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1 **Postprint version**

2

3 **Predicting the in situ rate constant of soil carbon mineralisation from laboratory-**
4 **based measurements in tropical soils under contrasting tillage management**
5 **systems**

6

7 Jorge Sierra*, Lucienne Desfontaines

8 ASTRO Agrosystèmes Tropicaux, INRA, 97170, Petit-Bourg, Guadeloupe,
9 France

10 * Corresponding author. E-mail: jorge.sierra@inra.fr

11

12

13 **Abstract**

14

15 Predicting soil organic carbon (SOC) mineralisation in the field is crucial to
16 assessing the impact of changes in land use and tillage practices. Although soil
17 data from long-term field experiments are essential to calibrate model parameters
18 for SOC mineralisation, these are frequently lacking regarding some parts of the
19 tropics. The aim of this study was to develop and test an indicator for the in situ
20 SOC mineralisation rate constant using data obtained during soil incubation in the
21 laboratory. Sixty-nine plots corresponding to four soil types (andosol, nitisol,
22 ferralsol and vertisol) under six crops (banana, sugarcane, vegetables, yam, melon
23 and pineapple) involved in 12 tropical cropping systems were analysed. Soil
24 sampling and laboratory incubation procedure were designed to reflect the long-
25 term impact of cropping systems on SOC dynamics. Data from long-term
26 experiments were obtained from a previous study performed on the same cropping
27 systems in Guadeloupe (Caribbean). While SOC contents and stocks were only
28 controlled by soil type, mineralised SOC in the laboratory (C_{\min}) was con-
29 trolled to the same degree by both soil type and crop. Moreover, the C_{\min}/SOC ratio, which is
30 an indicator of the more active SOC fraction, was only controlled by the crop.
31 Although C_{\min} and C_{\min}/SOC were not affected by recent C inputs from crop
32 residues, they were negatively correlated with the rate constant of SOC
33 mineralisation observed in the field (k_{field}). These results indicate that differences
34 between the cropping systems (i.e. perennial vs. annual crops) concerning the
35 management of soil tillage markedly affected depletion of the mineralisable SOC
36 fraction. Overall, the results showed that C_{\min} measured under regulated laboratory

37 conditions could be helpful to estimate k_{field} . This is important in tropical regions in
38 order to anticipate the effects of changes in land use and tillage management
39 before changes in SOC stocks become noticeable in the field.

40

41 *Keywords:* Caribbean, Cropping system, Indicator, Long-term effect, Soil
42 incubation, Soil type

43

44

45 **1. Introduction**

46

47 The accurate prediction of soil organic carbon (SOC) mineralisation under field
48 conditions is of crucial importance from both the agronomic and environmental points of
49 view (Oelbermann et al., 2017). In the long-term (e.g. decade or century), predicting
50 SOC mineralisation is necessary to assess the impact of changes in land use, farming
51 practices and tillage management on soil quality and C emissions (Lal, 2004). Although
52 some authors used soil incubations to estimate the rate constants to be included in
53 models devoted to conceptualising and de- scribing SOC mineralisation in the field
54 (Brisson et al., 2003), an alternative procedure involves the statistical fitting of data
55 obtained from diachronic measurements of SOC content in the field (e.g. Andriulo et
56 al., 1999; Sierra et al., 2015). The advantage of this method over laboratory incubations
57 is that it integrates all aspects of managing the plant-soil system over many years,
58 including the impacts on SOC turnover of crop residue management and soil tillage
59 (Cerri et al., 2007). However, this method requires a relatively important soil database
60 including information on the farming practices that affect SOC turnover (e.g. rotations,
61 amount and quality of crop residues, management of organic amendments, intensity of
62 soil tillage), which may be unavailable, particularly in tropical regions (Sierra et al.,
63 2017).

64 Although changes in agricultural management may influence the mineralisation
65 rate constant, the ability of the models of SOC dynamics to assess the impact of such
66 changes depends on including of farming practices in the model framework. For
67 example, only a few models of SOC dynamics have explicitly considered the increase
68 in SOC decomposition following soil tillage (Bortolon et al., 2009), which is a major
69 process that affects the SOC balance (Martínez et al., 2017). In the case of the
70 Century model adapted to the conditions of Southern Brazil, soil tillage is represented
71 by a cultivation parameter which operates as a multiplier to enhance the mineralisation
72 rate constant of SOC fractions during the two months that follow tillage operations

73 (Bortolon et al., 2011). However, it may be difficult to extrapolate this empirical approach
74 based on local information about farming practices to other tropical regions such as the
75 Caribbean, where these practices may vary considerably as a function of farmer's
76 resources and the orientation of agricultural production; e.g. perennial crops such
77 as sugarcane and banana vs. annual food and vegetable crops (IFAD, 2014). For
78 example, Sierra et al. (2017) found that vegetable crop systems in Guadeloupe, an
79 archipelago in the Caribbean, could be represented by five farm types that applied
80 contrasting tillage systems on very different soil types, ranging from manual cultivation
81 to more labour-intensive strategies which include up to six tillage operations per year.
82 By contrast, soil tillage under perennial crops is only applied once every five or six
83 years, at the time of planting (Raphael et al., 2012).

