorizedplowing. Indeed, thisismainly the group of plots on which LP wascarried out with a greater extremum rangingfrom 226 s or 3 min 46 s to 319 s or 5 min 19 s. On the other hand, the interval of time lostisless important for the otherthree, especially for LAS where the time lostisbetween 108 s, or lessthan 2 min, and 130 s, or exactly 2 min 10 s.

This differenceiseven more observedthrough the histogram of the averageswith an average time lost of around 273 s for LP while the threeotherplowingtrajectoriesindicate an average time lostrangingfrom 118 s (LPA) to 141 s (LPR).

Kruskal-Wallis chi-squared = 6.589; Pr = 0.086*

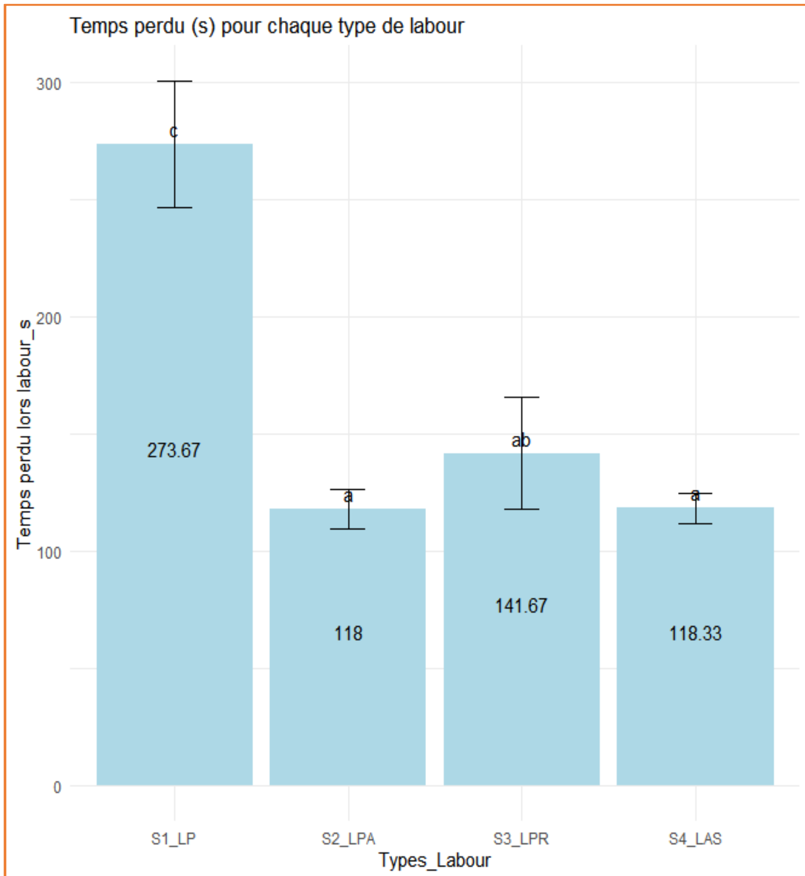


Figure12: Comparison of the average time lost (s) whenexecutingtrajectories for motorizedplowing

