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Soil quality with traditional management in the Chambira native community

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Abstract: The traditional management applied by the Native Community of Chambira (NCCh) is based on agroforestry plots with diverse species and areas with rotation of legumes, cassava and maize. The objective was to evaluate behaviour of the physicochemical indicators of soil quality with traditional crop management in the NCCh. A completely randomised design was applied, where the treatments were traditional mixed fruit management (MF), crop rotation (CR) and native forest (NF) as reference. Physical indicators of the surface layer did not show differences, the apparent density (AD) and the resistance to penetrability (RP) increased with depth; chemical indicators differed in the MF and CR had higher results compared to NF. The AD and RP had a significant negative correlation with soil organic carbon (SOC) and positive correlation between SOC, P, Ca, Mg, K available and cation exchange capacity. The MF and CR managements developed in the NCCh are techniques with great potential for soil conservation.

Keywords: farming system; monoculture; soil fertility; species diversity; soil properties

Native communities (NC) are made up of families linked culturally and socially, and the state promotes comprehensive education, training in technical aspects of agriculture, livestock and forestry in the NC (Decree-Law No. 22175/1978). However, there is pressure for their lands endangered with conventional rice and maize management systems under a monoculture system with mechanisation and the use of agrochemicals. The Peruvian state has not been able to take effective measures and the NC have preferred to live away from the government's actions, protected by the Political Constitution, which recognises broad autonomy in the use and free disposal of their lands (Peña 2010).

Agricultural practices such as monoculture, mechanisation and use of agrochemicals degrade soil structure and lead to changes in soil fertility and quality (Stehlíková et al. 2016). Conservation tillage with agroforestry system and crop rotation improves yield, soil fertility and optimises the plots (Bogunović et al. 2019, Ahmed et al. 2020), turning them into environmentally sustainable areas. In the NCCh agriculture begins with cutting and burning of forests; according to natives' worldview, burning offers multiple benefits. However, it differs from conventional management by installing agroforestry plots and rotating maize, beans, cassava and plantain, making appropriate use of natural resources (Magnussen 2015, Ahmed et al. 2020). Therefore, these areas are ecologically, socially and economically important (Valladolid 2015). Furthermore, native forest (NF) and crop rotation (CR) are parts of conservation tillage, which offers multiple benefits, improving density and penetrability of the surface layer, supply of organic matter and nitrogen and availability of bases, among others (Verhulst et al. 2015, Bogunović et al. 2019, Ahmed et al. 2020).

Management in NC has been studied with a cultural and conservation approach to the diversity of flora and fauna (Álvarez and Shany 2012, Orantes et al. 2013, Magnussen 2015, Gutiérrez et al. 2016, Saturno and Zent 2016), as well as systems that offer

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species diversity, food security and substances to maintain good health. However, they are conservation farming systems with long-term advantages for the soil and, in general, for the agroecosystem (Kaci et al. 2018, Bogunović et al. 2019, Faligowska et al. 2019). Therefore, the present study identifies traditional management developed in the native community of Chambira and evaluates behaviour of quality physicochemical indicators in different soil strata in the crop rotation area, mixed fruit (MF) and native forest as reference.

MATERIAL AND METHODS

Study area. The research was carried out in the jurisdiction of the NCCh in the Ponaza valley, located in the buffer zone of the Cordillera Azul National Park. It belongs politically to the Shamboyacu district, Picota province in the San Martin region, Peru. The general climatic conditions correspond to a tropical climate; the average temperature is 27 °C, annual average rainfall of 1 500 mm and the altitude is 500 m a.s.l.

Selection of areas. MF management was highlighted in this area. An annual crop such as corn, beans or cassava was initially installed. After the harvest the area begins a process of natural regeneration and the community members randomly plant fruit species (Table 1) with different nutritional properties, vegetative cycles and production stages; for the species planted during the first and second year, manual cleaning of weeds is carried out only around the plant, to guarantee their growth. The mixed fruit is located at the coordinates 7°02'45''E and 76°06'23''N.

Table 1. Species identified in the management of mixed fruit

Local name	Scientific name
Caimito	*Pouteria caimito* L.
Guaba	*Inga edulis* Mart.
Sapote	*Matisia cordata* Bonpl.
Pijuayo	*Bactris gasipaes* H.B.K.
Guayaba	*Psidium guajaba* L.
Taperiba	*Spondias cytherea* Parkinson
Huito	*Genipa americana* L.
Guanábana	*Annona muricata* L.
Coco	*Cocos nucifera* L.
Naranja	*Citrus sinensis* L.
Limón rugoso	*Citrus limon* L. Burm

The area with CR (Table 2) is dedicated to the production of basic community foods such as maize, cassava and beans, which are systematically sown during the year, with a short rest period during the rainiest months in the area (January–March). It is located at the UTM coordinates 7°02'59''E and 76°06'31''N, it produces annual crops on a rotation basis, with no fertilisation plans and agrochemicals use.