84 Compared with complex models of SOC dynamics, simple models of the
85 annual SOC balance require minimal data inputs and few parameters (Saffih-Hdadi
86 and Mary, 2008) and are therefore well suited to situations with scarce agricultural
87 data, such as in the Caribbean. This also concerns the lack of suitable model
88 parameters regarding most tropical food and vegetable crops (Nin-Pratt et al.,
89 2011). Undoubtedly, such models may be less robust than process-based models, so
90 that their accuracy in assessing the impact on SOC dynamics of new cropping
91 systems or changes of farming practices needs to be tested (Coucheney et al.,
92 2015). In this context, the use of soil indicators of the SOC mineralisation rate
93 constant calibrated from long-term field experiments may be helpful to predict SOC
94 changes under new agricultural scenarios. This is important in tropical regions in
95 order to anticipate the effects of changes in land use (e.g. conversion of food to
96 energy crops) and practices (e.g. manual vs. mechanical soil tillage) (FAO
97 Subregional Office for the Caribbean, 2013), before changes in SOC stocks may be
98 noticed in the field.

99 In a previous study, Sierra et al. (2015) designed the MorGwanik model of
100 SOC dynamics adapted to the pedoclimatic conditions of the Caribbean in order to
101 assess SOC changes under export and diversified agriculture at the level of the
102 Agro-Ecological Region (AER). The aim of the present study was to evaluate the
103 ability of an indicator based on SOC mineralisation under laboratory conditions to
104 predict the mineralisation rate constants obtained by these authors from long-term field
105 studies, which involved twelve cropping systems under contrasting tillage
106 management. To achieve this, four conditions were imposed to the laboratory
107 experiment: i- only soils under monoculture were selected for the trial in order to
108 best reflect the impact of the management of each crop, ii- soil sampling from each

109 selected plot was carried out on sub plots that did not receive crop residues following
110 the harvest of the previous crop, in order to reduce their effect on the mineralisable
111 C fraction, iii- soil samples were neither dried nor disrupted to reduce the presence of
112 artefacts linked to sample handling during soil incubation (e.g. the Birch effect;
113 Jarvis et al., 2007) and, iv- relatively long-term soil incubation periods (i.e. 15 wk)
114 were applied to obtain a substantial amount of mineralised C so as to ensure the
115 reliability of the analysis. Under these conditions, we hypothesise that SOC
116 mineralisation during the laboratory experiment reflects the impact of the cropping
117 systems on SOC dynamics in the field. The goal was therefore to develop and to test an
118 indicator that could be used during future research concerning the impact of new
119 agricultural practices on SOC stocks in the soils of the Caribbean region. The study was
120 carried out in the Guadeloupe archipelago (Lesser Antilles) which within a small area
121 displays nearly every physical landscape and cropping system found in the
122 Caribbean.

123

124

125 **2. Materials and methods**

126

127 *2.1. Study location*

128

129 The study was carried out in the Guadeloupe archipelago in the eastern
130 Caribbean. Guadeloupe is composed of two main islands (Basse- Terre: 848 km² and
131 Grande-Terre: 586 km²) and several smaller islands. Only the soils of the two main
132 islands were analysed during this study. Although Grande-Terre is characterised by a
133 gently undulating surface, Basse-Terre Island is dominated by a volcanic mountain
134 chain oriented northwest to southeast with elongated hills with convex slopes in the
135 lowlands. We analysed four soil types (FAO, 2006):

136 i- Andosols located in the uplands of southern Basse-Terre, which had developed on
137 young ash deposits. These soils are acidic (Table 1) and characterised by high
138 allophanic clay contents (75%). The mean temperature in this region is 23.9 °C and the
139 mean annual rainfall is 3800 mm.

140 ii- Nitisols located in the lowlands of southern Basse-Terre, which had developed on old
141 ash deposits. These soils are acidic and rich in halloysite clay (70%). The mean
142 temperature is 25.0 °C and the mean annual rainfall is 2200 mm.

143 iii- Ferralsols located in the northern and eastern parts of Basse-Terre, which had
144 developed on old ash deposits. These soils are acidic and rich in kaolinite clay (70%)

145 and active aluminium and iron hydrous oxides. The mean temperature is 25.4 °C and
146 the mean annual rainfall is 2300 mm.

147 iv- Vertisols located in Grande-Terre, which had developed on coral reef limestone.
148 These soils are relatively alkaline and characterized by a high clay content (80%)
149 dominated by smectite. The mean temperature is 26.5 °C and the mean annual rainfall
150 is 1100 mm.

151 In all of these regions there is a dry season from December to May; it is less
152 pronounced in the uplands of southern Basse-Terre (i.e. 45% of annual rainfall during
153 the dry season) and more marked in Grande- Terre (i.e. only 30% of annual rainfall
154 during the dry season).

155

156 *2.2. Management o the cropping systems*

157

158 In this section we present the principal characteristics of the management of the
159 cropping systems analysed in this study, mainly those that directly affect SOC
160 dynamics.

161 Sugarcane is the dominant crop in Guadeloupe and it is cultivated on ferralsols
162 and vertisols as a monoculture or in rotation with tuber and vegetable crops. When
163 sugarcane is cultivated in rotation this is under a 5–6-yr cycle. The growth season is 12
164 months and harvesting is mechanical, where residues (tops and leaves) are shredded
165 before being returned to the soil surface. After harvesting, the remaining stubble grows
166 new shoots (ratoon crop). For this reason, soil tillage is only applied before planting in
167 the first year of the cycle. Most sugar production is exported to European markets.

168 Banana is mainly cultivated on andosols, ferralsols and nitisols, as a monoculture
169 or in rotation with vegetable crops with a 5–6-yr cycle. Harvesting is manual and each
170 plant is harvested separately. Residues (leaves and stems) are cut and placed on the
171 soil surface. After harvesting, a sucker from a lateral shoot of the mother plant grows
172 a new stem. Soil tillage is therefore only applied before planting in the first year of the
173 cycle. Most banana production is exported to European markets.