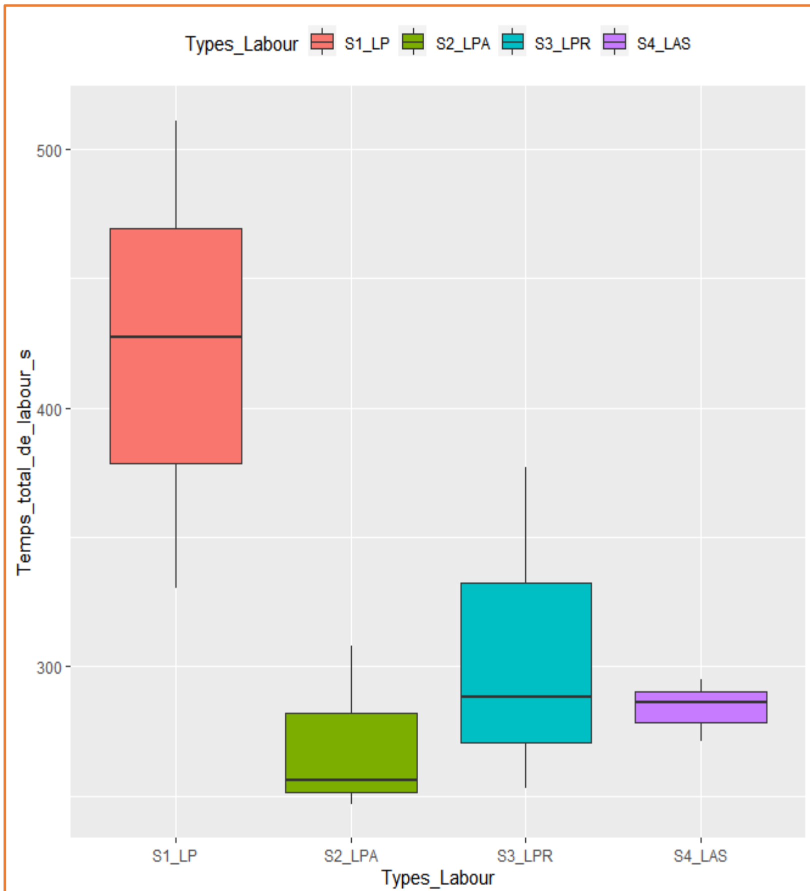
However, not following a normal distribution, the Kruskal-Wallis test shows a significantdifference in terms of time lost for eachtrajectory for motorizedplowing. Thus, the operatortakes more time to reposition himselfwhenheexecutes the trajectory for flat plowing (LP) thanwhenheexecutes one of the threeothertrajectories for motorizedplowing, especiallythat for plowing on a plank by leaningagainstit. (LPA).

This isalsowhatisreflected in the pairwisecomparisonresultingfrom the Mann-Whitney analysiswhich shows that the time lostduring the execution of LPsissignificantlydifferentfrom the otherswhileLPAs and LASs are statisticallysimilar. interms of wasted time. The results of(Zenebe & Chernet, 2016)confirm our results in the case where they lost for the plowing of one hectare, 1954 s using thecircular (square) plowing model fromridges (LPA) versus 2580 s using the circular (square) plowing model fromboundaries (LPR).

3.6. Total plowing time(s)

Overall, an assessment of the total time (workforce plus wasted) makesit possible to identify the trajectorythatallows time to besaved.

The analysis of the boxplotslinked to thisparameteralsoclearlyindicatestwodifferent groups in terms of evaluation of total time for the realization of the differenttrajectories for motorizedplowing. Indeed, initiallywefind the plots on which the trajectories for flat plowing(LP) werecarried out with a greater extremum rangingfrom 330 s or approximately 5 min 30 s to 511 s or approximately 8 min 30 s. On the other hand, the interval of time lostisless important for the otherthree, especially for the trajectories for superimposedalternatingplowing (LAS) where the total time seems to belessvaried, i.e. between 271 s and 295 s at most.



<u>Figure13</u>: Boxplot of the total plowing time (s) according to the differenttrajectories for motorizedplowing

The histogrammakesit possible to betterperceivethisdifferencewith an average total time of approximately 422 s for LP, or approximately 7 min, while the threeothertrajectories for motorizedplowingindicate an average total time rangingfrom 270 s (LPA) to 306 s (LPR).

