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(Article begins on next page)

16 **Influence of crops on soil properties in agricultural lands of northern**

17 **Iran**

18

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30

31 **Abstract**

32

33 This study evaluates the effects of land use and soil management on a combination of
34 physico-chemical, biological and hydrological properties of soil, in order to assess its
35 quality. Three land uses were selected at the Fuman area, near Masouleh (Iran),
36 grouping soils covered by tea, garden crops and rice. A total of 24 soil samples (3 land
37 uses × 4 replications × 2 soil layers, topsoil and sub-surface soil) was collected;
38 microbial respiration, available water, stability of soil aggregates, pH, organic matter,
39 cation exchange capacity and nutrient content (P, K, N, Mg and Ca) were determined in
40 each land use/soil layer.

41 In comparison with other land uses, garden showed the highest available water,
42 aggregate stability, microbial respiration, nutrient contents and cation exchange
43 capacity, whereas the latter three soil properties had the lowest values in soils covered
44 by tea and rice crops. Based on these results, under the experimental conditions garden
45 | **had presents** the highest soil quality among the investigated land uses. Conversely, much
46 | caution must be paid to some soil properties of tea and rice crops, such as cation
47 | exchange capacity, microbial respiration and nutrient contents, which are the lowest
48 | among the investigated land uses. Moreover, the differences in the analysed soil
49 | properties between the two soil sampling depths were statistically significant ($p < 0.05$).
50 Finally, a Principal Component Analysis clearly clustered soils covered by garden, tea
51 and rice crops in three differentiated groups according to the sampled soil properties.
52 This study provides a contribution in understanding the variability of soil properties
53 under different land uses, indicating that some of these properties must be considered
54 with caution, in order to avoid a decay of soil health.

55

56 **Keywords:** tea crop; rice crop; garden; soil quality; soil management practices;
57 Principal Component Analysis.

58

59 |

60 |

61 |

62 **1. Introduction**

63

64 Soil, a key resource for human well-being (Fao, 2010), plays an important role in
65 natural and anthropogenic ecosystems (Hannam et al., 2006), provided that its quality is

66 protected and improved. Soil quality is defined as its ability and capacity to perform
67 functions as one of the components of the environment (Bunemann et al., 2018), and
68 consists of the physico-chemical and biological properties. The evaluation of the effects
69 of land management on soil quality by a quantitative approach is a challenging task, due
70 to the number of soil processes and characteristics impacted by land use (Carter, 2002;
71 Tiwari et al., 2006).

72 For this quantitative evaluation a set of soil quality indicators can be selected. These
73 indicators measure the physico-chemical and biological properties of soil, according to
74 the soil functions of interest (Zornoza et al., 2015) (for instance, agricultural production
75 and mitigation of erosion risk). When land use and the linked management practices are
76 thought to modify soil quality of agricultural lands (Cherubin et al., 2017), the selection
77 and application of these indicators is essential to protect and possibly improve its
78 properties. This evaluation is important to preserve fertility, which must support growth
79 and replication of plants and crops as well as soil microorganism communities (Hannam
80 et al., 2006), and control the hydrological response of a soil, in order to avoid the
81 flooding and erosion risk (Bombino et al., 2019; Lucas-Borja et al. 2018a; 2019).

82 Various studies have used a combination of several physical, chemical, biological and
83 biochemical properties as indicators of soil quality (Kalu et al., 2015; Lucas-Borja et al.,
84 2012; Lucas-Borja et al., 2019; Burgess et al., 1990). For instance, pH (Lucas-Borja et
85 al., 2012), nutrient content and form (Burgess and Wetzell, 2000; Santa-Regina and
86 Tarazona, 2001), texture (Fterich et al., 2014), organic carbon (Parras-Alcántara and
87 Lozano-García, 2014), microbial respiration (Bastida et al., 2007; Lucas-Borja et al.
88 2018b) have been considered as useful indicators of soil quality and thus have been
89 used to advance in the understanding of changes in soil properties. The hydrological
90 properties of soil and the related indicators (e.g., water storage capacity, aggregate

91 stability, hydraulic conductivity) are also important, since they quantify the
92 hydrological response of a soil (namely the capacity of generating water runoff and
93 triggering soil erosion), which is strongly influenced by land use (Lucas-Borja et al.,
94 2019).

95 Changes in land uses and deviations of actual from natural land uses (the so-called
96 “environmental land use conflicts”, Pacheco et al., 2014; Valle Junior et al., 2014)
97 strongly impact on soil fertility (Valera et al., 2016). Therefore, these changes are
98 reasons of soil quality reduction (Jamala and Oke, 2013), as shown by the deterioration
99 of the soil properties that are critical for soil health (Khormali et al., 2009). On this
100 regard, the efforts of some countries (e.g., Brazil) to regulate land uses and minimize the
101 impacts of land use conflicts through enforcement of the "polluter-pays" principle are
102 noticeable (Valera et al., 2017). An inappropriate land use may lead to unsustainable
103 land degradation processes. In particular, the use of land for intensive agriculture may
104 generally cause soil damage (Cherubin et al., 2017; Claessen, 1997). Therefore, it is
105 necessary to study how a specific land use modifies the different properties related to
106 the quality of a given soil, possibly by a quantitative approach using the suitable
107 indicators. As well known, agriculture, particularly when it is intensive and subject to
108 frequent tillage operations, may strongly affect and degrade the properties of soil,
109 making it more prone to erosion and fertility decay (Lucas-Borja et al., 2019). The
110 research about the effects of land exploitation for agricultural production on soil
111 properties is not complete, due to the huge number of local situations (soil properties,
112 crops, agricultural practices) and on-site processes. Therefore, the large variability of
113 the soil characteristics and processes from a site to another requires further
114 investigations, leading to a better understanding of impacts of agriculture on soil
115 quality. Iran is one of the Asian countries most devoted to agriculture. During the past

