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1 Trade-off between agronomical and energetical 2 performances during barley sowing varying adjustable 3 parameters in a tractor-tire-tool system

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16 Abstract

17 Soil compaction on seedbed, resulted from the traffic of a tractor-tire-tool system, alters soil
18 structure and harmfully impacts crop production. Soil conservation during sowing operations
19 and the optimization of energy consumption of tractor-tire-tool system, form the focus of the
20 global agriculture policies and farmers under the energetical and the agroecological transitions.
21 The present study aims to find a trade-off between the agronomical and the energetical
22 performances, during a sowing operation of spring barley (*Hordeum vulgare*), varying
23 adjustable parameters (controlled factors) in tractor-tire-tool system (i.e. tractor speed, axle load
24 distribution, inflation pressure and soil working depth). The adjustable parameters have been
25 chosen as to be adjustable by a regular tractor operator. The study was carried out on a silty
26 loam soil (with an average soil gravimetric water content of 23.4%) located in Northern-France.
27 The used tractor-tire-tool system consisted of a Four-Wheel Drive tractor (140 HP of power)
28 equipped with 480/70 R28 front tires and 580/70 R38 rear tires, and hitched to an air seeder.
29 Agronomical performance is evaluated via the conservation of soil physical properties, and via

30 the success of the sowing operation. The energetical performance is evaluated via the
31 optimization of energy consumption. The conservation of soil physical properties was assessed
32 via soil bulk density (BD) and air permeability (k_a). The success of the sowing operation was
33 assessed via barley seedling, counting the emerged plants at one to two leaves stage, and crop
34 yield. Energy consumption was assessed via the consumption of fuel per hectare. BD and k_a
35 were negatively correlated ($\rho=-0.56$ and $p\text{-value}<0.001$), but k_a was significantly more
36 influenced by the controlled factors and their combinations showing higher sensitivity of pore
37 continuity to the structural disturbance than pore space. Crop seedling and yield were slightly
38 influenced by the variation of the controlled factors and their combinations. All these
39 agronomical indicators depended significantly on the combination between the four factors
40 showed as single treatment. Fuel consumption decreased significantly with the equal load
41 distribution and increased with tractor speed and soil working depth solely. Nonetheless, it
42 showed higher dependence on the combinations between the factors. As a conclusion, soil
43 physical properties could be conserved, better barley seedling and yield could be obtained, and
44 energy consumption could be optimized by equally distributing the axle load, accelerating
45 tractor at 14 km/h, working the soil at 10 cm of depth and inflating tires at 140 or 80 kPa of
46 inflation pressure.

47 **Keywords:** seedbed soil conservation, crop seedling and yield, fuel consumption, performance
48 optimization, tractor-tire-tool system, adjustable parameters.

49 **1 Introduction**

50 A successful agricultural operation is the one that prevents soil damage and energy waste and
51 that allows a sustainable consumption agronomical production (Botta et al., 2007; Naujokienė
52 et al., 2022). For sowing operations, it is essential to have a suitable seedbed for the germination
53 of grains and to obtain the needed crop yield (Barnhisel and Hower, 1997; John et al., 2011).

54 The agriculture machinery and its connected tools increased in weight and size to meet the
55 massive requirement of agricultural operations, from sowing to the harvesting of different crops
56 (Keller and Or, 2022). The barley sowing occurs usually in mildly wet conditions of soil, which
57 has the potential to increase soil damage and energy waste (Asinyetogha et al., 2019; Reintam
58 et al., 2009). The traffic of a tractor-tire-tool system upon the soil in such wet soil conditions,
59 applies a mechanical stress to the soil and results in serious soil degradation by compaction
60 which stands behind the degradation of 23% of arable lands (Bai et al., 2008; Hillel, 2003). The
61 well aerated soil structure undergoes a deformation when the mechanical stress exceeds its
62 bearing capacity, which is a compression of the biopores, shearing of pores' continuity and
63 change of pores' size distribution (Keller et al., 2022). This deformation is translated directly
64 by the increase of soil penetration resistance, bulk density and shear strength (Alblas et al.,
65 1994; Forster et al., 2018; Raper, 2005). The compaction results in a reduction of mineralization
66 of organic matters, resource availability for plants, soil permeability, germination ability of
67 grains, and root development and penetrability (Forster et al., 2020, 2018; Kuncoro et al., 2014).
68 Topsoil compaction influences soil hydric states leading to reduce tillage performance and the
69 effectiveness of fertilizers amendment, then indirectly it leads to a loss in crop yield and
70 cultivatable areas, then creates a significant cost for farmers and society (Batey, 2009;
71 Håkansson and Medvedev, 1995; Keller et al., 2022).

72 The interaction between topsoil and tire causes a stochastic tire deflection and soil deformation,
73 which wastes up to 55% of the tractor available energy (Janulevičius and Damanauskas, 2015;
74 Pranav and Pandey, 2008). The achievable energy optimization is obtained when all the energy
75 from fuel combustion are used in the drawbar work of tractor without soil damage (Grisso et
76 al., 2004). In fact, manufacturers of machinery and tires worked to develop new technologies
77 to improve the vibration process and stress distribution in the soil, and reduce tire defection
78 (Kising and Göhlich, 1989; Schjønning et al., 2012). Even though new tires could carry heavier

79 load with lower inflation pressure, tire innovation and development could not overcome the
80 heavy impact of machinery traffic in agricultural operations (Comparetti et al., 2019; ten
81 Damme et al., 2019). Therefore, practices focusing on the interaction between soil and the
82 tractor-tire-tool system could play a significant role to improve soil-tractor-tire-tool interaction
83 and contribute to mitigate soil compaction and energy waste. The previous studies show that
84 the operator can improve this interaction by some adjustable parameters on its tractor-tire-tool
85 system, where some settings are reviewed, such as the adjustment of tractor speed, tires and
86 ballast, as well as soil tillage methods and working depth (Farias et al., 2019; Janulevičius and
87 Damauskas, 2015; Spagnolo et al., 2012; Tayel et al., 2015). Most of studies focused on tire
88 adjustment as stress transmitter, when the primary focus is to widen the soil-tire contact area
89 which affects the rolling resistance, which in turn has high impact on fuel consumption
90 (Taghavifar and Mardani, 2012). There is some available methods that provide wider contact
91 area between soil and tire (Raper, 2005). Wider contact area can be obtained using dual tires,
92 but it leads to impact a wider surface, then better results can be obtained lowering the inflation
93 pressure of single tires (Raper, 2005; Schwanghart, 1991). One of the effective methods to
94 widen this contact area is the use of rubber tracks instead of tires, which results in a lower
95 compression but can lead to a higher shear of soil (Blunden et al., 1994; Lamandé et al., 2018).
96 Low-corrected inflation pressure can reduce the compaction severity, increase traction
97 efficiency and decrease fuel consumption (Antille et al., 2013; Battiato and Diserens, 2013; D
98 L Antille et al., 2008; Douglas et al., 1992; Schwanghart, 1991; Udompetaikul et al., 2011).
99 However, an over-inflation of tires can result in a ballooning effect, reducing energy waste by
100 the reduction of tire deflection (Taghavifar et al., 2014). Ground pressure is the principal
101 element controlling the severity of topsoil compaction (Raper, 2005). During tractor-pull
102 operations, like sowing, an appropriate adjustment of tire load and pressure is essential to
103 improve tractor traction through the diminution of tire slippage and thereby reduce soil