Anova: F = 4.28; Pr = 0.044*

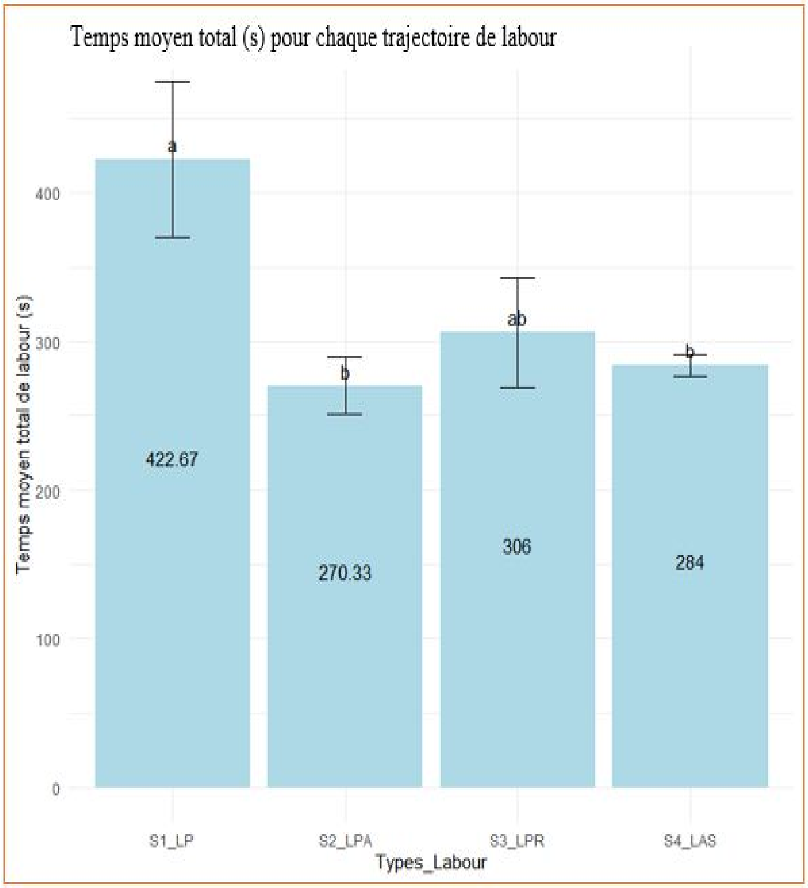


Figure14: Comparison of the total averageplowing time (s) according to the differenttrajectories for motorizedplowing

The assessment of normalitythrough Shapiro showedthatthisparameterfollows a normal distribution in general. As a result, the one-wayanalysis of variance (ANOVA 1) shows a significantdifference at the 10% threshold in terms of total time carried out for eachplowingtrajectory. Thus, the operatortakes more time not only for the actual LP operations but also loses a lot of time beforeitsrepositioning.

Furthermore, the pairwisecomparisonfromTukey'sanalysisindicatesthat LAS and LPA belong to the same group in terms of total time spent for plowingoperationswhileLPRs are statisticallycloser to LPs. This analysisisconfirmed by the workof(Sarkar et al., 2016) which showed that the overlapping alternation (LAS) model required 18 min of total plowing time compared to 25 min for the circuit alternation (LPR) model. The work of(Zenebe & Chernet, 2016)“Comparative Evaluation of Alternate Plowing Pattern Designs at Metahara Sugar Estate of Ethiopia” also shows that the trajectory for back-to-back plowing (LPA) takes less time than the path for splitting-plank plowing (LPR).

3.7. Designation of the best trajectory for motorizedplowing

3.7.1. Fuel consumption per hectare (g/ha)

The evaluation of fuel consumption per hectare initially shows, from the boxplots, two groups of methodshaving a verydifferentlevel of consumption per hectare. Indeed, the trajectory for flat plowing (LP) stands out considerablywithextremesbetweenapproximately 9000 g/ha and more than 10,000 g/ha, while the otherthreetrajectoriespresent a consumption range rangingfrom 5000 g/ha at approximately 7000 g/ha.