116 50 years, the amount of Iran's cultivated land has grown by more than five times (DEL,
117 2003). Land-use changes in Northern Iran have been more rapid in recent year (e.g.
118 Sadeghi, et al., 2007; Emadi, et al., 2008); therefore, in this important agricultural
119 context, the evaluation of soil quality and fertility, as affected by intensive agriculture,
120 is compulsory to give land managers insights about the most suitable crops and
121 cultivation practices. In the agro-forest contexts of Iran, literature about the effects of
122 land uses on soil ~~por~~properties is not exhaustive and mainly focused on the
123 forest areas. Khormali et al. (2009) investigated on loess soils in semi-arid region of
124 northern Iran, reported reducing of soil quality indices upon cultivation of native soils,
125 and highlighted the impact of deforestation on soil quality in loess-derived soils of
126 Golestan province. In the same province, Ayoubi et al. (2011) evaluated the effects of
127 land use changes on properties in a Loess soil. Pourbabaei et al. (2015) analysed the
128 relationships between the plant ecological groups and soil properties of common hazel
129 stand in the ~~N~~orthern of Iran. Especially in Guilan (the same area of this study),
130 Gholoubi et al. (2019) showed that after land use change, soil physical and chemical
131 characteristics were changed due to land use effects, resulting in significant decreases in
132 organic carbon, available potassium, soil microbial respiration and pH. Rezaei et al.
133 (2012) reported the impacts of land use changes on soil properties and mineralogy of
134 clayey forest soils in the Caspian Sea Region; these authors found that after changing
135 land use, pH, cation exchange capacity, clay content and the amount of organic carbon
136 of the soils were decreased in Lahijan region located in northern Iran. More in general,
137 Bahrami et al. (2010) found that intensive cultivation and mismanagement have caused
138 environmental problems and soil degradation in Northern Iran, showing that soil
139 properties in different duration of plantation have significantly changed under long-term
140 inappropriate cultivation activities.

141 | In spite of these significant outcomes of these literature studiesTherefore, more research
142 | is needed, in order assess to how and to what extent soil quality is modified by the
143 | typical croplands in these important agricultural environments through the analysis of
144 | individual case studies.
145 | The general objective of this study is the evaluation of the changes in soil quality
146 | induced by agricultural practices in important croplands of Northern Iran. More
147 | specifically, in an attempt to determine whether soil properties vary with different land
148 | uses and to compare effects of land use changes on soil characteristics, this study
149 | analyses the effects of three different land uses (agricultural lands with tea and rice
150 | crops and garden with production of fruits and vegetables) on a combination of physico-
151 | chemical, hydrological and biological properties of soil at two different depths (topsoil
152 | and sub-surface soil). We hypothesize that all the properties of a given soil can be
153 | affected by significant changes due to the different agricultural practices on crops.
154 | Awareness of soil quality is important for land use systems and the information
155 | obtained in this work would allow planning and adoption of suitable management
156 | practices targeted to the increase of soil health.

157

158 | **2. Materials and methods**

159

160 | *2.1. Study area*

161

162 | The study was carried out in three croplands within the Fuman area, near Masouleh City
163 | (49°18' 33.70" E and 37°13' 18.09"N, Guilan province, North of Iran) with an area of
164 | about 10 km² (Figure 1). The altitude ranges from 950 to 1150 m above medium sea
165 | level. The climate is typically Mediterranean, Csa according to the Köppen-Geiger

166 classification (Kottek et al., 2006). The average annual rainfall and temperature are
167 1275 mm and 15.7 °C, respectively.

168 The main land uses are gardens (the main land use of the area, which can be considered
169 as crop reference), rice and tea, covering more than 50% of the total study area. Beside
170 the main crop, the area covered by tea consists of various trees, shrubs, and bushes. Rice
171 is cultivated on a flattened and irrigated field, in which rice is dominant crop. In
172 gardens, fruits (kiwi, apple and greengage), wheat and seasonal vegetables (soybean and
173 black-eyed pea) are cultivated (Table 1).

174 Texture of soils, quite homogenous in all the studied land uses, is mainly silt loam,
175 while parent materials include limestone and shill (Pourbabaei and Adel, 2015) (Table
176 1). Soil is fertile and the quality is variable among the studied land uses, because of
177 different management practices.

178

179 2.2. *Soil sampling and analyses*

180

181 The soil of the three land uses was sampled using a completely randomized design with
182 four replications at two depths. The soil sampling took place in the fall (October 2014),
183 winter (January 2015), spring (April 2015), and summer (July 2015). Twenty-four
184 samples, eight per land use, of which four in the surface soil (0-15 cm) and as many in
185 the sub-surface layer (15-30 cm), were collected and analysed in laboratory, in order to
186 measure the main characteristics (texture, hydrological, biological and physico-chemical
187 properties), evaluated by as many indicators.

188 Soil texture was measured by sieving samples, followed by the hydrometer method
189 (Gee and Bauder, 1986), and evaluated by clay, silt and sand contents.

190 The hydrological indicators (field capacity, FC; permanent wilting point, PWP;
191 available water, AW; and mean weight diameter, MWD, the latter being an indicator of
192 the soil aggregate stability) were measured according to the methods proposed by
193 Cassel and Nielsen [1986, for FC and PWP], Klute [1986, for AW]; and Kemper and
194 Rosenau [1986, for MWD].

195 The soil biological activity was determined measuring the microbial respiration (MR),
196 in terms of accumulated C-CO₂, according to Anderson (Anderson, 1982).

197 Among the soil physico-chemical properties, the following indicators were measured:
198 organic matter (OM, by Walkley-Black method (1934); pH, on 1:2.5 soil:water ratio
199 (Hesse, 1971); total nitrogen, N, by Kjeldahl method, Bremner and Mulvaney
200 (Chapman, 1965); total phosphorous (P); potassium (K); Calcium (Ca) and Magnesium
201 (Mg) (using the methods reported by Claessen) (1997); cation exchange capacity
202 (CEC), according to Chapman (2012); and CaCO₃, according to Sparks (1996).

203

204 2.3. *Statistical analysis*

205

206 | A two-way Analysis Of VAriance (ANOVA) was used to evaluate the statistical
207 | significance of differences in soil indicators among the studied land uses and the soil
208 | depths, and their interaction. The three land uses (tea, rice and garden) and the two soil
209 | depths (topsoil, 0-15 cm, and sub-surface soil, 15-30 cm above ground) were considered
210 | as independent factors, while the soil indicators were the dependent variables. Due to
211 | the sampling procedure, all point samples were considered as spatially independent. An
212 | independent Fisher's minimum significant difference test (LSD) was used for the post-
213 | hoc analysis comparisons. A $p < 0.05$ level of significance was adopted. To satisfy the
214 | assumptions of ANOVA (equality of variance and normal distribution), variables were

215 square root transformed when necessary. Finally, a Principal Component Analysis
216 (PCA) was applied to the soil parameters, in order to find correlations (using Pearson's
217 method, Rodgers and Nicewander) (Rodgers and Nicewander, 1988) and dependency
218 among the indicators, according to the investigated land uses and soil depths. All
219 statistical analyses were carried out using the statistical software Statgraphics[®] Plus 6.0
220 and JMP[®] 7.0.