104 compaction and energy waste (Davies et al., 1973; Janulevičius and Damanauskas, 2015). This
105 improvement is usually performed by configuration of load distribution of ballast between rear
106 and front tires (Janulevičius and Damanauskas, 2015; Mamkagh, 2018; Pranav and Pandey,
107 2008). Wheels are used to be loaded by 55-65% of total axle load in static conditions, and an
108 overloading ballast increases rolling resistance and soil compaction which, also, waste the
109 energy (Damanauskas et al., 2015; Janulevičius and Damanauskas, 2015; Pranav and Pandey,
110 2008). Soil compaction occurs under a process of vibration of the mechanical pressure. The
111 increase of tractor speed decreases the hold-time of this process and take up more power at
112 lower slip, and therefore may provoke a lesser compaction to the soil (Al Aridhee et al., 2020;
113 Davies et al., 1973). On the other hand, consumption of fuel increases with the increase of speed
114 leading to use higher energy for the motion of tractor and decreasing the traction efficiency
115 (Adewoyin and Ajav, 2013; Taghavifar et al., 2014). The optimization of an agricultural
116 operation take into account the duration to perform the operation. Thus, an optimal operation is
117 the one does not waste time also. Accordingly, it should find a compromise between saving
118 time and fuel to a better energetical performance depending on the soil conditions. For instance,
119 an increase of traffic speed could achieve the operation in a reasonable duration and result in
120 an acceptable compaction within a conventional system, when the soil has lower bulk density,
121 but at the same time it could result higher energy waste (Stafford and de Carvalho Mattos,
122 1981). Except of the no-till system, the farmers work their soils to prepare the seedbed for the
123 sowing. Therefore, to reduce soil degradation and energy waste, the operator can play on the
124 tillage or soil working depth. Soil tillage or working before sowing softens the compacted soil
125 by decompression and cracking of compacted blocs (Parkhomenko et al., 2019; Zimdahl, 2018).
126 Primary tillage is one of the effective practices to prepare the seedbed increasing structural
127 macro-porosity and breaking up compacted soil, but a significant soil compaction could be
128 generated following a secondary tillage over a freshly tilled soil (Botta et al., 2009; Zimdahl,

129 2018). However, it is one of the highest energy consuming between the agricultural operations
130 (Badalíková, 2010; Moitzi et al., 2013). The effect of tillage, and its different methods and
131 practices, is vastly arguable, but it depends always on soil and climatic conditions (Badalíková,
132 2010; Bogunovic et al., 2018). For example, an increase of tillage depth can positively affect
133 crop yield but negatively affect soil structure, as well as it requires higher energy supply
134 (Arvidsson et al., 2013). Even though, the conventional tillage using mouldboard ploughing
135 reduces soil bulk density and results in a higher crop yield, it can increase compaction and
136 erosion risk and decrease soil bioactivity (Arvidsson et al., 2013; Badalíková, 2010; Bogunovic
137 et al., 2018).

138 To the best of our knowledge, the combination between all the adjustable settings to reduce soil
139 compaction and optimize energy consumption is not documented. These settings are usually
140 setup together, as single combination, but the previous researches focus on the closest settings
141 only, such as tire inflation pressure and ballasting or tire inflation pressure and tractor speed
142 etc. Energetic and agronomic performance are rarely treated as a single target of a successful
143 agricultural operation. The objective of the present study is to examine the possibility of
144 conciliating the optimization of energetic performance, via the reduction of fuel consumption,
145 and the optimization of agronomic performance, via the conservation of soil physical properties
146 on seedbed and a best crop production. The aim of this study is to find the best combinations
147 consisted of adjustable parameters (i.e. tire inflation pressure, tractor speed, axle load
148 distribution and soil working depth) to present the trade-off between the energetical and
149 agronomical performances.

150 **2 Materials and methods**

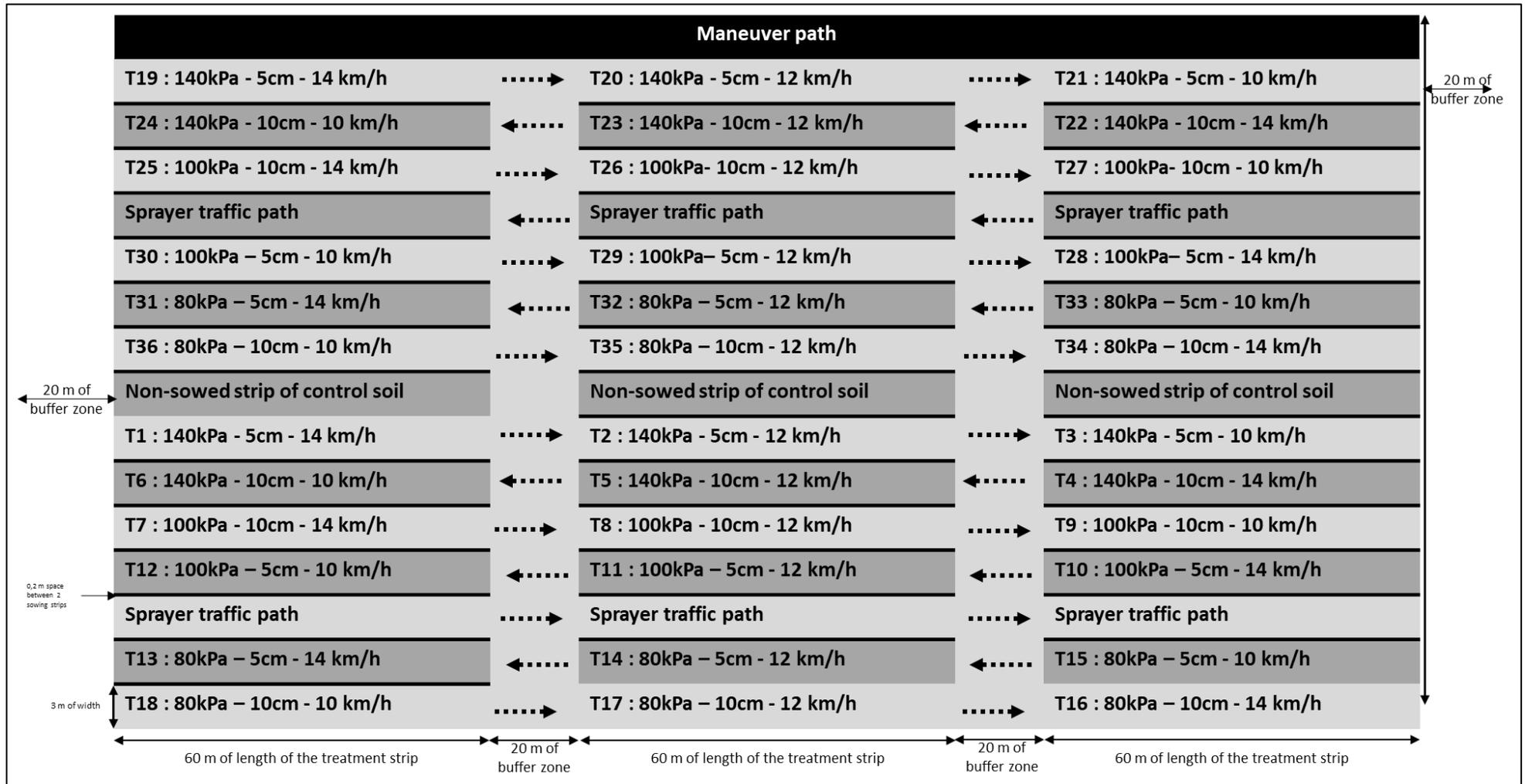
151 **2.1 Study site and experimental design**

152 The study was conducted on an agriculture parcel of 1.5 ha of flat surface, located in Milly-sur-
153 Thérain, Northern-France (49°29'48.6"N 2°01'10.3"E). The climate is sub-oceanic with average
154 of annual precipitation of 749 mm and average annual temperature of 10.8 °C (Climate-
155 Data.org). The soil is a Luvisol (IUSS Working Group WRB, 2015) of silty loam texture, with
156 an average of clay content of 167 g/Kg, an average of organic matter content of 17.5 g/Kg, an
157 average of cation exchange capacity (CEC) of 8.93 cmol+/Kg and an average of pH (in distilled
158 water) of 7.9. The parcel is used for cereal cultivation: before the barley (*Hordeum vulgare*),
159 the parcel was cultivated in wheat (*Triticum turgidum L. var. durum*). The two cereal crops
160 were separated by Brassicaceae cover crop of white mustard (*Sinapis alba*). The parcel was
161 stubbled then soil was tilled up to 30 cm and shallow tilled up to 5 cm just before sowing.