174 Most diversification crops (i.e. vegetables, yam, pineapple, melon) are cultivated
175 in rotation with export crops (i.e. sugarcane and banana), but vegetable crops and
176 pineapple are also cultivated as monocultures. Vegetables are cultivated on andosols,
177 nitisols and vertisols, yam on ferralsols and vertisols, melon is only cultivated on
178 vertisols, and pineapple is only grown on ferralsols. All these crops are managed as
179 annual crops and their cycle within the rotation varies from 3 yr for yam to 6 yr for
180 pineapple. Soil tillage is quite intensive in these cropping systems, with 4–6 tillage

181 operations per year. Yam is cultivated on mechanically-prepared ridges. Except for
 182 yam, harvesting is manual and the residues (leaves and stems) are placed on the soil
 183 surface or buried at a depth of 0.1–0.2 m. Pineapple residues are shredded before
 184 being returned to the soil. Yam is harvested mechanically and the residues (leaves and
 185 stems) are partially buried during ridge removal. Most production from diversification
 186 crops supply local markets, except for melon which is mainly exported to Europe.

187

188 *2.3. Laboratory experiment*

189

190 Sixty-nine plots representing 12 soil x crop situations were selected using the
 191 database developed for the TropEmis Project carried out in Guadeloupe (Sierra et al.,
 192 2015). The soil x crop situations and mean values of soil properties are presented in
 193 Table 1. This database contains information on soils, crop management and farm
 194 characteristics that cover all AERs of the archipelago. Only plots under monoculture
 195 were selected for the sugarcane, banana and vegetable crops. For other crops, the
 196 length of the cycle at the time of soil sampling was 3 yr for yam, 6 yr for pineapple and
 197 5 yr for melon. To reduce the effect of recent crop residues, soil samples for each
 198 selected plot were collected from five sub-plots of 10 m² that had not received crop
 199 residues following the last harvest. Soil samples were collected after harvest in the last
 200 year of the cycle of each crop, from January 2015 to March 2015. For all the selected
 201 plots, soil sampling was performed after a rainfall, thus raising soil moisture to a level
 202 slightly higher than field capacity. This was designed to prevent the effect of drying and
 203 rewetting the soil sample on the burst of C respiration following the start of the
 204 laboratory experiment (i.e. the Birch effect; Wade et al., 2016). Soil samples were
 205 taken from the upper 0.25 m soil layer on a systematic grid using a 0.06-m diameter
 206 auger and collecting three sub-samples per sub-plot. Although it is well known that the
 207 contribution of deeper layers to SOC mineralization can be important (e.g. Zhu et al.,
 208 2017), in this study we focused on the topsoil because SOC in that layer is very
 209 sensitive to changes in land use and tillage management in the tropical soils
 210 analysed here (Sierra et al., 2015).

211 Soil organic C (determined with a C analyser) and organic N (Kjeldahl
 212 method) analyses were performed on a composite sample at the SADEF Soil
 213 Testing Laboratory in France. The stock of SOC (SOC_{stock}, Mg C ha⁻¹) was
 214 calculated as:

215

$$216 \text{SOC}_{\text{stock}} = \text{SOC}_{\text{cont}} \times (\text{BD} \times \text{L} \times 10,000) \quad (1)$$

217
 218 where SOC_{cont} (Mg C Mg^{-1} soil) is the SOC content, BD (Mg soil m^{-3} soil) is the bulk
 219 density of the soil, L (m) is the depth of the soil layer analysed for SOC_{cont} (i.e. 0.25 m in
 220 this study) and $10,000$ ($\text{m}^2 \text{ ha}^{-1}$) is used to express $\text{SOC}_{\text{stock}}$ by hectare. Bulk density
 221 was determined using the soil core method (NRCS, 2014) with 5 replicates per plot.

222 A part of the composite sample was used for laboratory incubations but the
 223 sample was not sieved (aggregate size 5 mm) to reduce the effect of soil disturbance
 224 (Balesdent et al., 2000). Soil moisture was set at -30 kPa using a regulated vacuum
 225 pump. At this water potential the gravimetric water contents were on average 0.66 kg
 226 kg^{-1} for andosols, 0.40 kg kg^{-1} for nitisols, 0.43 kg kg^{-1} for ferralsols and 0.46 kg kg^{-1}
 227 for vertisols. Laboratory incubations were carried out as described by Raphael et al.
 228 (2012). Briefly, a glass vial containing 20 g (dry matter) of soil was placed in a glass
 229 jar and incubated at 30 °C in the dark for 15 wk using four replicates per plot. The CO_2
 230 released from SOC mineralisation (i.e. microbial respiration) was trapped in a 0.3 M
 231 NaOH solution and determined by titrimetry. The traps containing the NaOH solution
 232 were changed after each measurement which was performed seven times during the
 233 experiment.

234 Differences in SOC stocks and SOC mineralisation between soil-crop situations
 235 were assessed using ANOVA under an incomplete two-way design with the version
 236 19.5 of the XLSTAT program.