The NF (Table 3) is located at the UTM coordinates 7°02'46''E and 76°06'15''N; in past decades, species of high commercial value were selectively extracted and non-timber products were used for handicrafts, medicine and other products.

Field sampling. It was carried out between the months of November and December 2019, following the guidelines for the description of soils, 4th Edition of the FAO (2009), for which 2 000 m^2 of land was selected as the sub-sampling area in MF, CR and NF.

Six samples of random points were extracted at 0.20 m depth for analysis of chemical indicators. For physical indicators apparent density (AD) and resistance to penetrability (RP), six random samples were evaluated in strata of 0.0–0.1 (AD10 and RP10), 0.1–0.2 (AD20 and RP20) and 0.2 to 0.3 m (AD30 and RP30).

The physical and chemical indicators (Tables 4 and 5) of the soil were analysed, following the protocols

Table 2. Annual crop rotation (CR)

Crop	2016			2017			2018			2019		
	Jan–Mar	Apr–Jul	Aug–Dec	Jan–Mar	Apr–Jul	Aug–Dec	Jan–Mar	Apr–Jul	Aug–Dec	Jan–Mar	Apr–Jul	Aug–Dec
Phaseolus vulgaris		×						×				
Vigna unguiculata					×						×	
Manihot esculenta			×						×			
Zea mays						×						×
Fallow	×			×			×			×		

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Table 3. Species identified in the native forest

Local name	Scientific name
Moena	*Amarilla aniba amazonica* Meiz.
Pashaco blanco	*Macrolobium acaciaefolium* Benth.
Shimbillo	*Inga edulis* Mart.
Oje	*Ficus* Willd.
Capirona	*Calycophyllum Spruceanum* (Bent.) Hook
Palo lápiz	*Polyscias murrayi* (F. Muell.) Harms.
Ana caspi	*Apuleia leiocarpa* (J. Vogel) J.F. Macbr.
Bellaco caspi	*Himatanthus tarapotensis* Willd.
Tornillo	*Cedrelinga cateniformis* D. Ducke
Cashimbo	*Cariniana domestica* Mart.
Setico	*Cecropia* Bertol.
Topa	*Ochroma pyramidale* Cav. ex Lam.
Huasai	*Euterpe oleracea* Mart.

described by Bazán (2017); texture (Bouyoucos), bulk density (test tube), penetrability resistance (cone Penetrometer), pH (electrometric), soil organic carbon (Walkley and Black), available phosphorus (modified Olsen), exchangeable potassium, calcium and magnesium (ammonium acetate).

Statistical analysis. The design used is completely randomised, where the treatments are the different types of traditional management, with sample size $n = 6$ (samples by type of management and stratum sampled). The data was submitted to the analysis of variance and Duncan's test ($P < 0.05$) for the comparison of means and the Pearson's correlation to find the relationship between the physical and chemical indicators evaluated. The IBM-SPSS 25 software (USA) was used for data processing.

RESULTS AND DISCUSSION

Physical indicators. The NF and MF managements have sandy clay loam and clayey texture for CR, finding differences in all the fractions (Table 4) and correspond to soils that allow the development of most crops (SAGARPA 2012). It is an important property since it influences fertility factor and the ability to retain water, aeration, drainage, soil organic carbon (SOC) content and other properties. The variation in the texture class is due to different experimental plots. The plots are approximately 300 m apart, however, with the same geological formation; this can be contrasted with the common chemical characteristics between the areas (Table 5).

The AD increases with depth and does not differ in the surface strata, except AD30, which is more influenced by soil mineralogical factor (Luca et al. 2008). The result (Table 4) shows that density increases with the depth, based on the management (Fidalski 2015, Da Silva et al. 2015), which includes the use of several species in the case of mixed fruit and almost systematic alternation of maize, tubers and legumes in crop rotation, and on the soil preparation that excludes the use of machinery and agrochemicals. This allowed greater plants

Table 4. Comparison of means and determination of differences in physical indicators between the operations