221

222

223 **3. Results**

224

225 *3.1. Textural, hydrological and biological indicators of soils*

226

227 | ~~In spite of~~ **Despite** the same class (silt loam) of the investigated soils, textural and
228 hydrological properties of the soils were significantly different not only among the three
229 studied land uses ($p < 0.05$), but also at both investigated depths, except for SaC and
230 PWP. The interactions between land uses and soil depths were significantly different (p
231 < 0.05) only for textural properties, but not for the hydrological parameters (Table 2).
232 More specifically, SaC and CC were the highest in rice crop and the lowest in garden,
233 while SiC was lower in tea crop and mainly in rice crop, compared to garden (Figure
234 2a). These differences in soil texture also reflect on the hydrological properties of soils,
235 as highlighted by the values of FC, PWP (both higher in garden) as well as AW and
236 MWD (showing a significant gradient between garden and rice/tea crops) (Figure 2e).
237 As regards the biological activity of the soils, MR significantly varied among land uses
238 and soil depths and the interaction between these variability factors was significant ($p <$

239 0.05, Table 2). This soil biological property was more pronounced in garden and
240 smoother in rice crop (Figure 2f).

241

242 3.2. *Physico-chemical indicators of soils*

243

244 ~~All of~~All the physico-chemical properties of soils were significantly different among the
245 analysed land uses and soil depths ($p < 0.05$), except for the content of OM. The latter,
246 although falling in a large range of variability, was not significantly different among the
247 three land uses. The statistical significance of these differences also reflected on the
248 interaction between the two variability factors (that is, land use and soil depths), with
249 the exception of OM and nutrient (N and P) contents of soils (Table 2). A deeper
250 analysis of these properties shows that: (i) pH was higher in rice crop (on average 5.0)
251 and lower in tea crop (3.75); (ii) soil OM was very similar among all the analysed land
252 uses (from 2.8% of tea crop up to 3.4% of garden); (iii) garden showed the highest soil
253 content of nutrients (0.18% of N, 4.2 mg/kg of P and 215 mg/kg of K) and rice crop the
254 lowest (0.1% of N, 2.1 mg/kg of P and 39.9 mg/kg of K); (iv) there was a gradient
255 garden > rice crop > tea crop in Ca and Mg contents of the soil. Finally, the soil content
256 of CaCO_3 was quite similar between garden and rice crop and lower in tea crop, while
257 garden and rice crop showed the highest and the lowest CEC, respectively (Figures 2b,
258 2c and 2d).

259

260 3.3. *Correlation analysis*

261

262 Soil pH was significantly correlated with a large number of other indicators. In
263 particular, a positive correlation ($r = 0.81$) was shown with CaCO_3 and negative

264 relationships were found with nutrient contents ($|r| > 0.52$) and MR ($r = -0.53$).
265 Moreover, the latter indicators (MR and N, P, K contents) were fairly and positively
266 correlated among them ($r > 0.66$). Soil content of OM was positively correlated with N
267 content ($r = 0.55$) and MWD ($r = 0.54$), but not with AW of the soil ($r < 0.18$). Strong
268 and positive correlations were also found between CEC and nutrient contents ($r > 0.62$).
269 As regards the hydrological properties of the soils, only FC was significantly correlated
270 with the textural parameters ($|r| > 0.42$), PWP ($r = 0.47$) and AW ($r = 0.76$). Finally, the
271 latter was strongly correlated with MWD and MR (Table 3).

272

273 3.4. *Principal Component Analysis*

274

275 Using PCA two principal components (PCs) were identified, explaining together about
276 70% of the total variance of the original variables. In more detail, PC1 explained 49%
277 of this variability, whereas PC2 another 20%. The first PC was associated with
278 significant loadings to the P content, CEC and MR of soil, while the other nutrients and
279 AW had a strong association with PC2 (Table 4).

280 Plotting the sample scores on the first two PCs, differences in soil properties emerged
281 not only among land uses, but also between soil sampling depths. Three well-
282 differentiated groups, one for each land use, were clustered and, within each cluster, a
283 gradient separating the indicators of samples collected at the different soil depths was
284 evident (Figure 3).

285

286

287 **4. Discussion**

288

289 It is well known, at least by a qualitative approach, how land use of a given territorial
290 unit affects soil properties in several ways and at various rates. Different authors
291 working in Iran have demonstrated that a change in land use is the major factor
292 affecting the soil physico-chemical and biological properties and altering the dynamics
293 and availability of soil nutrients (Ayoubi et al., 2011; Rezaei et al. 2012). The results of
294 this study are in close accordance with these findings. The silt loam texture of the
295 investigated soils was the same in all studied land uses, indicating the homogeneity of
296 soil forming processes and similarity of parent materials (Foth, 1990). Nevertheless,
297 over a very long period of time, pedogenesis processes such as deposition, erosion,
298 weathering, and eluviations have change the soil texture (Foth, 1990; Brady and Weil,
299 2002). The agricultural practices, different crop by crop in the studied land uses, may
300 have played an important role in modifying the other soil quality properties. This is
301 demonstrated by the recorded variability of hydrological, biological and physico-
302 chemical properties of both the surface and the sub-surface layers of the soils, which are
303 mainly due the individual land uses. More specifically, with regard to the physico-
304 chemical properties, the analysed land uses determined a significant variability of
305 almost all the investigated parameters; moreover, the two studied layers (topsoil and
306 sub-surface layer) are also influenced by a significant variability of soil properties.