237

238 *2.4. Field rate constant of SOC mineralisation*

239

240 The SOC mineralisation rate constants in the field (k_{field} , in yr^{-1}) for each soil-
 241 crop situation analysed during the present study had been reported by Sierra et al.
 242 (2015), who determined changes of SOC stocks using the following equation:

243

$$244 \quad \text{dSOC}_{\text{stock}}/\text{dt} = [\text{C}_{\text{res}} \times h_{\text{res}}] - [\text{SOC}_{\text{stock}} \times (\text{k}_{\text{AER}} \times \text{k}_{\text{crop}})] \quad (2)$$

245

246 where $\text{dSOC}_{\text{stock}}/\text{dt}$ is the annual change in SOC stock ($\text{Mg C ha}^{-1} \text{ yr}^{-1}$), C_{res} (Mg C ha^{-1}
 247 yr^{-1}) is the annual C input from crop residues, h_{res} (unitless) is the humification
 248 coefficient of crop residues, k_{AER} (yr^{-1}) is the mineralisation rate constant for each AER
 249 (i.e. for each soil type in the present study), and k_{crop} (unitless) is the coefficient
 250 accounting for the effect of the cropping system on k_{AER} . Although k_{AER} reflects
 251 the effect of pedoclimatic conditions on SOC mineralisation, k_{crop} links with the
 252 impact of soil tillage on SOC mineralisation (Sierra et al., 2015). Therefore, k_{crop} is

253 lower for perennial crops where soil tillage is applied every 5–6 yr (e.g. banana and
 254 sugarcane), and higher for annual crops that involve several tillage operations per year
 255 (e.g. vegetables and yam).

256 Using this approach, the rate constant of SOC mineralisation in the field (k_{field} ,
 257 yr^{-1}) can be calculated as:

258

$$259 \quad k_{\text{field}} = k_{\text{AER}} \times k_{\text{crop}} \quad (3)$$

260

261 Sierra et al. (2015) estimated k_{AER} and k_{crop} using 253 plots with diachronic
 262 measurements of SOC stocks between 1998 and 2014, and information concerning
 263 the rotations and management of C inputs included in the database. The k_{AER} , k_{crop}
 264 and k_{field} values for each soil-crop situation included in the present study are presented
 265 in Table S1 of the Supplementary Data file. The characteristics of crop residues are
 266 presented in Table S2 (e.g. residue biomass, N and lignin content, C/N ratio,
 267 coefficient of humification and C input from crop residues).

268

269

270 **3. Results and discussion**

271

272 *3.1. SOC stocks and C mineralisation under laboratory conditions*

273

274 The organic C and organic N contents were highest in andosols, and there
 275 were no significant differences between the other soil types ($P < 0.05$) (Table 1).
 276 SOC stocks were mainly affected by soil type (Table 2), which was due to differences
 277 in SOC content (Table 1). SOC stocks in the 0–0.25 m soil layer decreased
 278 significantly in the following order: andosols (74 Mg C ha^{-1}) > vertisols (60 Mg C ha^{-1}) =
 279 ferralsols (58 Mg C ha^{-1}) > nitisols (46 Mg C ha^{-1}) ($P < 0.05$) (Table 1). It is well known
 280 that andosols store a great amount of SOC because allophanic minerals incorporate
 281 organic compounds that develop amorphous gels, which in turn provide physical
 282 protection for SOC against microbial decomposition (Kramer and Chadwick, 2016). By
 283 contrast, in lowlands dominated by nitisols under a less humid climate, some gel minerals
 284 gradually reorganise into crystalline 1:1 clay minerals (e.g. halloysite), which adsorb
 285 organic matter on their surfaces thus decreasing the degree of physical protection
 286 (Colmet-Daage and Lagache, 1965). Aluminium and iron hydrous oxides in ferralsols and
 287 smectite clay in vertisols offer a degree of physical SOC protection that is intermediate
 288 between the allophanic minerals of andosols and the halloysite clay of nitisols, which

289 explain their intermediate SOC stocks compared to these soil types (Powers and
290 Schlesinger, 2002). ANOVA indicated that SOC contents and SOC stocks were not
291 affected by the crop (Table 2), which confirms that although crop management may
292 affect the annual SOC balance (Sierra et al., 2015), it does not affect the differences in
293 SOC between soils, which are dependent on the inherent pedoclimatic characteristics
294 of each AER (Cabidoche et al., 2004).

295 The procedure applied to evaluate SOC mineralisation under laboratory
296 conditions was suited to preventing artefacts due to sample handling. Indeed, SOC
297 mineralisation displayed a linear time course without evidence of an initial stimulation of
298 CO₂ release due to rewetting and soil disruption during the preparation of soil samples
299 (Jarvis et al., 2007) (Fig. 1). Such a linear time course differed from the results of SOC
300 mineralisation under laboratory experiments reported by other authors who observed an
301 exponential pattern of C release indicating first-order kinetics and a dependence of C
302 mineralisation upon the size of the mineralisable SOC pool (e.g. Benbi and Khosa,
303 2014). However, other authors found that in some cases, SOC mineralisation could be
304 described by applying different kinetics models (i.e. zero-order, first-order, mixed zero-
305 and first-order) (Saviozzi et al., 2014). In our laboratory experiment the rate of SOC
306 mineralisation was constant in time, which suggests that the decrease in the size of the
307 mineralisable SOC fraction during soil incubation did not affect that rate. This apparent
308 zero-order kinetics was probably linked to the relatively small size of the mineralised
309 SOC fraction when compared with the total amount of SOC (e.g. the C_{min}/SOC ratio
310 averaged 3.7% for the 69 soils; Table 1).