162 The used tractor-tire-tool system consisted of a Four-Wheel Drive tractor of 140 HP (Massey-
163 Ferguson 6714 S) equipped by Michelin Multibib 480/70 R28 and 580/70 R38 tires (front and
164 rear tires respectively), and hitched to a towed mini-till air-seeder fitted with a disc harrow
165 concave scalloped discs (Kuhn Espro 3000). The adjustable parameters chosen as controlled
166 factor were: tractor speed (three levels: 10, 12 and 14 Km/h), inflation pressure (three levels:
167 80, 100 and 140 kPa equivalent to 0.8, 1 and 1.4 bar), soil working depth (two levels: 5 and 10
168 cm) and the static axle load distribution (two levels: 60%/40% and 50%/50% on rear and front
169 axles respectively). The total load of the whole system within unequal axle load distribution
170 was 9.3 Mg and within the equal one was 9.28 Mg.

171 The combination between all controlled factors established an experimental design consisting
172 of 36 treatments enumerated from T01 to T36 (see table AII-I in Appendix II). Each treatment
173 was used to sow one strip of 60 m of length and 3 m of width. As shown in figure 1, Treatment

174 strips were randomized in three blocks horizontally. A buffer zone of 20 m of width was settled
175 between the blocks and served as setting adjustment zone (adjustment of parameters' level).
176 Each parallel treatment strips were spaced about 20 cm apart to prevent any possible sowing
177 overlap. Three additional lines of 3 m of width were also settled between treatment strips: the
178 first one is non-sowed line serving as control soil and the others served as traffic path of the
179 sprayer (later intervention in the cultivation process) to protect the treatment strips from any
180 additional traffic after sowing (c.f. figure 1). Sowing took place late February and soil was near
181 field capacity during sowing (average soil gravimetric water content = 23.4% and average
182 matric potential = -14.9 kPa).



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Figure 1: Schema of the experimental design showing the treatment strips enumerated from T01 to T36 and their distribution on field. Each treatment is defined in the schema starting by axle load distribution (%), inflation pressure (kPa), soil working depth (cm), and tractor speed (km/h). The dashed arrows indicate the direction of sowing.

186 2.2 Energetic data acquisition

187 Energy consumption was characterized by the specific fuel consumption per worked hectare.
188 Absolute fuel consumption was provided by the volumetric differential flow meter Aquametro
189 Contoil DFM8D installed in the supply and return lines of tractor's engine. Tractor pull was
190 determined using a dynamometric frame, equipped with two three-axial force transducers
191 SIXAXES FX2.3 (0.8 to 1.5 mV V⁻¹). A part of data such as an engine's RPM (Rotation Per
192 Minute), tractor real speed and Global Position System (GPS) data were provided through CAN
193 (controller area network) bus network (CAN 2.0A, 500 kb s⁻¹). Data were recorded every 10
194 ms with a universal acquisition unit (SIRIUSi 8xSTG+, DEWESoft) on the same time scale.
195 All necessary computing and conversions were made through the post-processing software
196 (Devesoft X) provided by DEWESoft. The straightforward during trails was controlled by an
197 autosteering option of Massey Ferguson Auto-Guide 3000 coupled with an RTK receiver
198 (Trimble AG-382) installed in the tractor cab and used position protocol J1939 with a precision
199 of 2.5 cm. In each treatment, mechanical data recording was started once the target value of the
200 ground speed is reached and motor regime was stabilized. In average, motor regime stabilized
201 after about 20 m from the beginning of the sowing on a treatment strip.



202
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Figure 2: Energetical data acquisition setup. a. general view of the tractor-seeder assembly. b. volumetric differential flow meter, c. dynamometric frame, d. three-axial force transducer, e. GPS-RTK receiver, f. universal acquisition unit.

205 **2.3 Soil properties and crop data acquisition**

206 Sampling was conducted on the zone where the motor regime is stabilized during sowing. To
207 insure a uniform sampling, the sampling was performed following the direction of sowing and
208 on the traffic trail of the right tires. Two sampling transects were selected, the first one at 30 m
209 of length, and the second one at 45 m. On each transect, three repetitions, spaced 1 m apart,
210 were sampled (i.e. six sampling repetition per treatment). Soil was sampled between 3-7 cm of
211 depth (on the seedbed) using a metallic cylinder of 100 cm³ of volume (inner diameter 5 cm,
212 height 5.1 cm). Soil sampling took place the next day after the sowing and soil was near field
213 capacity (same conditions of soil during the operation). The sampled cylinders were used to
214 measure air permeability (k_a in μm^2) using the method of Iversen et al. (2001) with a pressure
215 gradient of 5 hPa. Then, soil samples were oven-dried at 105 °C for 48 hours to determine bulk
216 density (BD in g/cm^3) using core method (ISO 11272). Barley emergence was assessed
217 counting the emerged barley plants at one to two leaves' stage on a linear meter for two
218 successive sowing arrays. Barley harvest was carried out late July and three repetitions were
219 sampled on a 5 m of length and 3 m of width of each treatment, then barley grains were weighted
220 and yield crop was calculated.

221 **2.4 Statistical analyses**

222 The relations between the controlled factors (i.e. tractor speed, inflation pressure, soil working
223 depth and axle load distribution) as explanatory variables and the normally distributed response
224 variables (i.e. BD, count of emerged plant, crop yield and fuel consumption) were examined
225 applying ordinary least square regression (OLS). The relations between the controlled factors
226 as explanatory variables and the non-normally distributed response variable (i.e. k_a) were
227 examined applying generalized linear model regression (GLM) using Poisson family. The
228 acquisition of tractor speed simultaneously with the energetic data acquisition offers the use of

229 the values of tractor speed as continuous explanatory factor to analyze the energetic response
230 variables, in which these values are close or equal to the three levels of tractor speed in a
231 stabilized motor regime. The interaction between the explanatory variables was considered in
232 the examination of the regressions. Then, the treatment was applied as explanatory variable of
233 the different response studied variables to examine its effect as single body factor. Analysis of
234 variance (ANOVA) was applied on the regression models to test the effect of the explanatory
235 variables and their interactions (in case of interaction) on the response variables. Multiple mean
236 comparison using post-hoc Duncan test following ANOVA analysis of variance was performed
237 to compare between the means of the different response variables with respect to the treatment.
238 Furthermore, means of BD per treatment was compared to the bulk density threshold for soil
239 compaction of 1.4 g/cm^3 (USDA Natural Resources Conservation Service) to assess whether
240 the treatment induced soil damage or not. Mean count of emerged barley was compared to the
241 count should be obtained with the germination rate of the sowed variety (51 plants/m) to assess
242 the effect of treatment on the success of the germination and seedling. Mean crop yield per
243 treatment was compared to the 2021 average crop yield of spring barley in Northern France
244 (Hauts-de-France state), which is equal to 6.32 t/ha (Arvalis, 2021), to assess the effect of
245 treatment on the success of the operation. A principle component analysis (PCA) was performed
246 to reveal the correlation between the agronomical performance indicators. Fuel consumption
247 means were also compared referring to the median of the fuel consumption, and the treatments
248 show significantly equal or lower consumption than this median are considered as showing
249 optimal consumption. To better explain the variation of fuel consumption as energetic response
250 variable, tractor pull (expressed in KN) was analyzed in the same way to discuss the effect of
251 controlled factors on energy consumption and traction efficiency. Then a Granger-Causality
252 test was performed to test the possible forecasting of fuel consumption by tractor pull.