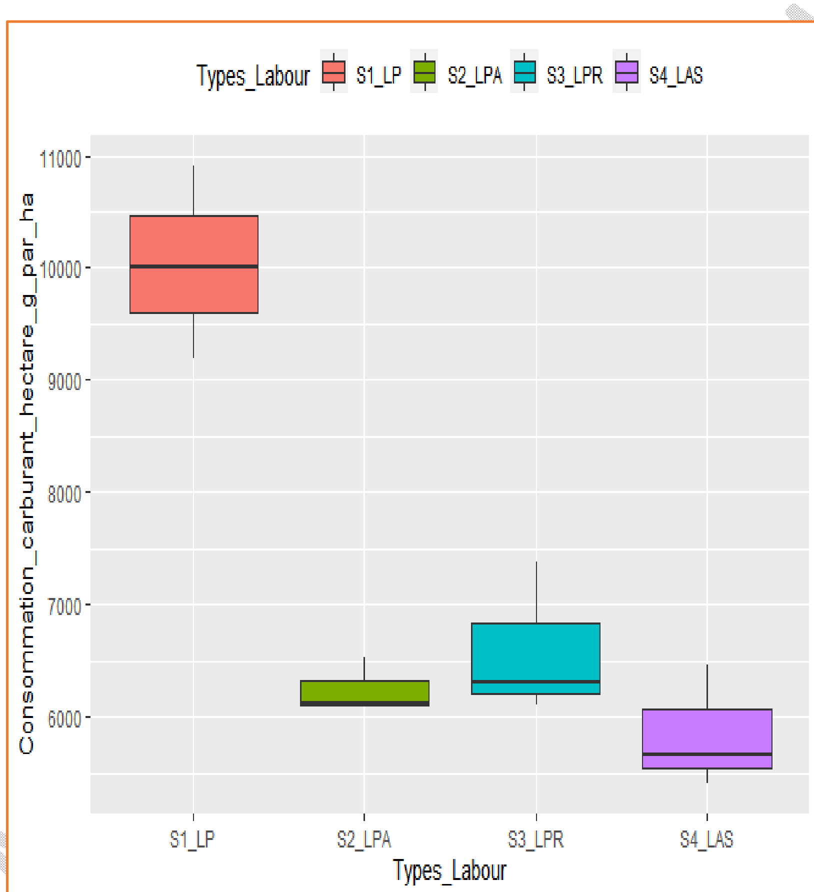


Figure15: Boxplots of fuel consumption per hectare (g/ha)

On average, as shown in the histogram (figure 15), 10034 g/ha of fuel wereconsumed for the establishment of the plots on which LP wascarried out compared to respectively 5845.16 g/ha, 6246 g/ha and 6593.8 g/ha for the plots havinghosted the LAS, LPA and LPR trajectories.

Kruskal-Wallis chi-squared = 7.307; Pr = 0.06271*

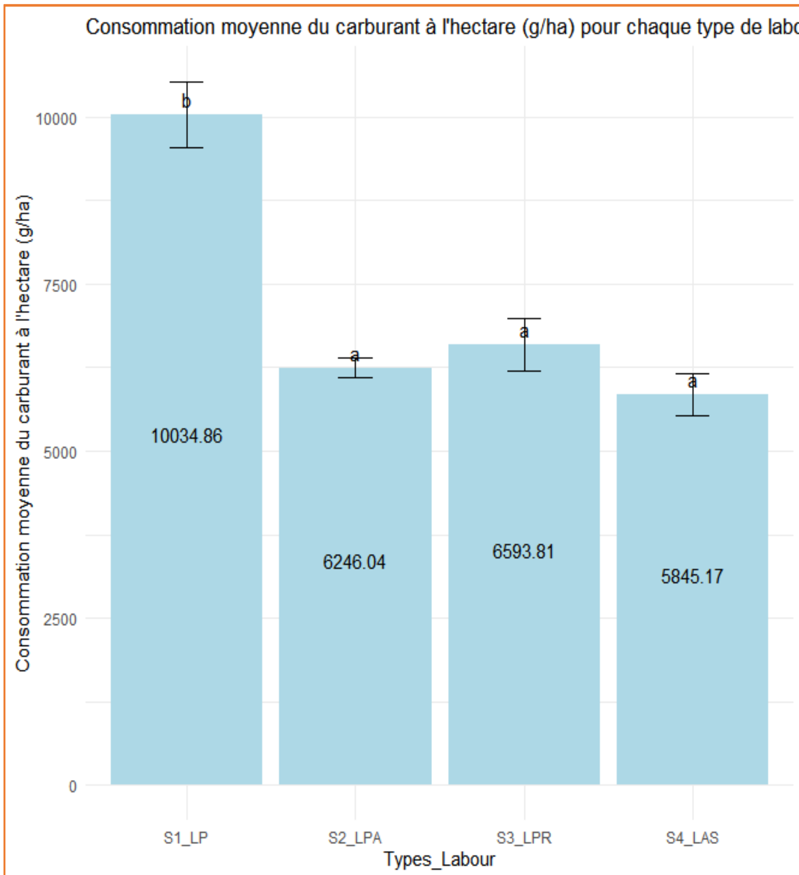


Figure16: Average fuel consumption per hectare (g/ha)