311 Unlike the findings with respect to SOC contents and SOC stocks, soil type
312 and crop affected in a similar extent the amount of mineralised SOC after 15 wk of
313 laboratory incubation (C_{min}) ($P < 0.01$; Table 2). On average, C_{min} ranged from 1.4
314 g C kg⁻¹ in andosols (4.0% of the SOC content) to 0.8 g C kg⁻¹ in vertisols (3.5%),
315 and from 1.3 g C kg⁻¹ in soils under banana (4.8%) to 0.6 g C kg⁻¹ under sugarcane
316 (3.0%) (Table 1). It appears that the effect of soil type on C_{min} was driven by the
317 SOC content, as suggested by the highest values being observed in andosols
318 (Table 1) and the significant correlations found between the two variables in
319 andosols and vertisols (Fig. 2). However, this correlation was induced by small
320 number of extreme high SOC values in both soil types (i.e. two extreme high values
321 in andosols and one extreme high value in vertisols; Fig. 2a and d). In fact, when
322 these extreme values were excluded from the analysis, the correlation between C_{min}
323 and SOC content was not significant in either andosols or vertisols ($P < 0.05$). The
324 weakness of the relationship between C_{min} and SOC was induced by the impact of

325 the crop on C_{\min} , which was particularly noticeable in ferralsols and nitisols (Fig. 2b
326 and c). Indeed, soils under banana in nitisols and ferralsols, and under pineapple in
327 ferralsols, presented the highest C_{\min} values regardless of their SOC content. Some
328 authors have reported that crop residues recently returned to the soil may increase
329 the more biodegradable SOC fraction and then boost soil respiration (e.g. Austin et
330 al., 2017; Lian et al., 2017). Our results indicated that the relationship between C_{\min}
331 and C input from crop residues was not significant ($P < 0.05$; Fig. 3), and the same
332 was found between C_{\min} and other chemical and biological characteristics of the
333 residues for the six crops analysed during this study (i.e. residue biomass, N and
334 lignin contents, C/N ratio and coefficient of humification; Table S2) (these
335 relationships are not shown in Fig. 3). Similarly, although soils under sugarcane
336 presented simultaneously the highest C input from residues and the lowest C_{\min} ,
337 soils under banana exhibited the highest C_{\min} and a C input value that was 40%
338 lower than that from sugarcane (Fig. 3). As discussed in Section 3.2, it appears that
339 C_{\min} was dependent on the global impact of the cropping system rather than on
340 recent C inputs from crop residues. This supports the suitability of the procedure
341 used for soil sampling, whose aim was to reduce the impact of residues from the
342 previous crop.

343

344 *3.2. Relationship between SOC mineralisation under field and laboratory conditions*

345

346 Negative and significant correlations were observed between C_{\min} and k_{field} and
347 between C_{\min} and k_{crop} ($P < 0.05$) (Fig. 4). The relationship between C_{\min} and k_{AER}
348 ($R^2 = 0.22$) was not significant ($P < 0.05$; data not shown in Fig. 4). These negative
349 relationships support our hypothesis concerning a direct link between k_{field} and SOC
350 mineralisation under the conditions imposed to the laboratory experiment. These
351 results suggest that the organic C pool involved in SOC mineralisation under
352 laboratory conditions was depleted in soil-crop systems with high SOC mineralisation
353 in the field (i.e. high k_{field} and k_{crop}), which induced a lower C_{\min} . It is interesting to note
354 that this C pool could not be expressed in terms of SOC content because its
355 relationship with C_{\min} was quite inconsistent for most of the soil-crop systems
356 analysed in this study (Fig. 2). Further, although the negative relationship between
357 C_{\min} and k_{crop} indicated that the cropping system affected C_{\min} (Fig. 4b), ANOVA
358 revealed that the crop did not affect the SOC content (Table 2). It thus follows that the
359 organic C pool involved in SOC mineralisation during the laboratory experiment was
360 probably associated with the more labile fractions of organic matter, which were more

361 or less depleted as a function of the level of C mineralisation in the field. These
362 results disagree with those of some studies which reported a significant correlation
363 between total C and N contents and the mineralised N observed under laboratory
364 conditions (e.g. Ros et al., 2011; Wade et al., 2016). However, our results are in line
365 with those obtained from long-term field experiments concerning the impact of tillage
366 systems on SOC dynamics (Martínez et al., 2017; Muñoz-Romero et al., 2017).
367 These authors found that the labile SOC fraction was larger under a no-tillage
368 system than with conventional tillage, and that this fraction controlled SOC
369 mineralisation under laboratory conditions. These results were attributed to the effect of
370 tillage on the degree of exhaustion of the less stable forms of SOC in the field. This
371 proposal could be utilised to interpret some of the differences between cropping
372 systems observed during the present study. For example, in banana systems, soil
373 tillage is applied every 5 yr and its impact on the labile C fraction would be smaller than
374 that in yam and vegetable crop systems including several operations of tillage per year.
375 Therefore, the marked differences in C_{min} observed between these cropping systems
376 reflected the effects of farming practices on SOC turnover. Under our approach, the
377 effect of soil tillage was represented by the k_{crop} coefficient (Eq. (2)).

378 A more interesting finding was that the C_{min}/SOC ratio was markedly
379 affected by the crop but not by the soil type (Table 2). This ratio is frequently
380 referred as being an indicator of the more active SOC fraction involved in SOC
381 mineralisation under laboratory conditions (e.g. Campbell and Souster, 1982).
382 During our study, the C_{min}/SOC content ratio decreased significantly in the following
383 order (Table 1): banana (5.0%) > pineapple (4.2%) > melon (3.4%) >
384 vegetables (3.2%) = yam (3.2%) > sugarcane (3.0%) ($P < 0.05$). The lack of an
385 effect of the soil on this ratio was associated with the strong impact of banana and
386 sugarcane, which respectively presented the highest and lowest C_{min}/SOC values
387 regardless of soil type. Martínez et al. (2017) reported significant correlations
388 between the active SOC fraction determined under laboratory conditions and C input
389 from previous crops. As cited above, this relationship was not significant in the present
390 study (Fig. 3). We therefore concluded that SOC mineralisation as determined in the
391 laboratory reflected the overall impact of the soil-crop system on SOC over several
392 years of crop monoculture. This conclusion was supported by the significant
393 relationship between C_{min} and k_{field} ; the latter was determined from a long-term field
394 study (i.e. 17 yr; Sierra et al., 2015).