Indicator	Treatment			Statistics	
	NF	MF	CR	*F*-value	significant
Sand	61.33 ± 7.94^b	62.33 ± 8.33^b	23.66 ± 3.01^a	61.76	< 0.001**
Silt	17.33 ± 8.14^a	14.16 ± 5.31^a	31.33 ± 4.8^b	12.78	0.001**
Clay	21.33 ± 1.63^a	23.33 ± 4.13^a	45 ± 2.76^b	113.5	< 0.001**
AD10	1.11 ± 0.03^a	1.14 ± 0.03^a	1.14 ± 0.04^a	1.84	0.193
AD20	1.24 ± 0.03^a	1.19 ± 0.04^a	1.21 ± 0.02^a	3.52	0.056
AD30	1.28 ± 0.03^{ab}	1.25 ± 0.0^a	1.31 ± 0.03^a	6.01	0.012*
RP10	1.99 ± 0.21^a	1.9 ± 0.1^a	1.84 ± 0.22^a	0.93	0.416
RP20	2.49 ± 0.08^b	2.18 ± 0.22^a	1.93 ± 0.32^a	8.91	0.003**
RP30	2.72 ± 0.12^a	2.8 ± 0.52^a	2.34 ± 0.44^a	2.34	0.131

Different letters in each column indicate significant differences between different treatments ($P < 0.05$; Duncan's test); NF – native forest; MF – mixed fruit; CR – crop rotation; *F* – distribution value; *$P < 0.05$; **$P < 0.01$; AD10 – density in stratum 0.0 to 0.10 m; AD20 – density in stratum 0.10 to 0.20 m; AD30 – density in stratum 0.20 to 0.30 m; RP10 – resistance to penetrability in stratum 0.0 to 0.10 m; RP20 – resistance to penetrability in stratum 0.10 to 0.20 m; RP30 – resistance to penetrability in stratum 0.20 to 0.30 m

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Table 5. Comparison of means and determination of differences in chemical indicators between the operations

Indicator	Treatment			Statistics	
	NF	MF	CR	*F*-value	Significant
pH 1:1	7.43 ± 0.27[b]	6.62 ± 0.46[a]	7.75 ± 0.12[b]	20.51	< 0.01**
SOC (%)	4.726 ± 0.41[a]	5.79 ± 0.04[b]	5.88 ± 0.05[b]	43.02	< 0.01**
N (%)	0.23[a]	0.29[b]	0.29 ± 0.01[b]	857	< 0.01**
P (ppm)	3.26 ± 0.93[a]	10.12 ± 2.43[b]	5.09 ± 1.83[a]	22.39	< 0.01**
K available (ppm)	48.98 ± 5.57[a]	123.2 ± 46.7[b]	76.91 ± 11.57[a]	10.78	0.001**
Ca ($cmol_+$/kg)	3.75 ± 1.06[a]	6.5 ± 1.75[b]	5.58 ± 0.93[b]	6.99	0.007**
Mg ($cmol_+$/kg)	0.62 ± 0.19[a]	1.1 ± 0.36[b]	0.96 ± 0.18[b]	5.51	0.016*
K interchangeable ($cmol_+$/kg)	0.19 ± 0.03[a]	0.5 ± 0.15[c]	0.31 ± 0.03[b]	17.31	< 0.01**
Na ($cmol_+$/kg)	0.17 ± 0.04[a]	0.38 ± 0.09[c]	0.25 ± 0.03[b]	18.09	< 0.01**
CEC ($cmol_+$/kg)	4.73 ± 1.29[a]	8.53 ± 2.37[b]	7.1 ± 1.12[b]	7.78	0.005**

Different letters in each column indicate significant differences between different treatments ($P < 0.05$; Duncan's test); *P <0.05; **P < 0.051; NF – native forest; MF – mixed fruit; CR – crop rotation; F – distribution value; SOC – soil organic carbon; CEC –cation exchange capacity

residues cover the surface and as a consequence it resulted in the decrease in AD on the surface. The results correspond to generally low values (1.11 to 1.31 kg/m^3) categorised as BD1 to BD2, in soils with porous conditions according to the FAO (2009) and soils with ideal density AD < 1.4 for SAGARPA (2012). Also, these values indicate a suitable environment for root growth, aeration and desirable changes in water infiltration (Verhulst et al. 2015).

The RP also increases with depth, the MF and CR present lower values than the NF, finding significant differences in the stratum of 0.1 to 0.2 m (RP20). The CR presents the lowest means; it is explained by the cultivation of beans, which means incorporating significant amounts of SOC and N (Navarro et al. 2019), and the rotation with cassava that produces a soil inversion at the time of extraction, incorporating these residues and removing the profile at this depth, reducing thus its RP. Similar results were