The assessment of normalitythrough Shapiro showedthatthis fuel consumptiondoes not also follow a normal distribution. However, the Kruskal-Wallis test carried out to compare theseaverageconsumptionsshowed a significantdifference at the 10% threshold;which in factmeansthat fuel consumption varies statisticallydepending on the trajectory for motorizedplowingadoptedwithgreaterconsumption per hectare for LP. However, the studyof(Sarkar et al., 2016) on the selection of a suitable tillage model for fuel economy revealed that the amount of fuel consumed by the tractor for plowing one hectare using the tillage model overlap alternation (LAS) is the same as that consumed by the tractor when using the rectilinear alternation model (LP with reversible plow) which was not studied in our work.

Furthermore, we cannot confirm its results which indicate that the overlap alternation model (LAS) consumes 17.78 l of fuel per hectare compared to 21.11 l per hectare for the circuit alternation model. (LPR) because the author has not done any statistical study that proves his assertion.Thisisreflected in ourstudy by the pairwisecomparisonresultingfrom the Mann-Whitney analysiswhich shows that the trajectories for motorizedplowing LAS, LPA, then LPR presentsignificantlysimilar fuel consumption per hectare. Andlowerthanthat of the LPsstudied.

3.7.2. Time efficiency in the field (%) for each type of plowing

To designate the best trajectory for motorizedplowing, otherparameters, in particularthat of time efficiency (%) and fieldcapacity (ha/h), wereevaluated and compared.

Field time efficiencyiscalculated by comparing effective plowing time (time duringwhichworkisactuallydone) to total plowing time (total time spent on the field). The higher the time efficiency in the field, the more efficiently time isused to accomplishwork, indicatingbetterproductivity.

The boxplot (Figure 17) shows the variation in the efficiencylevel for eachpath for motorizedplowing. The analysis of theseboxplotsinitiallyindicatesthatthereis a variation in the level of efficiencyfrom one plowingtrajectory to another. With an extremum of 31.52% and 37.57%, the trajectory for flat plowing (LP) is the least efficient with an averageefficiency of 34.82%. This relativelylowefficiencycompared to the efficiencies of the othertrajectoriessuggeststhatonly 34.82% of the total plowing time isusedeffectively to accomplish the work.