307 The soil was acidic in all the land use and this may be due to the severe seasonal
308 rainfalls in the period of the sampling activity, when precipitation may have leached
309 cations. In general, the soils devoted to agricultural purposes show light acidity (Tran et
310 al. 2014). Soil pH was lower in the sub-surface soil layer compared to the topsoil,
311 presumably because of lower organic matter content. This acidity deserves much
312 attention, since very low values of pH may be dangerous for crop and soil health. The
313 low pH values of the soils of the sites covered by tea cultivation are due to a

314 combination of agricultural practices: (i) the intensive application of nitrogen fertilizers;
315 (ii) the addition of plant residuals and litter; (iii) an intensified decomposition of soil
316 organic matter, which determined the oxidation of nitrogen and subsequent a reduction
317 in the soil pH. Also Rezaei et al. (2012) showed that, in tea cultivation, pH and the
318 amount of organic carbon of the soils can significantly decrease. The higher soil pH
319 values measured in rice cropland compared to the other land uses may be due to
320 repeated addition of inorganic fertilizers and manures to agricultural soils. This in
321 accordance with other studies (Khormali et al., 2009; Celik, 2005), which stated that the
322 rapid hydrolysis of urea in the soil can result in higher soil pH values. When urea is
323 completely hydrolyzed, NH_4 ion is produced and, if this is not converted to NO_3 by
324 nitrification or not taken up by plant, soil pH increases.

325 Soils cultivated with rice are exposed to continued drying and wetting cycles. The
326 mechanisms mainly caused by the flooding water and surface puddling create
327 | differences in properties from other land uses owing to different physical, chemical
328 | and biochemical processes (Zhang and He, 2004). Furthermore, nitrogen concentration
329 decreases with wetter conditions of rice crop and this could be due to the anaerobic soil
330 conditions.

331 The highest organic matter content detected in garden may be the result of its
332 accumulation due to root biomass (Reicosky and Forcella, 1998). Zhang et al. (2016)
333 stated that, when the rate of crop residues left on soil surface increases, as happened in
334 garden in comparison to rice and tea crops, its organic matter content raises up. The
335 lowest soil organic matter detected in tea crop could be due to decomposing
336 microorganisms, high oxidation and water erosion (Girmay et al., 2008). On the other
337 hand, management practices can increase soil organic matter such as fertilizer
338 applications (Angelova et al., 2013; Yang et al., 2016). However, the literature results

339 about organic matter content in soils are generally contrasting in the different land uses
340 of Asia. For example, Kalu et al. (2015) stated that soil organic matter content was
341 higher in forest of Nepal, whereas Shi et al. (2010) found that rice crops practiced on
342 Chinese soils show the highest soil organic matter content.

343 The high amount of soil organic matter detected in garden can explain its higher
344 microbial respiration compared to the other land uses. In other words, the higher
345 production of biomass and subsequent accumulation of more organic matter in the
346 garden played a significant effect on the microbial population of the soil. However,
347 microbial respiration in agricultural soils must be monitored with care, since Bonanomi
348 et al. (2011), who studied the soil quality indicators in different land uses, reported that
349 microbial respiration can be reduced by the annual tillage operations. Carter (2002)
350 stated that soil microbial activity is significantly reduced due to reduced organic matter
351 after severe tillage operations.

352 Significant differences in nutrient contents of soils under the three land uses were
353 detected in this study. More specifically, the higher nitrogen, phosphorous and
354 potassium content in the garden could be associated with the higher organic matter,
355 which in its turn resulted from crop residues left on soil, and to higher fertilizer (manure
356 and compost) application. Rasmussen and Douglas (1992) stated that continuous
357 application of phosphorus fertilizer leads to increased concentration of available
358 phosphorous in soils. Yousefifard (2004) showed that the majority of soil phosphorous
359 is in organic form, therefore, with increase in organic matter losses, phosphorus losses
360 also increase. Other studies (e.g., Moges and Holden, 2008) stated that nitrogen is not
361 significantly variable with land uses. Vice versa, the lower potassium in the rice crop
362 could be probably due to potassium leaching and soil degradation (Landon and Booker,
363 1991). This study showed that the nitrogen concentration was significantly higher in the

364 garden and tea croplands, which are frequently fertilized, compared to the rice site, less
365 fertilised. According to (Raison et al., 1990), slow and steady inputs of nitrogen or
366 repeated nitrogen additions could be favoured by nitrifying bacteria to accelerate the
367 nitrification process. The high soil nitrogen concentration in the garden and tea land
368 uses also may stimulate the nitrifier activity, which would result in a greater nitrate-N
369 leaching potential. Bengtsson and Bergwall (Bengtsson and Bergwall, 2000) showed
370 that the nitrogen concentration increased by 40% in a plot receiving the largest amount
371 of fertilizer compared with a control plot that was not fertilized.

372 One of the most important indicators of soil fertility and quality is its cation exchange
373 capacity (Doran and Parkin, 1994), since plants absorb nutrient elements in form of
374 cations (Sharma et al., 2015). It can be inferred that, among the investigated land uses,
375 garden has the highest quality and fertility, since it shows the higher cation exchange
376 capacity, mainly due to the highest content of calcium and magnesium. On the contrary,
377 the lowest cation exchange capacity measured in rice crop indicates the low level of
378 fertility and quality of this land use.

379 Lower concentration of CaCO_3 in tea land use was found at Fuman area. The decreased
380 calcium carbonate contents in tea cropland could be due to the peculiar management
381 practices, including some additions of lime. There are numerous interactive processes
382 responsible for the changes in carbonate contents, and an alteration in carbonate
383 contents has been considered as an indicator of soil loss and landscape stability
384 (Khormali et al., 2009).

385 Soil nutrient contents act as a major factor controlling the variability in soil microbial
386 respiration under different land uses (Tardy et al., 2014; Mganga et al., 2016). The high
387 soil respiration detected in garden can be explained by an increase in the contents of soil
388 nutrients (i.e. N, P, K, Ca and Mg), which stimulate microbial activity, thereby leading

389 to an increase in respiration from soil (Giesler et al., 2012). However, other studies
390 (Wang et al., 2013; Gorobtsova et al., 2016) stated that influence of land uses on soil
391 respiration is complex. Kooch et al. (2017) revealed the influence of the soil pH agrees
392 with the established concept that soil pH strongly determines microbial respiration; soil
393 pH close to seven is most suitable for microbial respiration.

394 In this study, the evaluation of soil hydrological indicators showed that land use
395 significantly affects the related properties and particularly the available water and
396 aggregate stability. The higher capacity of water storage in the soil available in garden
397 could be due to the higher aggregate stability, which, determining a higher porosity of
398 soil and thus increasing infiltration, may be linked to the higher organic matter content
399 of soil. Organic matter acts as a cementation agent and it is important to flocculate soil
400 particles and form soil aggregate (Kavdir et al., 2004). Gol (2009) stated that the
401 stability of aggregates is affected by land use and long-term human activities can bring
402 to a severe degradation of soil aggregate stability, shown by a significant decrease in the
403 mean weight diameter. Therefore, since soil management operations may determine a
404 reduction of aggregate stability and thus of available water in the soil, in soils subjected
405 to tillage operations this parameter must be analysed with care. Repeated plowing of
406 soil lets aggregates be poorly formed and makes soil more sensitive to degradation
407 (Gholami et al., 2016).