Table 6. Pearson's correlation between physical and chemical indicators

	AD10	AD20	AD30	RP10	RP20	RP30	pH	SOC	P	K	Ca	Mg	CEC
AD10	1												
AD20	–0.16	1											
AD30	–0.23	0.27	1										
RP10	–0.37	0.12	–0.04	1									
RP20	–0.22	0.56*	–0.26	0.42	1								
RP30	–0.15	–0.15	–0.34	0.39	0.49*	1							
pH	–0.05	0.09	0.45	0.19	–0.15	–0.29	1						
SOC	0.29	–0.62**	–0.03	–0.3	–0.69**	–0.29	–0.1	1					
P	0.40	–0.66**	–0.44	–0.04	–0.16	0.36	–0.49*	0.56*	1				
K	0.45	–0.44	–0.47*	–0.05	–0.12	0.14	–0.43	0.53*	0.78**	1			
Ca	0.42	–0.55*	–0.14	–0.06	–0.35	0.14	–0.19	0.5*	0.79**	0.79**	1		
Mg	0.40	–0.56*	–0.13	–0.01	–0.36	0.17	–0.12	0.47*	0.75**	0.76**	0.99**	1	
CEC	0.43	–0.55*	–0.18	–0.05	–0.33	0.14	–0.22	0.51*	0.81**	0.84**	0.99**	0.98**	1

AD10 – density in stratum 0.0 to 0.10 m; AD20 – density in stratum 0.10 to 0.20 m; AD30 – density in stratum 0.20 to 0.30 m; RP10 – resistance to penetrability in stratum 0.0 to 0.10 m; RP20 – resistance to penetrability in stratum 0.10 to 0.20 m; RP30 – resistance to penetrability in stratum 0.20 to 0.30 m; SOC – soil organic carbon; CEC –cation exchange capacity

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found by Silva and Fernández (2014), Fidalski (2015) and Navarro et al. (2019); no significant effect on RP was observed in superficial strata. In our case, soil compaction decreased because no load was applied to the surface, which caused changes in the physical properties of the soil, increasing resistance to penetration and bulk density (Demuner et al. 2013). In general, MF and CR have shown a great capacity to improve AD and RP in the superficial strata. According to Bogunović et al. (2019) the preservation of the surface layer of the soil is important.

Chemical indicators. Table 5 shows means of chemical indicators according to the management; the MF presents higher averages in P, K available, calcium, magnesium, exchangeable K and cation exchange capacity (CEC), and the CR presents higher averages in pH and SOC, higher values compared to NF, and presents significant differences.

Neutral pH (MF) and slightly alkaline soils (NF and CR) were found, which is an important indicator determining the availability of nutrients, solubility, mobility and availability of other constituents present in the soil. High pH values are present in soils with little precipitation and high evapotranspiration rates; there is less washing and the bases accumulate on the surface, generating high pH values (Jaurixje et al. 2013). The area has a tropical climate, with average rainfall of 1 500 mm. Furthermore, the pH means show that the CR and the MF surpass the NF, because these systems have high incorporation of residues, which generates an increase and availability of nutrients such as K, Ca and Mg available near the soil surface (Verhulst et al. 2015). It is the reason why the CR and MF exceed the NF in pH.

The SOC and N are indicators present in high concentrations (Table 5) in MF and CR, superior to the NF. In this regard, SOC in traditional agriculture is the basis of fertility, increasing the cationic exchange capacity and having capacity to retain a large proportion of essential nutrients, cations and trace elements (SAGARPA 2012).

These conditions maybe generated by MF management; it is a system that includes more than 11 fruit tree species, which return more residues and increase the levels of P, K, Ca and Mg available near the soil surface (Verhulst et al. 2015). In the specific case, CR with rotation of legumes, grasses and tubers, such as cassava, may also improve the aggregation and organic carbon in the surface layer, increasing levels mainly of N (Kaci et al. 2018) and changeable bases (Loss et al. 2016).

Traditional handling. MF and CR in the NCCh did not show differences (Table 4) in physical indicators in the superficial stratum, an important aspect highlighted by Bogunović et al. (2019); furthermore, the results show (Table 5) that the MF and CR management show higher values compared to the NF. Therefore, the results demonstrate that they are traditional techniques framed in agroecological and sustainable agriculture, which incorporates concepts of stability, resilience and adaptability (Álvarez and Shany 2012, Magnussen 2015, Valladolid 2015, Bedoya et al. 2017, Bogunović et al. 2019, Ahmed et al. 2020). They are traditional managements with great potential to conserve the quality of soils in the community of Chambira.

Correlation of indicators. The AD and RP present a significant negative correlation with the SOC (Table 6), in this case, the low values of AD and RP are due to the high levels of SOC. Furthermore, pH showed a significant negative correlation with phosphorus and SOC, a significant positive correlation with P and the changeable cations Ca, Mg, K available and CEC.

Phosphorus is linked to chemical processes, the type of mineral and to the pH levels of the solution. Decomposition of SOC releases bases and raises the pH, which in turn improves the availability of phosphorus (Verhulst et al. 2015, Loss et al. 2016). Therefore, the results are consistent with the management and preparation of the applied soil, as pointed out by Fidalski (2015) and Da Silva et al. (2015).

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