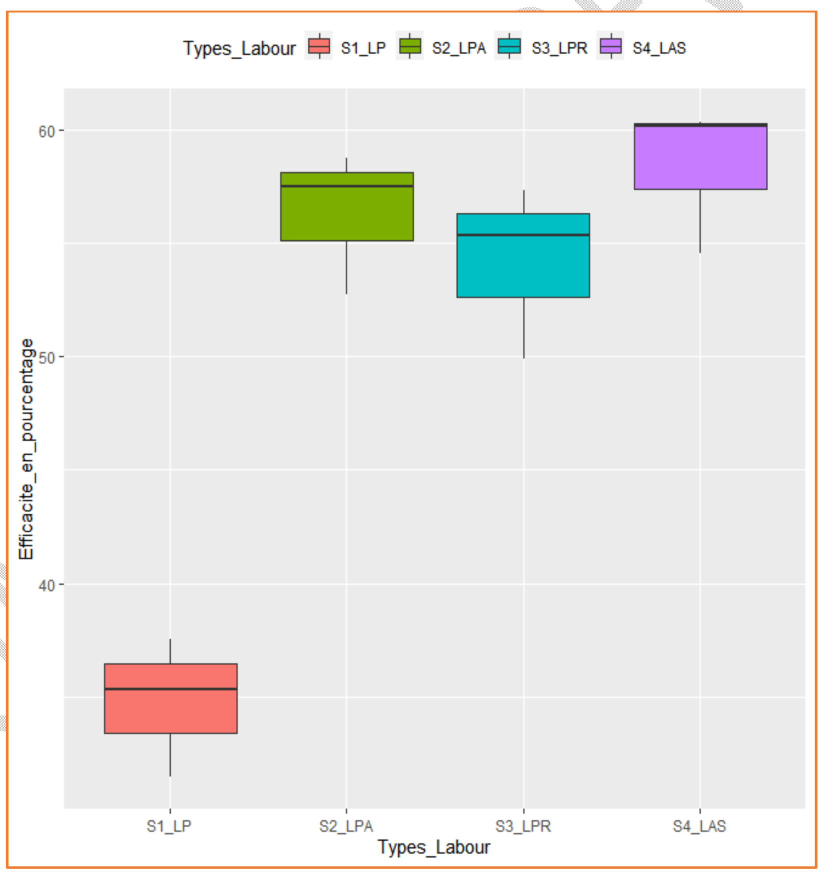


Figure17: Boxplot of field temporal efficiency (%) by trajectory for motorizedplowing

On the other hand, the threeothertrajectories for motorizedplowing show extrema which are equivalent and wellabove the first type of trajectory for motorizedplowing. Indeed, LAS are the most efficient with an extremerangingfrom 54.55% to 60.34% for an averageefficiency of 58.34%, thusreflectingthat 58.34% of the total time spent on the plot isused in an efficient manner. efficient to actually do the workwiththese LAS trajectories. Notwithstandingthis, LAS do not offer good plowingqualitywith the simple plowsused in ourstudy (photo 8 and photo 9). They are suitable for plowingcarried out withreversibleplows or hillers.

Kruskal-Wallis chi-squared = 7.513; Pr = 0.057*

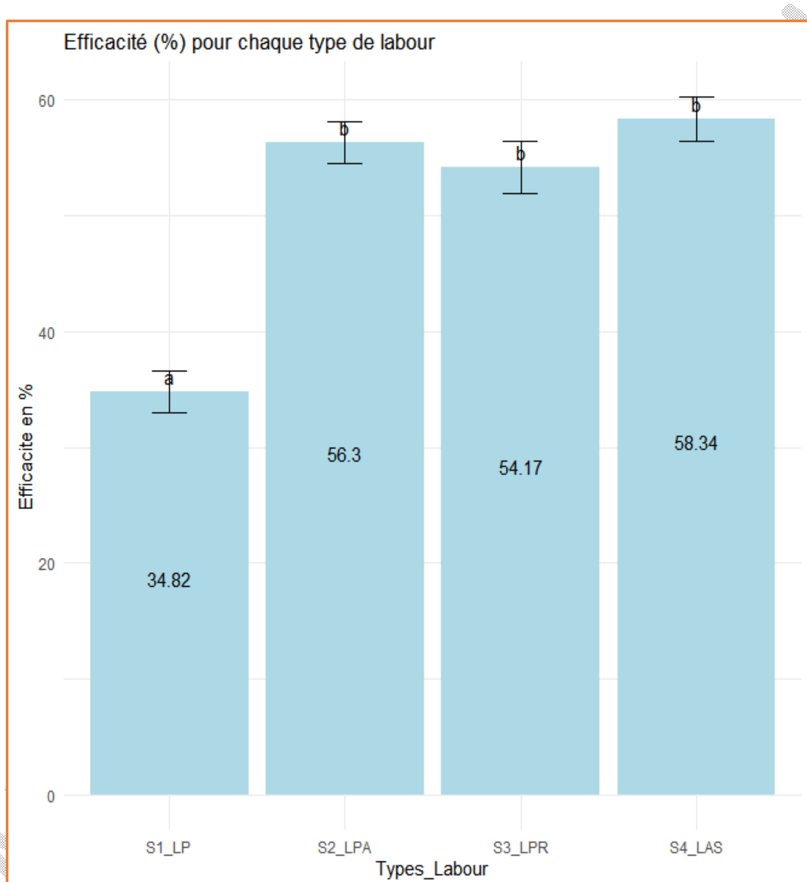


Figure18: Comparison of average time efficiency (%)

Furthermore, the comparison of theseaverageefficienciesshowed, however, thatthereis a significantdifference at the 10% threshold;whichmeansthat the efficiencyisdetermined by the plowingpathcarried out. However, the pairwisecomparisonresultingfrom the Mann-Whitney analysis shows that LAS, LPA and LPR have a similarlevel of efficiencywhileLPs have an averageefficiencysignificantlydifferentfrom the others. Wecannotthereforeconfirm the results of(Zenebe & Chernet, 2016)which present a difference between the temporal efficiency in the field which is 72.9% for thecircular (square) plowing model from the ridges (LPA) and the time efficiency in the fieldwhichis 68.3% for the circular (square) plowing model from the limits (LPR) especiallysinceitsThesestatements are not based on anystatisticalstudy.