408 The increased available water of soils with higher organic matter (such as garden)
409 detected in this study is in accordance with Wolfe and Schneider (2003), who reported
410 an increase of the available water capacity by about 1.5% with an increase by 1% of
411 organic matter content, and with a similar study of Rawls et al. (2003), who also noticed
412 high available water capacity in soils with high amount of organic matter. However, our
413 study does not report a significant correlation between available water and organic

414 matter contents of soil. Conversely, Hudson (1994), studying the effects of organic
415 matter on available water capacity of three soil texture (sandy, silty loam and silty clay
416 loam), noticed a positive and significant correlation between these two parameters. The
417 author explains this correlation by the fact that the increase of organic matter induces a
418 higher increase of field capacity compared to the permanent wilting point.

419 Finally, the results of PCA reveal that the different land uses clearly discriminate soil
420 properties, grouping in separate clusters soils covered by tea crop, garden and rice and
421 according to the soil properties, which mostly influence the two first principal
422 components (namely nutrient contents, cation exchange capacity, available water and
423 microbial respiration of soil). Moreover, these properties show a clear stratification
424 between topsoil and sub-surface soil, as results of different physico-chemical processes
425 specialising vertically the soil.

426

427

428 **5. Conclusions**

429

430 This study, where it has been hypothesized that all the soil properties of croplands can
431 be affected by significant changes due to the different agricultural practices, has
432 demonstrated how and to what extent soil quality is modified by agricultural land uses
433 (garden, in which wheat, fruits and vegetables are cultivated, tea and rice crops) in lands
434 of Northern Iran. Although the textural characteristics of the investigated soils were
435 very similar, the hydrological, biological and physico-chemical properties were
436 significantly different not only among the three studied land uses, but also in both
437 topsoil and sub-surface soils, as we hypothesized. Garden showed the highest available
438 water, aggregate stability, soil respiration, nutrient contents and cation exchange

439 capacity, which all are indices of a higher soil quality and a better hydrological
440 behaviour. Instead, pH and organic matter content were quite similar among the three
441 studied land uses. Conversely, much caution must be paid to some soil properties of tea
442 and rice crops, such as cation exchange capacity, microbial respiration and nutrient
443 contents, which are the lowest among the investigated land uses. As shown by the
444 results of PCA, the individual land use induces variations in the soil properties (in
445 particular nutrient contents, cation exchange capacity, available water and microbial
446 respiration, which mostly influence the first two principal components) and these
447 changes are different between the topsoil and the sub-surface soil. These differences can
448 be the results of the physico-chemical, biological and hydrological changes, induced by
449 the different soil management practices used in cultivated lands. Therefore, we can
450 conclude that, in spite of the homogeneous soil types, a specific land use may have
451 noticeable influences on soil quality.

452 Overall, this study provides a contribution in understanding the soil quality under
453 different land uses and suggests-related that some sustainable soil management
454 operations, minimizing soil disturbance, such as crop rotation, organic fertilisation, and
455 cover crops, ~~which~~ may be of help for soil quality preservation ~~in planning and adopting~~
456 ~~the most suitable cultivation practices targeted to the increase of soil health~~ under
457 intensive agriculture.

458

459

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690

691

692 TABLES

693

694 Table 1 - Main characteristics of soils and crops for the three land uses in the
 695 experimental site (Fuman area, Guilan province, Northern Iran).

696

Land use	Observation period (years)	Parent material	Soil texture	Main crop	Shrub and herbal vegetation	
					Cover (%)	Type
Tea	1	limestone and shill	loam silty	tea	30-35	Crataegus microphylla and Ilex spinigera
Garden				fruits, wheat and vegetables		Corylus avellana and Epimedium pinnatum
Rice				rice		Fagus orientalis and Asperula odorata

697

698 Table 2 - Results of ANOVA applied to the textural, hydrological, biological and
 699 physico-chemical properties for the three land uses (garden, rice and tea) and two soil
 700 depths (0-15 and 15-30 cm) in the experimental site (Fuman area, Guilan province,
 701 Northern Iran).

702

703

Soil physico-chemical properties	Factors	F-ratio	P-value
pH	LU	202.33	<0.05
	SD	266.78	<0.05
	LU x SD	24.11	<0.05
OM	LU	1.32	0.29
	SD	13.38	<0.05
	LU x SD	1.9	0.18
N	LU	19.25	<0.05
	SD	102.57	<0.05
	LU x SD	0.03	0.97
P	LU	72.17	<0.05
	SD	23.3	<0.05
	LU x SD	0.73	0.49
K	LU	9776.8	<0.05
	SD	498	<0.05
	LU x SD	600.08	<0.05
Ca	LU	637.81	<0.05
	SD	11.52	<0.05
	LU x SD	4.99	<0.05
Mg	LU	111.78	<0.05
	SD	7.79	<0.05
	LU x SD	28.14	<0.05
CEC	LU	98.54	<0.05
	SD	99.06	<0.05
	LU x SD	6.54	<0.05
CaCO ₃	LU	61.2	<0.05

	SD	40.66	<0.05
	LU x SD	6.87	<0.05
SaC	LU	11.18	<0.05
	SD	0.66	0.43
	LU x SD	12.76	<0.05
SiC	LU	33.68	<0.05
	SD	26.79	<0.05
	LU x SD	8.93	<0.05
CC	LU	7.22	<0.05
	SD	25.1	<0.05
	LU x SD	25	<0.05
FC	LU	28.03	<0.05
	SD	29.07	<0.05
	LU x SD	0.04	0.96
PWP	LU	5.34	<0.05
	SD	0.98	0.34
	LU x SD	2.68	0.10
AW	LU	16.9	<0.05
	SD	12.1	<0.05
	LU x SD	0.4	0.68
MWD	LU	37.31	<0.05
	SD	315.05	<0.05
	LU x SD	2.02	0.16
MR	LU	402.97	<0.05
	SD	216.03	<0.05
	LU x SD	9.89	<0.05

704 Notes: LU = land use; SD = soil depth; LU x SD = interaction between LU and SD; OM = organic matter;
705 CEC = Cation Exchange Capacity; FC = field capacity; PWP = permanent wilting point; AW = available
706 water; SaC = Sand content; SiC = Silt content; CC = clay content; MWD = medium weight diameter of
707 soil aggregates; MR = microbial respiration.