395 Whilst the soil and crop could explain almost 80% of total C_{min} variation
396 (Table 2), some results still need to be explained. Firstly, because the soil x crop

397 interaction was not significant some apparent interactions concerning vertisols (i.e.
398 similar C_{\min} values for four contrasting crops characterised by a broad range of soil
399 tillage intensities; Fig. 4) could not be accurately assessed. This was probably due
400 to the small number of degrees of freedom attributed to the interactions in our
401 incomplete two-way design. In other words, because the crops are not cultivated in
402 all the AERs concerned, only a small number of interactions were included in the
403 ANOVA. Secondly, soils under sugarcane presented the lowest values for C_{\min} and
404 C_{\min}/SOC despite its high rate of annual C input from residues and low intensity soil
405 tillage. We feel these two issues might be linked to the biochemical characteristics of
406 crop residues that could affect the level of the labile pool of SOC and then C_{\min} .
407 Several authors found that when lignocellulosic material decomposes in soil, the
408 lignin fraction is not incorporated into microbial biomass but is directly transferred
409 into SOC (e.g. Corbeels et al., 2005). Taking account of the fact that the turnover of
410 microbial metabolites contributes to the labile SOC fraction (Paul, 2016), it could be
411 hypothesised that part of the residues from sugarcane, with the highest lignin
412 content observed during the present study (Table S2), was not recycled into the
413 more labile C fraction, thus causing a relatively low C_{\min} . By contrast, banana
414 residues have low lignin content (Table S2), which together with a relatively large
415 quantity of residues induced the highest values for C_{\min} and the C_{\min}/SOC content
416 ratio observed in this study. It is possible that the similar C_{\min} values observed in
417 vertisols under the four contrasting cropping systems (i.e. sugarcane, vegetables,
418 yam and melon) were linked to the combined effects of the quantity and quality of
419 residues on the size of the labile C pool throughout the cycle of monocultures.
420 Despite some discrepancies between the field and laboratory experiments, our
421 results suggest that C_{\min} could be used as an indicator of the impact of new cropping
422 systems and practices on SOC, and to assess k_{field} before SOC changes become
423 noticeable in the field. However, the impact of residue quality on the size of the
424 mineralisable C fraction is not currently included explicitly in the k_{field} and k_{crop}
425 coefficients. Further work is therefore necessary to determine the relationship between
426 the biochemical properties of crop residues and the distribution of SOC fractions in
427 tropical soils under contrasting tillage management.

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430 **4. Conclusions**

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432 The major finding of this study was that SOC mineralisation under the

433 conditions imposed to the laboratory experiment (C_{\min}) was a suitable indicator of
434 the impact of cropping systems on the mineralisation rate constant (k_{field} and k_{crop})
435 estimated from long-term field experiments. The negative relationship between C_{\min}
436 and k_{field} was mainly controlled by the degree of depletion of the labile SOC fraction
437 induced by the management of the soil-crop system. Differences in the intensity of
438 soil tillage between cropping systems (i.e. represented by k_{crop}) were probably the
439 key factor affecting the degree of this depletion. It is important to point out that a low
440 C_{\min} does not imply that k_{field} and k_{crop} values will fall in the near future due to
441 exhaustion of the labile SOC fraction. In fact, C_{\min} indicates an earlier impact of the
442 cropping system but it does not predict a change to k_{field} , which is dependent on the
443 management of the cropping system and the pedoclimatic conditions that prevail in
444 each AER. Although laboratory soil incubation is a time-consuming method, our
445 results indicate that C_{\min} could be useful to quantify the impact of new agricultural
446 practices (e.g. manual vs. mechanical tillage) before SOC changes become
447 noticeable in the field. To achieve this, further work is necessary to assess the effect
448 of residue quality on k_{crop} under contrasting tillage management in tropics.

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462 **Appendix A. Supplementary data**

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464 Supplementary material related to this article can be found, in the online
465 version, at

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587 **Table 1**

588 Some soil properties of the 0–0.25m soil layer corresponding to the 12 cropping
 589 systems analysed during this study. For each property, mean values followed by
 590 different letters are significantly different at $P < 0.05$. SOC: soil organic C; SON: soil
 591 organic N; Cmin: mineralised C accumulated during the 15-wk laboratory experiment.

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Soil	Crop	Number of plots	Bulk density Mg m ⁻³	pH	SOC g kg ⁻¹	SON	SOC/SON ratio	SOC stock Mg ha ⁻¹	C _{min} g C kg ⁻¹	C _{min} /SOC ratio %
Andosol	Banana	6	0.81d	5.9 b	40.8 a	4.0 a	10.0 a	82 a	1.63a	4.2bc
Andosol	Vegetables	5	0.82d	5.9 b	32.8 a	3.2 a	10.0 a	66 a	1.12b	3.4c
Nitisol	Banana	5	0.92c	5.1 c	19.9 b	2.0 b	9.9 a	45 c	1.20b	6.2a
Nitisol	Vegetables	5	0.92c	5.0 c	21.2 b	2.1 b	9.8 a	48 c	0.51e	2.4d
Ferralsol	Banana	5	1.05b	5.2 c	24.1 b	2.4 b	9.9 a	63 ab	1.05bc	4.6b
Ferralsol	Sugarcane	6	1.05b	5.2 c	21.4 b	2.1 b	10.0 a	56 b	0.55e	2.5d
Ferralsol	Yam	5	1.07b	5.2 c	21.3 b	2.1 b	9.9 a	56 b	0.59e	2.8d
Ferralsol	Pineapple	6	1.03b	5.1 c	21.1 b	2.1 b	10.0 a	55 b	0.89cd	4.2bc
Vertisol	Sugarcane	8	1.14a	7.1 a	21.8 b	2.1 b	9.9 a	60 b	0.74de	3.4c
Vertisol	Vegetables	6	1.12a	7.2 a	21.4 b	2.2 b	10.0 a	59 b	0.78de	3.6bc
Vertisol	Yam	5	1.14a	7.0 a	21.6 b	2.1 b	10.0 a	59 b	0.80de	3.7bc
Vertisol	Melon	7	1.15a	7.2 a	21.6 b	2.2 b	10.0 a	59 b	0.73de	3.4c