3.7.3. Field capacity (ha/h) fromeachtrajectory for motorizedplowing

The evaluation of the fieldcapacity of the trajectories for motorizedplowingalsoconfirms the results of the temporal efficiency in the fieldpreviouslyobtained. This parametermeasures the area of land (in hectares) that the tractor can plow in one hour (ha/h) according to eachpath. In the context of the presentstudybased on motorizedplowingtrajectories, a high capacity for a preciseplowingtrajectoryindicatesgreaterefficiency of the machine tool or a good adaptation of the tractor-plowassemblyused for thistrajectory for preciseplowing, becauseit assumes thatit can plow a larger area of field in less time.

Indeed, the boxplots (figure 18) indicate a variation in the fieldcapacity for eachtrajectory. The analysis of theseboxplotsalso shows that LP has the lowestcapacitieswith an extremum of 0.19 ha/h and 0.23 ha/h. This capacityissignificantlylowerwith an average of 0.21 ha/h compared to that of othertrajectories, notablythat of LAS where the averagecapacityis 0.35 ha/h.

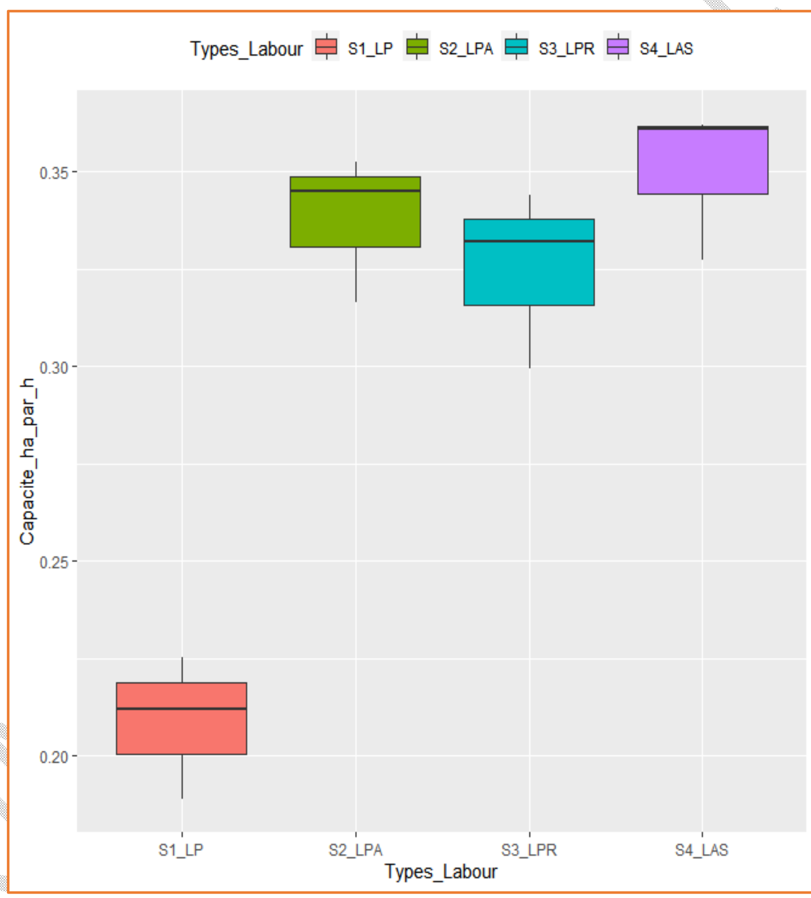


Figure19: Boxplot of fieldcapacity (ha/h) per trajectory for motorizedplowing

Just as for efficiency, the comparison of averagecapacitiesshowedthatthereis a significantdifference at the 10% threshold, thusreflectingthateachtrajectory for motorizedplowing has a givencapacitystatisticallydifferentfromthat of a other. However, the pairwisecomparisonresultingfrom the Mann-Whitney analysisalso shows that the LAS, LPA and LPR have significantlysimilarcapacities at the 10% threshold but differentfromthat of the LPs.