708 Table 3 - Correlation matrix among the textural, hydrological, biological and physico-chemical properties for the three land uses (garden, rice
 709 and tea) and two soil depths (0-15 and 15-30 cm) in the experimental site (Fuman area, Guilan province, Northern Iran).
 710

	pH	OM	N	P	K	Ca	Mg	CEC	CaCO ₃	SaC	SiC	CC	FC	PWP	AW	MWD	MR
pH		-0,16	-0,65	-0,67	-0,52	0,40	0,45	-0,71	0,81	0,02	-0,75	0,69	-0,48	0,01	-0,59	-0,67	-0,53
OM			0,55	0,21	-0,17	0,36	0,08	0,32	0,01	-0,06	0,22	0,06	0,35	0,06	0,18	0,54	0,33
N				0,72	0,31	0,26	0,07	0,80	-0,34	-0,22	0,73	-0,48	0,83	0,34	0,67	0,93	0,79
P					0,79	0,17	0,10	0,87	-0,28	-0,50	0,80	-0,43	0,73	0,33	0,77	0,64	0,88
K						-0,01	0,05	0,62	-0,25	-0,46	0,69	-0,37	0,49	0,19	0,61	0,23	0,66
Ca							0,83	0,09	0,71	-0,29	0,12	0,08	0,47	0,48	0,26	0,25	0,42
Mg								-0,03	0,78	-0,12	0,10	0,04	0,31	0,42	0,22	0,06	0,30
CEC									-0,41	-0,42	0,71	-0,40	0,77	0,38	0,74	0,81	0,91
CaCO ₃										-0,04	-0,36	0,50	-0,11	0,26	-0,27	-0,36	-0,12
SaC											-0,11	-0,26	-0,42	-0,35	-0,39	-0,13	-0,49
SiC												-0,69	0,69	0,25	0,74	0,69	0,76
CC													-0,42	-0,16	-0,55	-0,53	-0,40
FC															0,47	0,76	0,79
PWP																0,34	0,36
AW																	0,70
MWD																	0,77
MR																	

711 Notes: OM = organic matter; CEC = Cation Exchange Capacity; FC = field capacity; PWP = permanent wilting point; AW = available water; SaC = Sand content; SiC = Silt
 712 content; CC = clay content; MWD = medium weight diameter of soil aggregates; MR = microbial respiration. Significant parameters at P > 0.05 are reported in bold.

713 Table 4 - Loadings of the original variables - textural, hydrological, biological and physico-
 714 chemical properties for the three land uses (garden, rice and tea) and two soil depths (0-15
 715 and 15-30 cm) in the experimental site (Fuman area, Guilan province, Northern Iran) - of
 716 Principal Component Analysis on the first two Principal Components (PC1 and PC2)
 717 (significant parameters at $P > 0.05$ are reported in bold).

718

Original variables	PC ₁	PC ₂
pH	-0,258	-0,341
OM	0,119	-0,112
N	0,305	-0,007
P	0,314	-0,002
K	0,229	0,051
Ca	0,082	-0,487
Mg	0,040	-0,464
CEC	0,319	0,037
CaCO ₃	-0,127	-0,470
SaC	-0,133	0,181
SiC	0,302	0,073
CC	-0,205	-0,196
FC	0,305	-0,142
PWP	0,148	-0,280
AW	0,299	-0,031
MWD	0,299	0,008
MR	0,325	-0,132

719 Notes: LU = land use; SD = soil depth; LU x SD = interaction between LU and SD; OM = organic matter;
 720 CEC = Cation Exchange Capacity; FC = field capacity; PWP = permanent wilting point; AW = available
 721 water; SaC = Sand content; SiC = Silt content; CC = clay content; MWD = medium weight diameter of soil
 722 aggregates; MR = microbial respiration. The significant values for each principal component are reported in
 723 bold.