253 All statistical analyses were performed using R software environment (R. Core Development
254 Team, 2020).

255 **3 Results**

256 **3.1 Effect of controlled factors on soil properties**

257 The regression of BD as function of the controlled factors shows that BD increased significantly
258 with the combination of the unequal axle load distribution, tractor speed and soil working depth
259 (see table AI-I in appendix I). k_a increased significantly with: i) soil working depth, ii) inflation
260 pressure, iii) the combination of unequal axle load distribution, tractor speed and soil working
261 depth, iv) the combination of unequal axle load distribution, tractor speed and inflation pressure,
262 v) the combination of unequal axle load distribution, soil working depth and inflation pressure,
263 vi) and the combination of tractor speed, soil working depth and inflation pressure. k_a decreased
264 significantly with: i) the combination of unequal axle load distribution and soil working depth,
265 ii) the combination of tractor speed and soil working depth, iii) the combination of unequal axle
266 load distribution and inflation pressure, iv) the combination of soil working depth and inflation
267 pressure, and v) the combination of the four factors together (see table AI-II in appendix I).
268 Noteworthy, the coefficient of determination (R^2) for the regression models of BD and k_a in
269 function to the controlled factors were 0.06 and 0.25 respectively. On the other hand, when the
270 combination of the four factors together (treatment) was used as single factor, then R^2 increased
271 to be 0.49 and 0.55 for BD and k_a respectively with a p-value < 0.001 .

272 **3.2 Effect of controlled factors on the emergence of barley and crop yield**

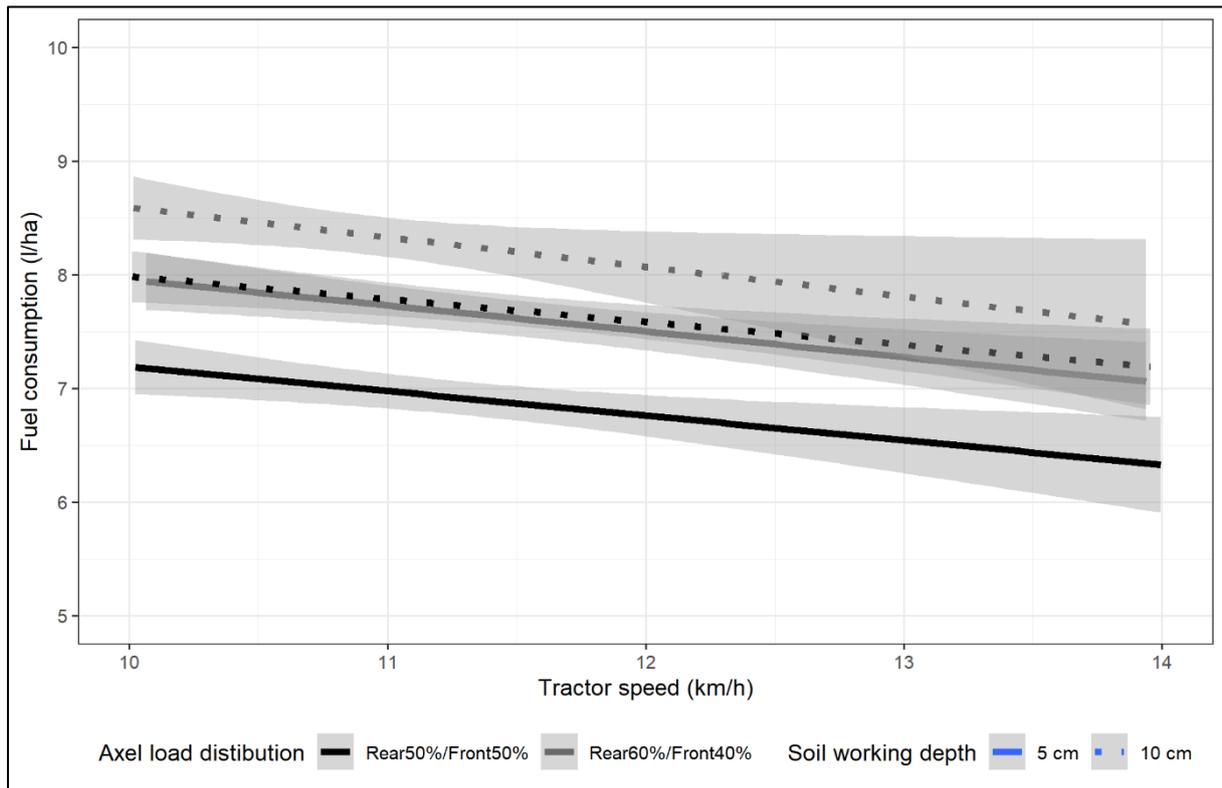
273 The count of emerged plant decreased significantly with the unequal axle load distribution, the
274 inflation pressure, and the combination of unequal axle load distribution, soil working depth
275 and inflation pressure (table AI-III, appendix I). Likewise, crop yield decreased significantly

276 with the combination of unequal load distribution, soil working depth and inflation pressure
277 (table AI-IV, appendix I). Noteworthy, R^2 for the regression models of the count of emerged
278 plant and the crop yield as function of the controlled factors were 0.46 and 0.19 respectively.
279 On the other hand, when the combination of the four factors together (treatment) was used as
280 single factor, then R^2 increased to 0.57 and 0.49 for the count of emerged plant and the crop
281 yield respectively with a p-value < 0.001 and p-value = 0.008 respectively.

282 **3.3 Effect of controlled factors on fuel consumption**

283 Fuel consumption increased significantly with: i) unequal axle load distribution, ii) soil working
284 depth, iii) tractor speed, iv) the combination of soil working depth and tractor speed, v) the
285 combination of unequal axle load distribution, tractor speed and soil working depth, vi) the
286 combination of unequal axle load distribution, tractor speed and inflation pressure, vii) the
287 combination of unequal axle load distribution, soil working depth and inflation pressure, and
288 viii) the combination of tractor speed, soil working depth and inflation pressure. Fuel
289 consumption decreased significantly with the combination of unequal axle load distribution and
290 inflation pressure, and ii) the combination of tractor speed and inflation pressure (table AI-V in
291 appendix AI). Noteworthy, R^2 of the regression model for fuel consumption as function of the
292 controlled factors was 0.50 and it increased to 0.56 when the combination of the four factors
293 together (treatment) was used as single factor. Considering the non-significant effect of
294 inflation pressure solely on fuel consumption, Figure 3 shows the fuel consumption as function
295 of the continuous tractor speed and categorized with respect to soil working depth and axle load
296 distribution. Irrespectively to the axle load distribution, fuel consumption was significantly
297 higher with the highest soil working depth, but the difference became non-significant when
298 tractor accelerate between 13 and 14 km/h (figure 3). Likewise, fuel consumption was higher
299 with the unequal axle load distribution (figure 3). Figure 3 shows that fuel consumption was
300 significantly equal using unequal axle load distribution combined to the 5 cm of soil working

301 depth or the equal axle load distribution combined to the 10 cm of soil working depth,
 302 independently from the speed of tractor. On the other hand, it shows that the combination
 303 between the equal axle load distribution and the 5 cm of soil working depth demonstrated the
 304 lowest fuel consumption. A slight decrease of fuel consumption with the continuous tractor
 305 speed was also found (figure 3).



306
 307 *Figure 3: Variation of fuel consumption in function to the continuous tractor speed and categorized with respect to soil working*
 308 *depth (line type) and axel load distribution (line color).*

309 **3.4 Trade-off between fuel consumption, soil conservation and barley** 310 **production**

311 Table 1 shows the means of the different studied indicators and the results of their comparison.
 312 Six treatments (T05, T12, T26, T27, T29 and T32) show an average of k_a significantly lower
 313 than the average k_a of the control soil ($9.46 \mu\text{m}^2$). There was no treatment showing an average
 314 BD significantly higher than the control soil (1.39 g/cm^3), but 10 treatments (T12, T13, T19,
 315 T26, T27, T29, T31, T32, T33, T36) showed an average BD higher than the threshold of
 316 compaction for a silty loam soil (1.4 g/cm^3). A total of 19 treatments (T01, T02, T07, T13, T17,

317 T18, T20, T21, T24, T25, T27, T28, T29, T30, T31, T32, T33, T35, T36) showed an average
318 count of emerged plant lower than the average of emerged plants expected at the germination
319 rate of the used variety of barley (51 emerged plant/m). For the reason of an operational
320 problem, we could not have the count of emerged plant for T19, T22, T23 and T34. A total of
321 11 treatments (T02, T05, T06, T07, T08, T17, T24, T25, T30, T31 and T34) showed an average
322 crop yield lower than the average of barley yield in Northern France in 2021 (6.32 t/ha). For
323 the reason of an operational problem, the yield of T19, T22 and T23 are missed.