Kruskal-Wallis chi-squared = 7.5128, Pr = 0.05723*

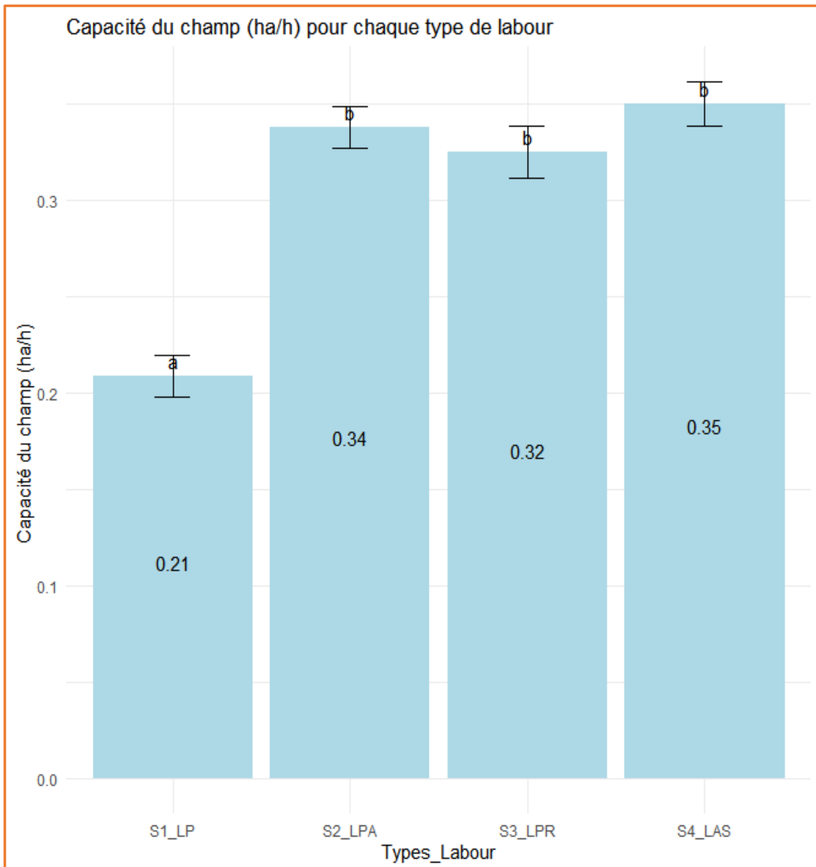


Figure20: Comparison of averagecapacity (ha/h) per trajectory for motorizedplowings

Thus, the resultsfromtheseanalyzes made it possible to evaluate the performance of the tractorswitheach type of trajectory for motorizedplowing, to identify the trajectorieswhich are the most productive (LAS, LPA and LPR) and thosewhichpossiblyrequireimprovements. toincreasetheirefficiency like the trajectory for flat plowing (LP) studied. As in terms of efficiencies, the results of(Zenebe & Chernet, 2016)which show a difference between the field capacities obtained with thecircular (square) plowing model fromboundaries (LPR) and the circular (square) plowing model fromridges (LPA) cannotbeconfirmedeitherbecausethey are not subject to anystatisticalanalysis.

CONCLUSION

This researchconsisted of the study of trajectories for motorizedplowing to draw out theiradvantages and disadvantages. It wasbased on the specification of trajectories for motorizedplowing in order to determine the differencebetweentheireconomic and agronomicparameterswith the aim of designating the best trajectory. Althoughthereis not a statisticallysignificantdifference at the 10% thresholdbetween the economicparameters of the

LPA, LPR and LAS trajectories, except the parameter of the maximum headlandwidthmeasured and takingintoaccount the resultsobtained, werecommend the LAS trajectory in the case whereplowingiscarried out with a reversibleplow or with a ridger. If plowingiscarried out with a simple plow, we first recommend the path for plowing in planks by backing LPA and thenthat for plowing in planks by splitting LPR because the path LPA offersbettereconomicparametersthan the path LPR.

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