724 **FIGURES**

725

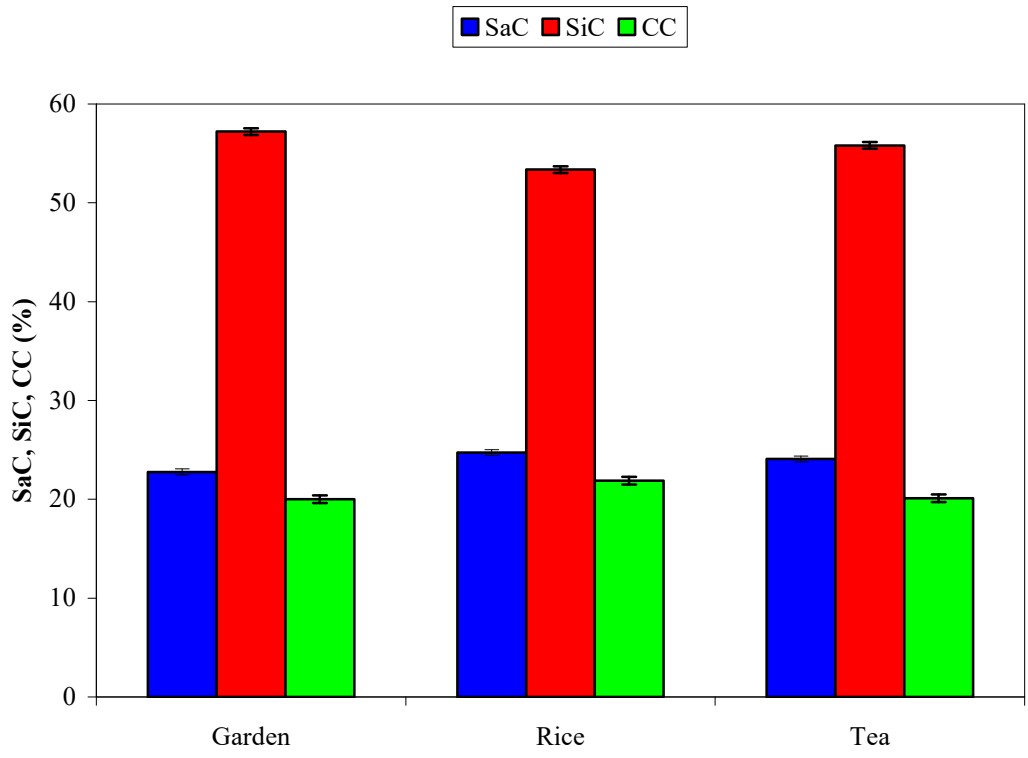


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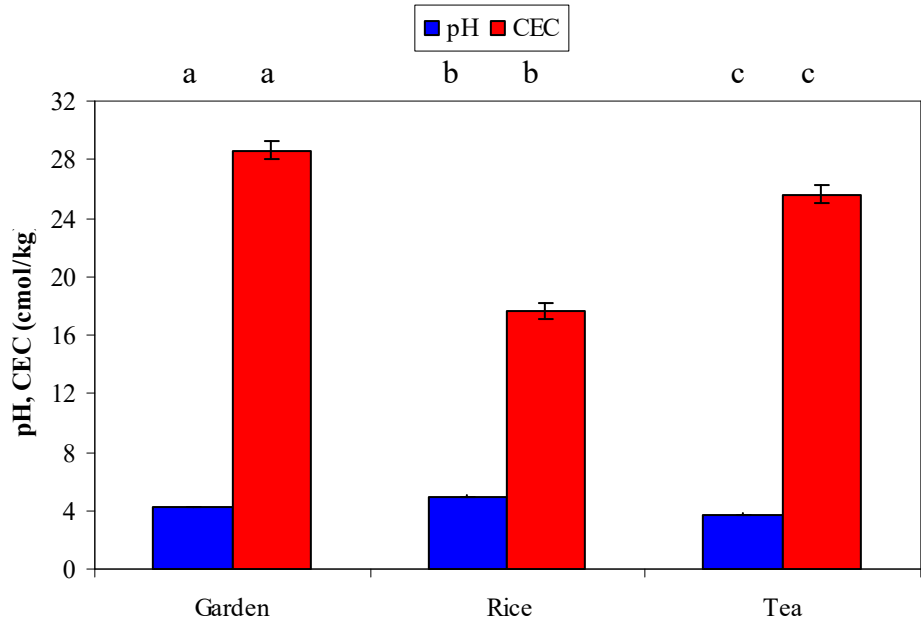
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729 Figure 1 - Geographical location and aerial map (source: Google® Map®) of the study
730 area.



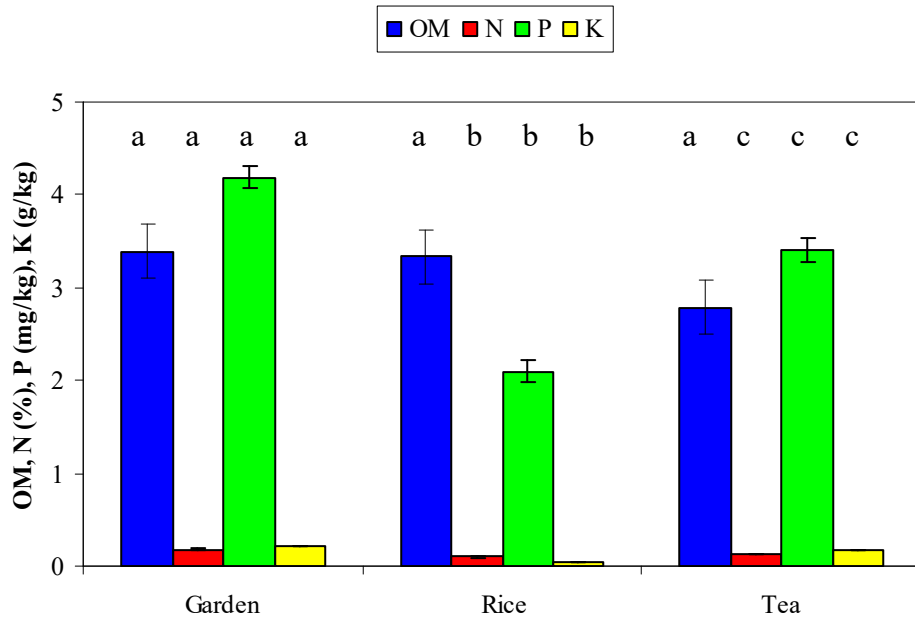
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(a)



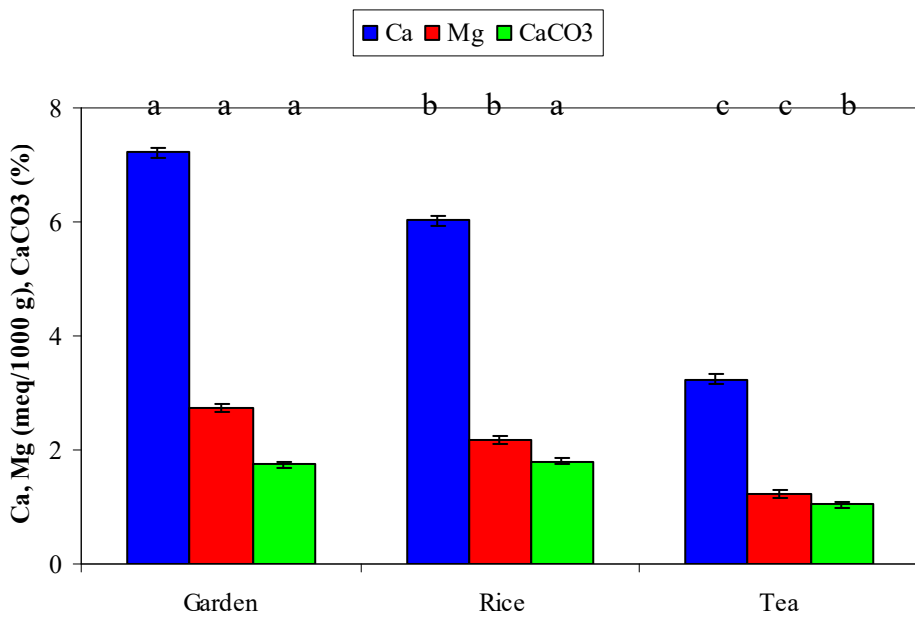
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(b)