324 *Table 1: Mean of the studied indicators (i.e. air permeability, bulk density, count of emerged plant, crop yield, fuel consumption*
325 *and traction power) and their groups resulted from post-hoc Duncan mean comparison analyses following one-way analysis*
326 *of variance (ANOVA). Means that are not in same group of letters are significantly different at a level of p-value ≤ 0.05 . NA*
327 *means No Available and corresponds to the missed data. (See Table AII-1 in Appendix II for the details of the treatments).*

Treatment	ka (μm^2)	BD (g/cm^3)	Count of emerged plant	Crop yield (t/ha)	Fuel consumption (l/ha)	Tractor pull (KN)
Control	9.46 klmnop	1.39 abcdef	NA	NA	NA	NA
T01	7.74 nopqr	1.26 gh	50.83 abcdef	6.378 abcdef	5.88 s	12.69 ij
T02	12.36 jkl	1.37 bcdef	49.83 abcdefg	5.964 cdef	7.15 lmno	12.69 ij
T03	5.12 klmnop	1.32 efg	53.5 abc	6.747 abcdef	7.46 hi	11.56 klm
T04	7.95 mnopqr	1.37 bcdef	54 ab	6.782 abcdef	7.05 pqr	14.19 fgh
T05	5.72 rst	1.39 abcdef	56.5 a	6.133 bcdef	NA	NA
T06	8.27 pqrs	1.33 cdefg	52.83 abcde	6.169 bcdef	7.62 ijkl	13.59 ghi
T07	15.88 hi	1.36 cdef	46.5 bcdefgh	6.262 abcdef	7.43 o	14.31 efgh
T08	21.11 f	1.25 gh	52.83 abcde	6.129 bcdef	7.75 klmno	15.15 bcde
T09	13.71 ijk	1.31 efg	54 ab	7.729 a	8.16 cde	14.14 fgh
T10	8.93 klmno	1.38 abcdef	52.67 abcde	7.049 abcd	6.23 rs	11.56 klm
T11	24.13 e	1.21 h	55 a	6.373 abcdef	7.09 jklmn	11.19 mno
T12	7.15 qrs	1.41 abcdef	53.5 abc	6.644 abcdef	7.03 op	11.44 lmn
T13	8.93 lmno	1.41 abcdef	50.33 abcdefg	6.076 bcdef	5.7 rs	12.18 jkl
T14	40.89 a	1.3 fg	52 abcde	7.609 ab	6.28 pqr	10.47 o
T15	12.84 klmn	1.37 bcdef	51 abcde	6.911 abcdef	6.59 qr	10.58 no
T16	8.71 nopqr	1.35 cdefg	53.33 abcd	6.72 abcdef	7.59 jklmn	13.36 hi
T17	7.75 klmno	1.37 bcdef	49.67 abcdefg	6.036 cdef	7.89 a	14.24 efgh
T18	12.35 klmno	1.38 abcdef	46.67 bcdefgh	6.533 abcdef	7.61 mno	14.23 efgh
T19	37.49 b	1.41 abcde	NA	NA	6.99 hij	12.39 jk
T20	20.46 fg	1.33 defg	49.33 abcdefg	6.56 abcdef	7.38 jklmn	12.79 ij
T21	3.85 t	1.36 cdef	50.33 abcdefg	6.711 abcdef	6.86 pq	12.36 jk
T22	10.35 jkl	1.39 abcdef	NA	NA	7.03 no	14.45 defg
T23	9.03 opqr	1.36 cdef	NA	NA	8.52 hij	14.84 cdef
T24	17.05 gh	1.36 bcdef	40 hij	5.431 ef	8.85 def	14.84 cdef
T25	11.64 klm	1.38 abcdef	40 hij	5.409 f	8.14 gh	15.78 b
T26	7.4 qrs	1.4 abcdef	48.67 abcdefg	7.391 abc	8.52 fg	15.31 bcd
T27	7.63 qrs	1.48 a	44.83 efghi	7.204 abc	8.87 bc	14.15 fgh
T28	17 hij	1.34 cdefg	46 bcdefgh	7.413 abc	7.71 gh	12.66 ij
T29	4.08 st	1.44 abc	36 j	7.347 abc	7.75 ijk	13.41 hi
T30	15.78 d	1.17 h	37.67 ij	6.218 abcdef	7.89 ijklm	11.41 lmn
T31	9.65 mnopqr	1.41 abcde	45.5 cdefghi	5.667 def	7.36 ijk	13 ij
T32	7.21 qrs	1.4 abcdef	37.83 ij	6.573 abcdef	6.69 op	12.82 ij
T33	9.58 mnopqr	1.43 abcd	40.83 hij	6.373 abcdef	8.58 bcd	12.8 ij
T34	10.64 klmnop	1.39 abcdef	NA	5.569 def	6.09 rs	10.43 o
T35	32.26 c	1.32 efg	39 hij	7.436 abc	8.43 b	16.93 a
T36	36.39 b	1.47 ab	42.83 ghij	6.942 abcde	8.71 efg	15.54 bc

328 Nine treatments (T09, T17, T24, T26, T27, T28, T33, T35 and T36) show an average fuel
329 consumption significantly higher than the median of the global consumption (7.46 l/ha). For a
330 reason of a technical problem during the registration of energetical data, the consumption of

331 T05 was missed. All the remaining treatments could be considered as performant for the
332 specific studied indicator. The common performant treatments between all the indicators are
333 considered as the expected trade-off between the soil conservation, barley production and fuel
334 consumption. Seven treatments (T03, T04, T10, T11, T14, T15, and T16) showed this trade-off
335 (see table AII-I in appendix II for the details of treatment combinations).

336 **4 Discussion**

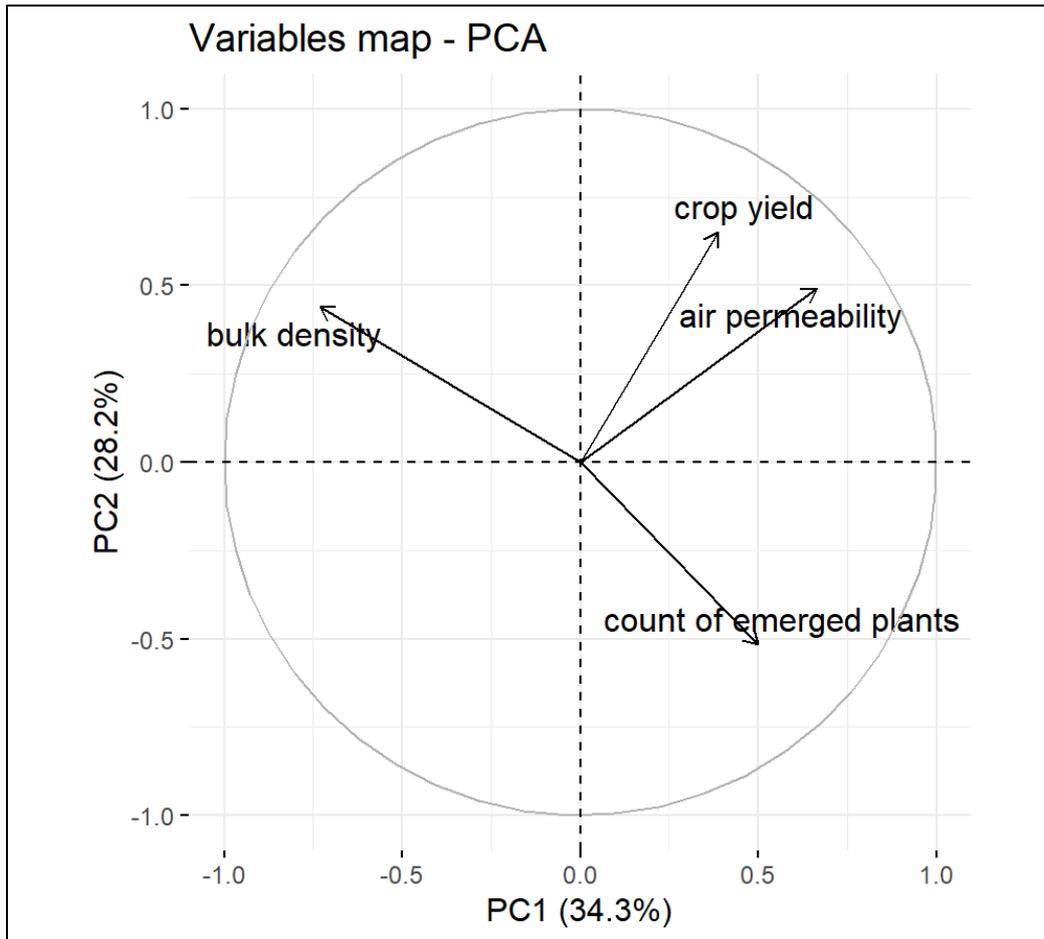
337 **4.1 Influence of adjustable parameters on the agronomical performance**