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602 **Table 2**

603 Results of the analysis of variance. SOC: soil organic carbon; C_{min}: mineralised C accumulated during the 15-wk
 604 laboratory experiment. The % variance refers to the contribution of each source of variation to the total variance observed
 605 for each soil parameter.

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Source of variation	Degrees of freedom	SOC content			SOC stock			C _{min}			C _{min} /SOC content		
		% variance	F-value	P-value	% variance	F-value	P-value	% variance	F-value	P-value	% variance	F-value	P-value
Soil	3	67	46.3	< 0.01	45	18.9	< 0.01	44	39.3	< 0.01	5	2.3	0.09
Crop	5	3	1.1	0.35	5	1.2	0.32	34	18.1	< 0.01	45	10.3	< 0.01
Soil × Crop	3	3	2.3	0.09	5	2.1	0.11	1	0.7	0.56	6	2.4	0.09
Error	57	27			45			21			44		

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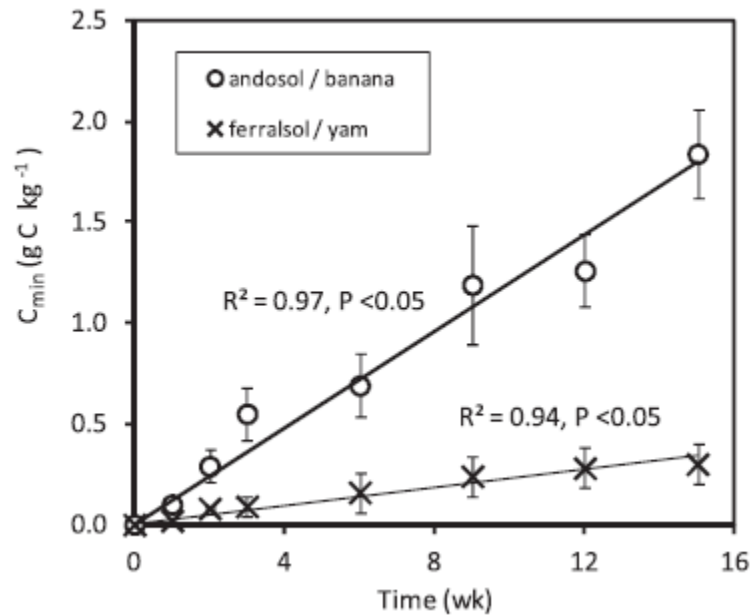


Fig. 1. Time course of SOC mineralisation during the laboratory experiment (C_{min}). The two soil-crop situations presented correspond to the extreme mineralised C values observed during this study. Vertical bars indicate the standard deviation.