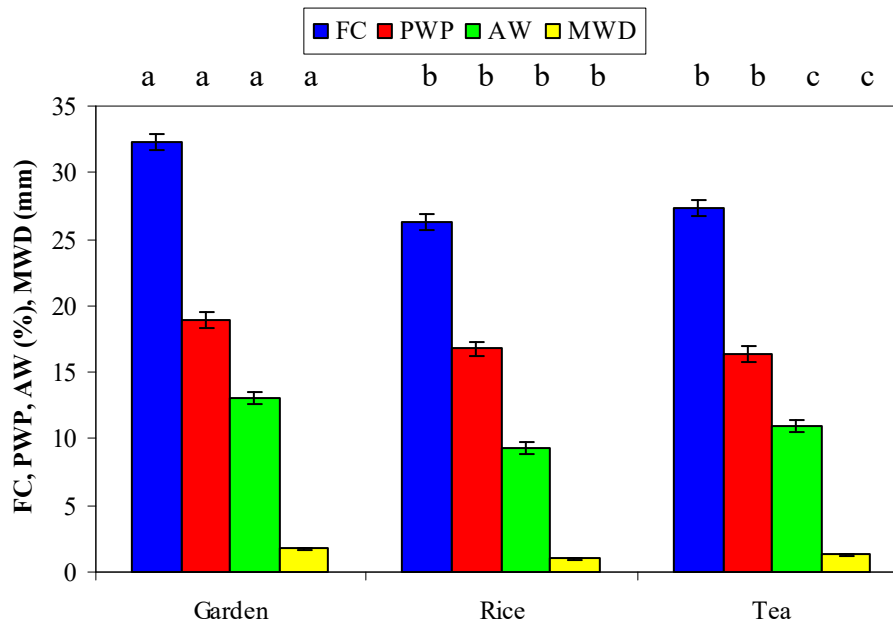
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(c)

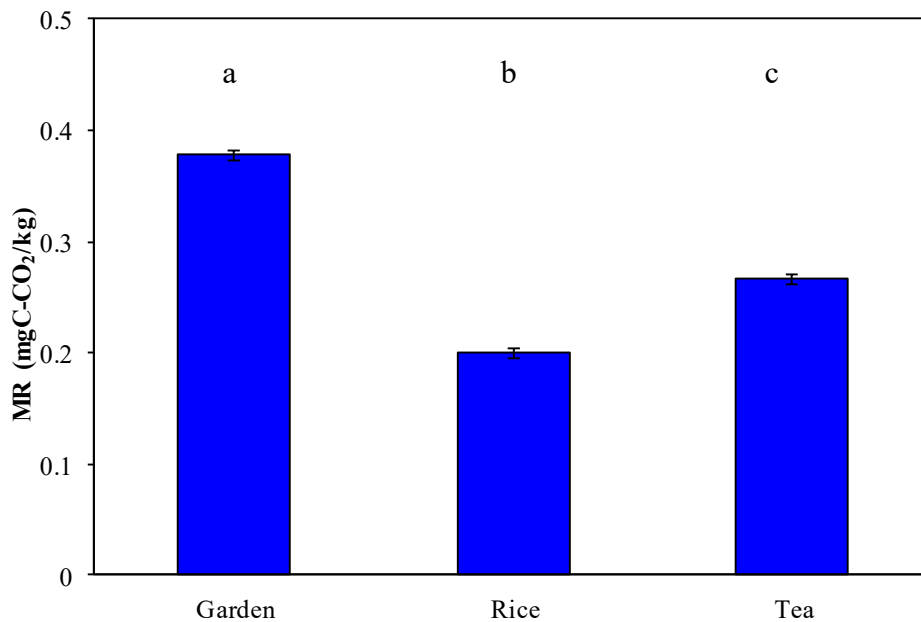


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(d)



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744 (e)

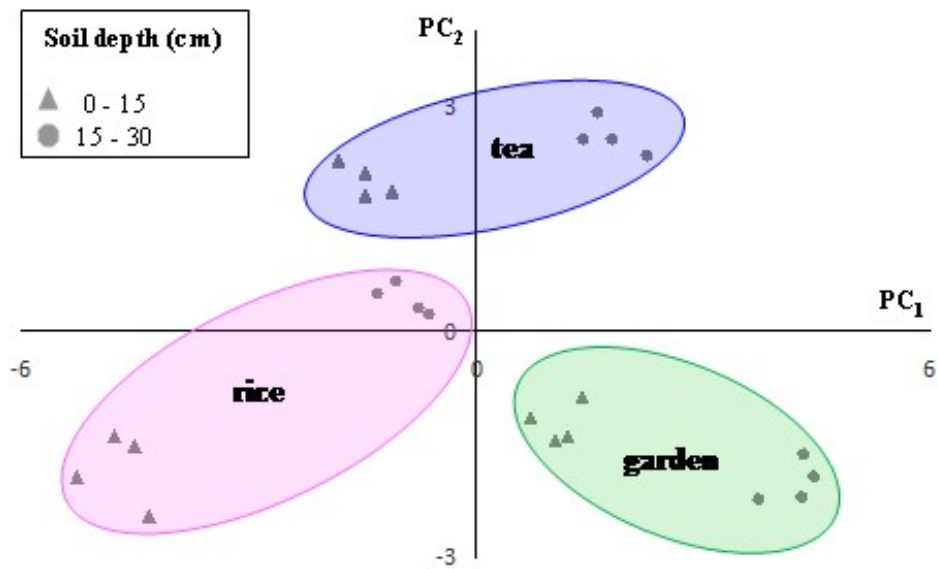
745 (f)

746 Notes: OM = organic matter; CEC = Cation Exchange Capacity; FC = field capacity; PWP = permanent
 747 wilting point; AW = available water; SaC = Sand content; SiC = Silt content; CC = clay content; MWD =
 748 medium weight diameter of soil aggregates; MR = microbial respiration.

749

750 Figure 2 - Main textural (a), physico-chemical (b, c and d), hydrological (e) and biological
 751 indicators for the three land uses (garden, rice and tea) - averaged at two soil depths (0-15
 752 and 15-30 cm) - in the experimental site (Fuman area, Guilan province, Northern Iran)

753 (mean values \pm standard error). Different lowercase letters indicate significant differences
754 ($p < 0.05$).



755

756 Figure 3 - Scores of the original variables - textural, hydrological, biological and physico-
 757 chemical indicators for the three land uses (garden, rice and tea) and two soil depths (0-15
 758 and 15-30 cm) in the experimental site (Fuman area, Guilan province, Northern Iran) - on
 759 the first two Principal Components (PC1 and PC2) provided by Principal Component
 760 Analysis.

761