338 The agronomical performance is evaluated with regard to the conservation of soil physical
339 properties and the success of the sowing operation. BD and k_a were negatively correlated ($\rho=-$
340 0.56 and $p\text{-value}<0.001$) but they did not show similar response. The impact of the controlled
341 factors and their combinations was higher on k_a than BD. Indeed, air permeability is reported
342 to be highly sensitive to macroporosity and pore continuity, and the change in pore continuity
343 exceed the change in pore volume (Chen et al., 2014; Dörner and Horn, 2009). The present
344 results agree with Tuli et al. (2005) showing the greatest effect of structural disturbance on air
345 permeability. The increase of k_a with the increase soil working depth indicates that a deeper soil
346 cultivation work can improve soil porosity and their continuity. Contrarily to what was
347 expected, the increase of inflation pressure did not lead to neither decrease k_a via the decrease
348 of soil-tire contact area, nor showing significant increase of BD. This could be attributed to
349 probable beneficial effect of soil compaction after deep tillage of the soil, under which
350 aggregate stability, as determinant factor of soil permeability, can be degraded (Cavalieri et al.,
351 2009; Tuli et al., 2005). Both, BD and k_a were influenced by the combinations of the controlled
352 factors, and the augmentation of R^2 when the treatment was applied as single body factor may
353 explain that the four adjustable parameters interact between them and act to explain the
354 variation in the soil properties. This support our hypothesis that to reduce soil compaction on

355 seedbed, a tractor-tire-tool system should be adjusted as an entire system rather to treat each
356 parameter in solo. For instance, the reduction of soil structural deformation via adjustments on
357 inflation pressure is well documented (see as example: Douglas et al., 1992; Keller, 2005;
358 Raper, 2005; Schjønning et al., 2008; Schwanghart, 1991), but rarely the distribution of axle
359 load between rear and front axles was reported in the considered researches. Our findings show
360 that the distribution of axle load between rear and front axle is an important factor to reduce
361 soil deformation, though its effect appears when it is coupled with adjustments of other factors.
362 As an example, the increase of BD with the combination of unequal axle load distribution,
363 tractor speed and soil working depth, can be explained by the combined effect of the higher
364 load on the rear axle and the deeper soil work on the traction which may increase slip and
365 increase soil compaction (Janulevičius and Damanauskas, 2015). This result is consistent with
366 Çarman (1994) who found that tire load has higher effect than tractor forward velocity on soil
367 cone index, shear strength and bulk density. The increase of k_a with the previous combination
368 may be justified by an increase of soil microporosity (Dickerson, 1976) increasing air diffusion.
369 Even though, the increase of inflation pressure showed a positive effect on k_a , it decreased when
370 inflation pressure joined the combination mentioned above. This suggests that the obtained
371 improvement of pore continuity and connectivity can be disadvantaged by the decrease of soil-
372 tire contact area and related closer to the inflation pressure than the other factors.

373 The controlled factors affected the crop yield and seedling of barley. Their effect appeared
374 clearly when they were analyzed as a single factor (i.e. treatment) by the increase of R^2 of the
375 regression models for the count of emerged plant and crop yield. The two models showed that
376 about 50% of the variation of crop yield and emergence of barley is explained by the treatment
377 as a single factor. However, there was no one evident effect of the controlled factors and their
378 combinations on these two indicators. The principle component analysis (PCA) showed a
379 positive correlation between crop yield and air permeability, as well as a negative correlation

380 between emergence of barley and bulk density (figure 4). Consequently, the compression of
381 soil porosity impedes barley seedling, but the increase of air permeability benefits the growth
382 of barley leading to a greater yield. Thus, the impact of the controlled factors on soil physical
383 properties leads to influence indirectly plant seedling and crop yield.



384
385 *Figure 4: Principal Component Analysis on the agronomic performance indicators*

386 A fully sufficient agronomical performance could be obtained without introducing damage on
387 soil physical properties disturbing soil aeration to obtain a favorable seedling and crop yield
388 (Tang et al., 2011). The treatments identified as agronomically performing are the ones showing
389 higher k_a , lowest BD, higher crop yield and higher count of emergence plant. The fully
390 agronomical performing treatments are T03, T04, T09, T10, T11, T14, T15, T16 (see table AII-
391 I in appendix II for the details of the treatment combinations). We remark that the agronomically
392 performing treatments belong to the equal distributed axle load. This result probably

393 demonstrates better distribution of stress on the soil when the load is equally distributed
394 between rear and front axle, leading to a lesser disturbance of soil structure, and therefore,
395 improving agronomical production.

396 **4.2 Influence of adjustable parameters on the energetical performance**

397 Our findings show the decrease of fuel consumption when the axle load was equally distributed.
398 They are consistent with previous studies showing the increase of fuel consumption with the
399 increase of tillage depth (named as soil working depth in the present study) and tractor speed
400 (Mamkagh, 2018). Even though, there was no significant effect of inflation pressure solely on
401 fuel consumption. Inflation pressure has the power to significantly decrease fuel consumption
402 when it is combined to tractor speed or unequal axle load distribution. In contrast, when soil
403 working depth is added to these two combinations, fuel consumption increases significantly.
404 The slight decrease of fuel consumption with the increase of tractor speed, shown in figure 3,
405 is induced by the effect of the combination of tractor speed, soil working depth and axle load
406 distribution. This combination showed a significant effect on decreasing fuel consumption
407 when soil working depth decreases and the axle load is equally distributed. Thus, an evident
408 higher effect of the working depth and axle load distribution compared to tractor speed on fuel
409 consumption is found. To better explain the variation of fuel consumption, tractor pull was also
410 examined through the same data analyses performed for fuel consumption. Regarding the
411 variation of tractor pull in function of the continuous speed of tractor and categorized with
412 respect to the soil working depth and axle load distribution, we observed almost a similar
413 relationship compared to fuel consumption, but inversely related to the tractor speed (see figure
414 AI-1 in appendix I). Fuel consumption and total tractor pull were correlated ($\rho = 0.47$, p-value
415 < 0.001), and these two variables depend on the variation of the controlled factors and their
416 combinations. Otherwise, the factors and their combinations that influenced significantly fuel
417 consumption showed significant influences on tractor pull. Running a Granger-Causality test to

418 investigate whether tractor pull is useful for forecasting fuel consumption or not, we found that
419 tractor pull significantly Granger-causes fuel consumption (F-value = 32.1, p-value < 0.001).
420 For instance, the lower tractor pull was found with the combination showed the lower fuel
421 consumption (see figure 3 and figure AI-1 in appendix I).