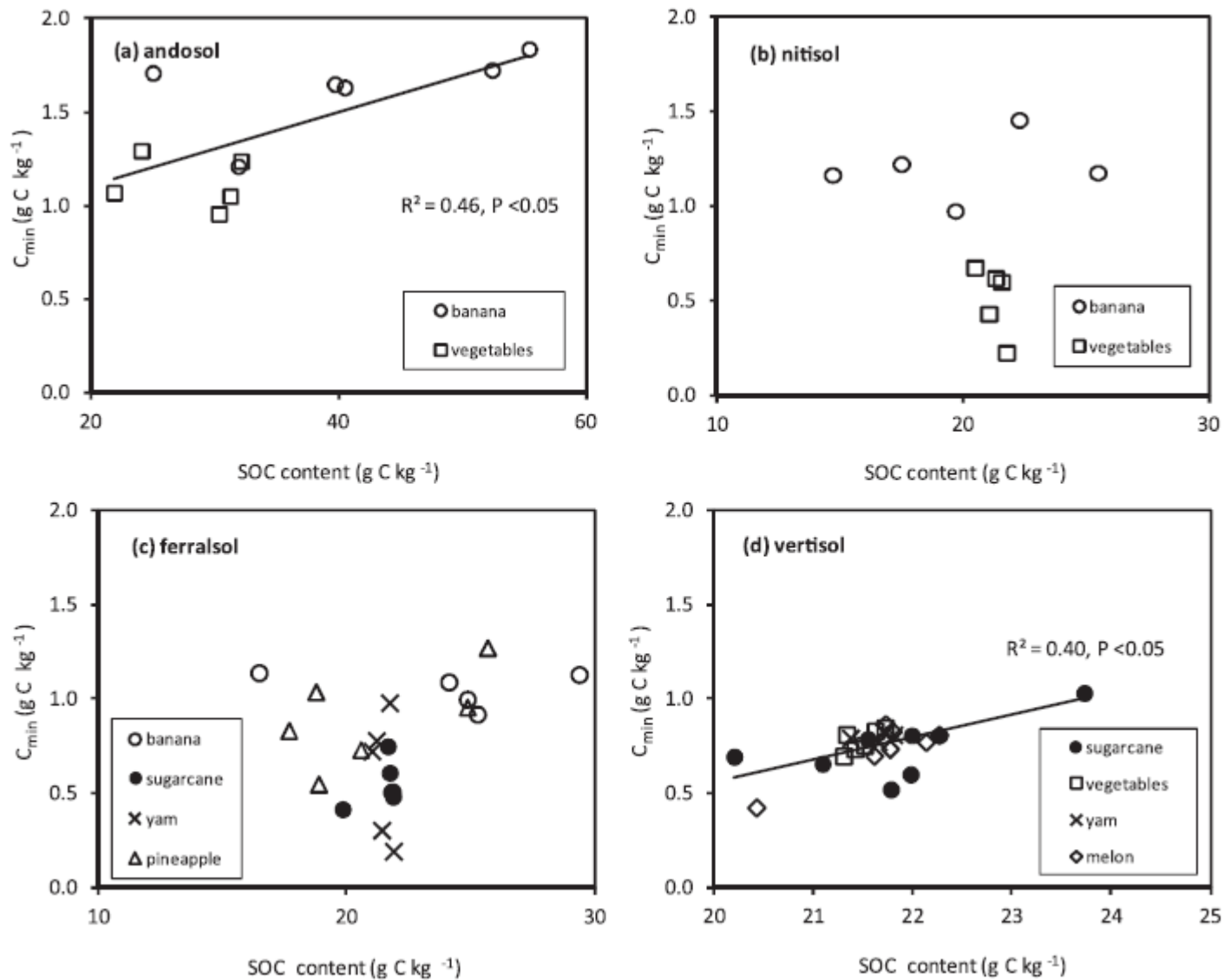


Fig. 2. Relationship between accumulated mineralised C after 15 wk of soil incubation in the laboratory (C_{min}) and the SOC content for each soil type and crop.

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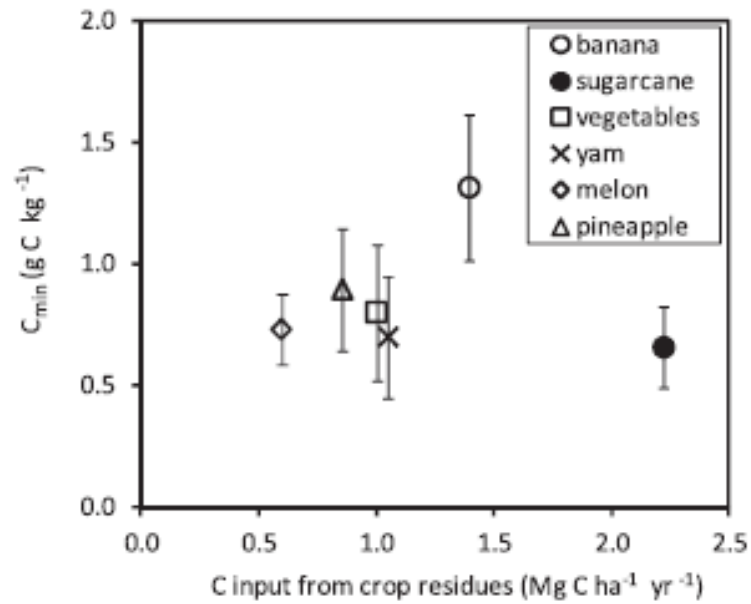


Fig. 3. Relationship between accumulated mineralised C after 15 wk of soil incubation in the laboratory (C_{min}) and C input from crop residues. Vertical bars indicate the standard deviation.

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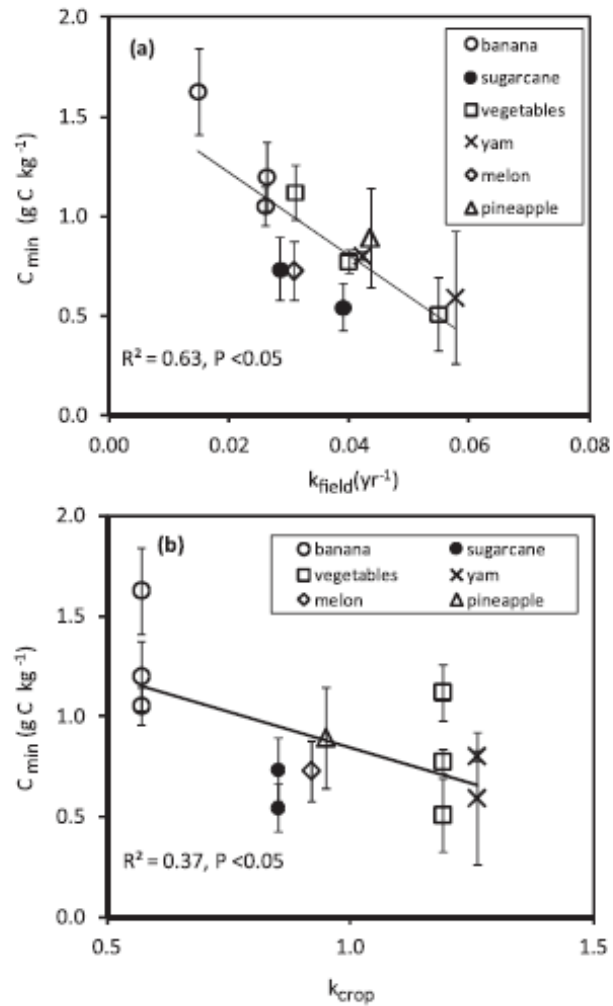


Fig. 4. Relationship between accumulated mineralised C after 15 wks of soil incubation in the laboratory (C_{min}) and (a) the SOC mineralisation rate constant (k_{field}), and (b) the coefficient reflecting the impact of tillage management on SOC mineralisation (k_{crop}). k_{field} and k_{crop} were obtained by Sierra et al. (2015) from long-term field experiments. Vertical bars indicate the standard deviation.