422 Similarly to what we found studying the agronomical performance for the tractor-tire-tool
423 system, the augmentation of R^2 when we applied the treatment as single body factor may explain
424 that the four adjustable parameters interact between them and act as a combination to explain
425 the variation of the energetical performance. The energetical performance must compromise
426 between efficient tractor pull (i.e. higher tractor pull) and the lower fuel consumption. Means
427 of tractor pull were compared using Duncan post-hoc test following ANOVA analysis of
428 variance, then they were compared referring to the median of tractor pull (13 KN). When a
429 tractor pull is significantly equal or higher than this median, the tractor power of the treatment
430 is considered efficient. Several treatments showed an efficient tractor pull and lower fuel
431 consumption, including the treatments showed high fuel consumption. The energetically
432 performant treatments are those showed optimal fuel consumption and efficient tractor pull.
433 Consequently, a total of 17 treatments (T01, T02, T04, T06, T07, T08, T16, T17, T18, T20,
434 T22, T23, T25, T29, T31, T32, T33) are considered as energetically performant.

435 **4.3 Trade-off between the agronomical performance and the energetical** 436 **performance**

437 Even though, the agronomical performance and the energetical performance could not be
438 correlated, the adjustable parameters on a tractor-tire-tool system influence them both. The
439 studied adjustable parameters on a tractor-tire-tool system (i.e. tractor speed, inflation pressure,
440 ale load distribution and soil working depth), shown as treatment, to affect, both, the energetical
441 and the agronomical performances. Thus, the adjustment on a tractor-tire-tool system should

442 consider all these four factors as a combination to optimize the performance energetically and
443 agronomically. A trade-off between the optimization of these performances could be obtained
444 considering the common treatments as energetically and agronomically performant in the
445 present paper. This trade-off can be obtained with T04 and T16, so applying an equal axle load
446 distribution, 10 cm of soil working depth, and accelerating tractor speed at 14 km/h combined
447 to 80 kPa or 140 kPa of inflation pressure.

448 **5 Conclusion**

449 The present paper presents the first study showing the combined effect of adjustable parameters,
450 in a tractor-tire-tool system, on soil conservation, agronomical production, and energy
451 optimization. Our study showed that the combination between tractor speed, axle load
452 distribution, soil working depth and inflation pressure could be adjusted in a simple way by the
453 operator to optimize the energetical and agronomical performances. We found that pore
454 continuity is more sensitive than pore space to the variation of the adjustable parameters in
455 tractor-tire-tool system. Fuel consumption depends on the variation of the adjustable parameters
456 and their combinations. The agronomical performance, revealed by barley successful seedling,
457 barley yield, and the conservation of physical soil properties on seedbed, as well as the
458 energetical performance, revealed by the optimization of fuel consumption, depend on the
459 combination of the studied adjustable parameters shown as treatment. Equally distributing the
460 axle load on the rear and the front axle may lead to better agronomical and energetical
461 performances. The trade-off between an agronomical performance and an energetical
462 performance, for a tractor-tire-tool system carrying out a sowing operation of spring barley on
463 a silty loam Luvisol with an average of gravimetric water content of 23.4% , can be obtained,
464 equally distributing the axle load distribution, working the soil at 10 cm of depth, and
465 accelerating tractor speed at 14 km/h combined to 80 kPa or 140 kPa of inflation pressure. We

466 state that the present work shows the results of an experiment conducted on one site with
467 specific soil conditions and over one season of an agricultural year. Therefore, as perspectives,
468 complementary studies will take place over other season (some of them are conducted) and on
469 other conditions, which they will support the finding presented in this manuscript.

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479 **7 Conflict of interest**

480 The authors declare no conflict of interest.

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Appendix I

Table AI-I: Descriptive of the regression model of soil bulk density as response variable to the controlled factors as explanatory variables and their combinations and the descriptive statistics of its analysis of variance (ANOVA). Significance is required at level of p-value ≤ 0.05

Factor	Regression model		One-way ANOVA	
	coefficient estimate	t value	F value	p-value
Intercept	-2420.1585	-1.104		
axle load distribution	47.56	1.2	0.4341	0.51088
tractor speed	194.6304	1.076	1.1436	0.28642
soil working depth	259.5075	0.945	1.0241	0.31299
inflation pressure	1362.7166	0.687	0.1555	0.69385
axle load distribution*tractor speed	-3.7847	-1.156	0.6287	0.42895
axle load distribution*soil working depth	-4.9872	-1.001	0.0363	0.84906
tractor speed*soil working depth	-19.4962	-0.862	1.2033	0.27423
axle load distribution*inflation pressure	-26.6938	-0.744	0.6164	0.43348
tractor speed*inflation pressure	-105.3601	-0.642	0.7889	0.37571
soil working depth*inflation pressure	-131.7564	-0.532	0.046	0.83038
axle load distribution*tractor speed*soil working depth	0.3747	0.912	3.9665	0.04802
axle load distribution*tractor speed*inflation pressure	2.0643	0.695	0.6699	0.41422
axle load distribution*soil working depth*inflation pressure	2.5349	0.564	0.4857	0.48683
tractor speed*inflation pressure*soil working depth	9.1423	0.447	0.0908	0.7635
axle load distribution*tractor speed*soil working depth*inflation pressure	-0.1769	-0.447	0.2271	0.63429

Table AI-II: Descriptive of the regression model of air permeability (*ka*) as response variable to the controlled factors as explanatory variables and their combinations and the descriptive statistics of its analysis of variance (ANOVA). Significance is required at level of p-value ≤ 0.05 .

Factor	Regression model		One-way ANOVA	
	coefficient estimate	z value	F value	p-value
Intercept	-71.127679	-2.976		
axle load distribution	1.469154	3.386	3.3941	0.06
tractor speed	8.058658	1.095	0.0591	0.8
soil working depth	6.322077	2.042	6.9021	0.008
inflation pressure	84.263647	3.778	9.0476	0.003
axle load distribution*tractor speed	-0.158306	-4.428	0.0015	0.97
axle load distribution*soil working depth	-0.120532	-2.158	8.3178	0.003
tractor speed*soil working depth	-0.721726	-2.842	14.6787	0.0001
axle load distribution*inflation pressure	-1.668115	-4.135	38.1062	< 0.001
tractor speed*inflation pressure	-8.616875	-4.717	54.8486	< 0.001
soil working depth*inflation pressure	-8.083682	-2.784	29.5376	< 0.001
axle load distribution*tractor speed*soil working depth	0.013822	3.014	13.6397	< 0.001
axle load distribution*tractor speed*inflation pressure	0.169227	5.129	23.782	< 0.001
axle load distribution*soil working depth*inflation pressure	0.154501	2.955	31.2684	< 0.001
tractor speed*inflation pressure*soil working depth	0.828213	3.488	6.1723	0.01
axle load distribution*tractor speed*soil working depth*inflation pressure	-0.015923	-3.724	13.9243	< 0.001

Table AI-III: Descriptive of the regression model of the count of emerged plant as response variable to the controlled factors as explanatory variables and their combinations and the descriptive statistics of its analysis of variance (ANOVA). Significance is required at level of p-value ≤ 0.05 .

Factor	Regression model		One-way ANOVA	
	coefficient estimate	t value	F value	p-value
Intercept	1096.29412	2.289		
axle load distribution	-20.66779	-2.373	1198.8177	< 0.001
tractor speed	-67.23739	-1.69	0.0021	0.96
soil working depth	-783.98693	-1.804	7.9275	0.005
inflation pressure	-126.67311	-2.03	0.5992	0.44
axle load distribution*tractor speed	1.34237	1.853	0.2026	0.65
axle load distribution*soil working depth	15.64402	1.982	0.4774	0.49
tractor speed*soil working depth	49.94223	1.386	1.9705	0.16
axle load distribution*inflation pressure	2.46372	2.158	0.176	0.66
tractor speed*inflation pressure	8.53557	1.635	0.6332	0.43
soil working depth*inflation pressure	100.26564	1.785	0.8358	0.36
axle load distribution*tractor speed*soil working depth	-1.01015	-1.542	0.1815	0.67
axle load distribution*tractor speed*inflation pressure	-0.16788	-1.753	2.3595	0.12
axle load distribution*soil working depth*inflation pressure	-1.95777	-1.911	11.7516	< 0.001
tractor speed*inflation pressure*soil working depth	-6.39916	-1.366	1.404	0.24
axle load distribution*tractor speed*soil working depth*inflation pressure	0.12673	1.48	2.1907	0.14

Table AI-IV: Descriptive of the regression model of crop yield as response variable to the controlled factors as explanatory variables and their combinations and the descriptive statistics of its analysis of variance (ANOVA). Significance is required at level of p-value ≤ 0.05 .

Factor	Regression model		One-way ANOVA	
	coefficient estimate	t value	F value	p-value
Intercept	298.56431	0.275		
axle load distribution	-4.48587	-0.222	0.0127	0.91
tractor speed	5.50072	0.059	1.9101	0.17
soil working depth	-68.03469	-0.74	0.6039	0.44
inflation pressure	101.85032	0.096	2.1096	0.15
axle load distribution*tractor speed	-0.09509	-0.054	0.2229	0.64
axle load distribution*soil working depth	1.44673	0.541	0.003	0.96
tractor speed*soil working depth	2.59027	0.207	1.0844	0.30
axle load distribution*inflation pressure	-1.98357	-0.1	0.0176	0.89
tractor speed*inflation pressure	-33.18263	-0.359	3.2114	0.07
soil working depth*inflation pressure	23.39295	0.166	0.7032	0.40
axle load distribution*tractor speed*soil working depth	-0.06162	-0.262	1.9576	0.17
axle load distribution*tractor speed*inflation pressure	0.63508	0.718	1.8725	0.17
axle load distribution*soil working depth*inflation pressure	-0.55876	-0.21	5.4257	0.02
tractor speed*inflation pressure*soil working depth	1.13126	0.09	0.2011	0.65
axle load distribution*tractor speed*soil working depth*inflation pressure	-0.01301	-0.054	0.003	0.96

Table AI-V: Descriptive of the regression model of fuel consumption as response variable to the controlled factors as explanatory variables and their combinations and the descriptive statistics of its analysis of variance (ANOVA). Significance is required at level of p-value ≤ 0.05 .

Factor	Regression model		One-way ANOVA	
	coefficient estimate	t value	F value	p-value
Intercept	-78.4	44.69		
axle load distribution	1.669	0.7983	104.1911	< 0.001
tractor speed	4.319	3.902	158.4399	< 0.001
soil working depth	2.941	6.368	104.857	< 0.001
inflation pressure	91.64	43.49	1.6555	0.198885
axle load distribution*tractor speed	-91.45	0.06965	0.7545	0.385527
axle load distribution*soil working depth	-0.06271	0.1124	1.7052	0.192282
tractor speed*soil working depth	-0.05395	0.5676	6.7989	0.009428
axle load distribution*inflation pressure	-1.774	0.7658	19.8829	< 0.001
tractor speed*inflation pressure	-5.52	3.834	4.2082	0.040813
soil working depth*inflation pressure	-4.75	6.517	2.4127	0.121065
axle load distribution*tractor speed*soil working depth	0.000265	0.01002	15.7643	< 0.001
axle load distribution*tractor speed*inflation pressure	0.11	0.06772	5.7153	0.017233
axle load distribution*soil working depth*inflation pressure	0.102	0.1143	22.386	< 0.001
tractor speed*inflation pressure*soil working depth	0.148	0.5868	3.9397	0.047773
axle load distribution*tractor speed*soil working depth*inflation pressure	0.00428	0.01029	0.1733	0.67739

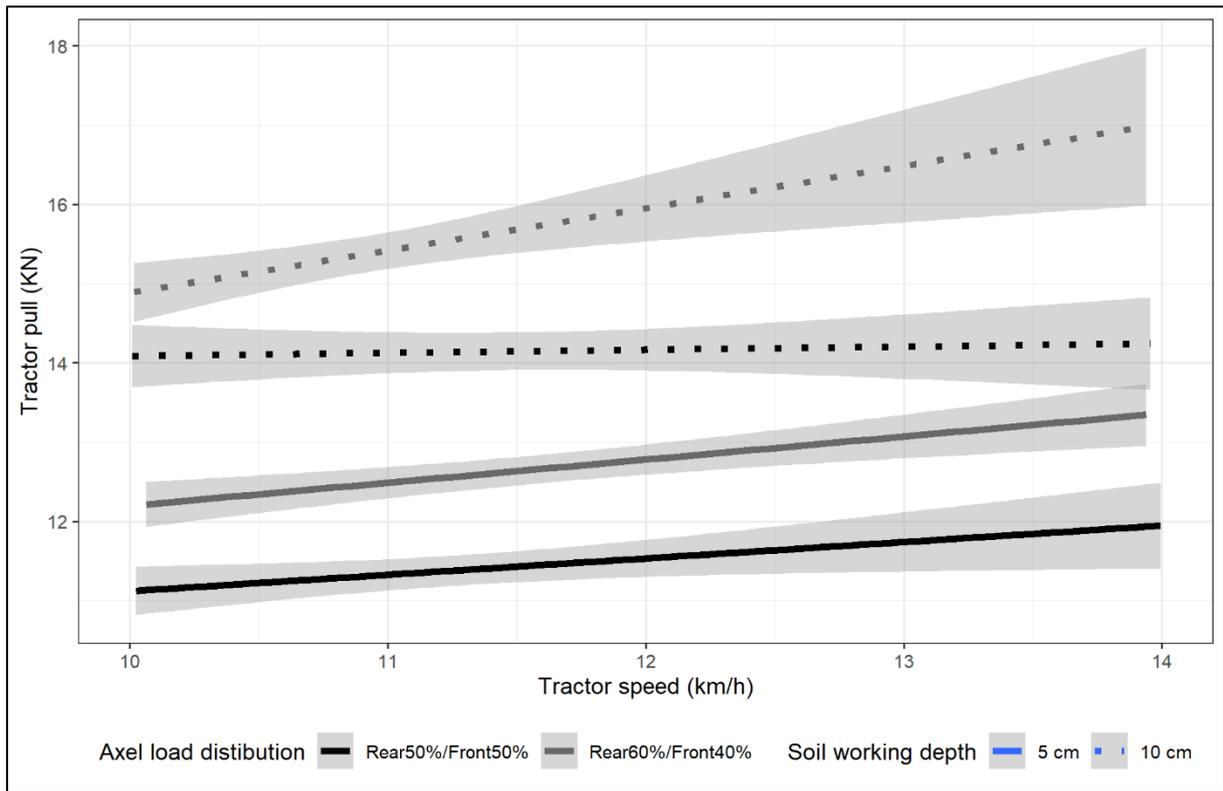


Figure AI-I: Variation of tractor pull (kN) in function to the continuous tractor speed and categorized with respect to soil working depth (line type) and axle load distribution (line color).

Appendix II

Treatment	Axel load distribution (rear axle/front axle)	Tractor speed (km/h)	Inflation pressure (kPa)	Soil working depth (cm)
T01	50%/50%	14	140	5
T02	50%/50%	12	140	5
T03	50%/50%	10	140	5
T04	50%/50%	14	140	10
T05	50%/50%	12	140	10
T06	50%/50%	10	140	10
T07	50%/50%	14	100	10
T08	50%/50%	12	100	10
T09	50%/50%	10	100	10
T10	50%/50%	14	100	5
T11	50%/50%	12	100	5
T12	50%/50%	10	100	5
T13	50%/50%	14	80	5
T14	50%/50%	12	80	5
T15	50%/50%	10	80	5
T16	50%/50%	14	80	10
T17	50%/50%	12	80	10
T18	50%/50%	10	80	10
T19	60%/40%	14	140	5
T20	60%/40%	12	140	5
T21	60%/40%	10	140	5
T22	60%/40%	14	140	10
T23	60%/40%	12	140	10
T24	60%/40%	10	140	10
T25	60%/40%	14	100	10
T26	60%/40%	12	100	10
T27	60%/40%	10	100	10
T28	60%/40%	14	100	5
T29	60%/40%	12	100	5
T30	60%/40%	10	100	5
T31	60%/40%	14	80	5
T32	60%/40%	12	80	5
T33	60%/40%	10	80	5
T34	60%/40%	14	80	10
T35	60%/40%	12	80	10
T36	60%/40%	10	80	10

Table All-I: the configuration of the combinations between the adjustable parameters (controlled factors).