Changes in Soil Quality under Conservation Agriculture Practices in West Nusa Tenggara, Indonesia

Perubahan Kualitas Tanah pada Praktek Pertanian Konservasi di Nusa Tengara Barat, Indonesia

Achmad Rachman*

Balai Penelitian Tanah, Jl. Tentara Pelajar No. 12, Cimanggu, Bogor 16124, Indonesia

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Abstract. The main challenge for cultivating a semi arid upland is the limited availability of water resources and accelerated deterioration of soil quality. This study evaluated changes in selected soil properties and soil quality (SQ) four years after the implementation of conservation agriculture (CA) practices. The study was conducted at the CA demonstration plots in East Lombok, West Nusa Tenggara. The surface soil texture was loam with slope ranging from 5 to 10%. Two CA Models and a conventional farmer practice (LP) were compared. Within a plot of each models, three locations were sampled: within the corn planted area (Position A), 0-10 cm from Position A (Position B), and 10-20 cm from Position A (Position C). Intact soil samples and bulk samples were taken from the three positions to determine soil physical and chemical properties. The CA treatment had significantly ($P < 0.01$) lowered bulk density (BD), and increased soil organic carbon (SOC) and available P (Av P), while sampling Position had significantly affected only BD. The lowest BD (0.87 ± 0.07 Mg m-3) and the highest SOC (1.51± 0.05%) and available pore water (AWC; 18.06 ± 0.76% vol) were found at Position A in CA with permanent pit (PIT). The highest SQ index was found in Position A followed by B and the least in C indicating that the crop rotation component in CA had a relatively small effect on improving SQ. The improvement of soil quality at Position A may benefit the crops planted in the dry season as it will store more water and nutrient for crop uptake.

Abstrak. Tantangan utama pemanfaatan lahan kering iklim kering untuk pertanian adalah terbatasnya ketersediaan sumberdaya air dan proses degradasi kualitas tanah yang cepat. Penelitian ini bertujuan untuk mengevaluasi perubahan beberapa sifat tanah dan kualitas tanah (SQ) setelah empat tahun diterapkannya pertanian konservasi (CA). Penelitian dilaksanakan di lokasi percontohan CA di Lombok Timur, Nusa Tenggara Barat. Tekstur tanah permukaan adalah lempung dengan kemiringan lahan antara 5-10%. Dua model CA dan 1 model petani (LP) dibandingkan. Pada setiap model, ditetapkan 3 posisi berbeda untuk pengambilan contoh tanah yaitu 1) dalam jalur tanam jagung (Posisi A), 2) 0-10 cm dari Posisi A (Posisi B), dan 3) 10-20 cm dari Posisi A (Posisi C). Contoh tanah utuh dan komposit diambil dari 3 posisi tersebut untuk penetapan sifat fisik dan kimia tanah. Model CA secara nyata ($P<0.01$) menurunkan BD dan meningkatkan C organik tanah (SOC) dan P tersedia (Av P), sementara Posisi berpengaruh hanya pada BD. Nilai BD terendah (0.87 ± 0.07 Mg m^{-3}) dan nilai SOC (1.51± 0.05%) dan kapasitas air tersedia (AWC; 18.06 ± 0.76% vol) tertinggi didapatkan pada Posisi A dari perlakuan CA dengan lubang permanen (PIT). Indek kualitas tanah tertinggi diperoleh pada Posisi A diikuti oleh Posisi B dan terkecil di C hal ini menunjukkan bahwa komponen rotasi tanaman pada sistem CA memberi pangaruh yang relatif kecil terhadap perbaikan kualitas tanah. Perbaikan kualitas tanah di Posisi A akan meningkatkan penyimpanan air dan hara tanah sehingga dapat mendukung pertumbuhan tanaman pada musim kemarau.

Introduction

Upland agriculture with dry climates is commonly found in the eastern part of Indonesia, especially in East Nusa Tenggara (NTT) and West Nusa Tenggara (NTB). It is characterized by a relatively low annual precipitation (<2,000 mm yr^{-1}) occurring mostly within 3 to 5 months period (Mulyani *et al*. 2014). Fahrudin *et al*. (2017) reported that about 87-90% of the precipitation occures in the rainy season of November to April, the rest of the months (7-9 months) are very dry with the potensial supply of water from rainfall is only 10-13% of the total annual precipitation. The high intensity of rainfall in the rainy season indicates that the sloping upland agriculture in the area is very vulnerable to soil erosion, different conditions occur in the long dry season where water availability is very scarce, even for domestic use.

* Corresponding author: arbb1@yahoo.com

Despite its low soil producitivity, West Nusa Tenggara contributes 4.5% to the total national corn production or the seventh highest in the country surpassing Gorontalo, NTT, and West Sumatera. There is a steady increase of 7,36% between 2012-2016 in the harvested area of corn in NTB. The harvested area of corn increased from 117,030 ha in 2012 to 203,010 ha in 2016 with an average yield of 6.06 t ha^{-1} which was higher than the national average of 5.03 t ha^{-1} (Pusdatin 2016). The potential increase of corn production in NTB is promising considering the possibility to expand the planted area and increased productivity through the introduction of best agricultural practices.

Corn is the main secondary crop grown by Indonesian farmers after rice in terms of its contribution to gross domestic product and portion of land planted to corn relative to the total area allocated for food crops. In the last five years, corn demand for feed, food and beverage industries increased by 10-15% per year. The demand for corn for feed by 2020 is expected to reach 14 million ton, which is about 49% of the total predicted corn production (Pusdatin 2016). Therefore, the production of corn affects the performance of the livestock industry. In the national economy, corn is the second largest contributor after rice in the food crops sub-sector.

The potential of dryland in Indonesia is enormous, covering an area of more than 140 million ha (Ritung *et al*. 2016), some 10.75 million ha of them lies in area with 8-9 months of very dry season, therefore, crops planted after the first crop harvest in those regions are mostly suffered from drought. In addition to the long dry season, soils in the eastern part of Indonesia, especially in Nusa Tenggara Barat (NTB) and Nusa Tenggara Timur (NTT) provinces are poor in their soil physical and chemical properties: shallow soil solum, and consists of many rock outcrops. Farmland is cultivated only four months in a year or one crop per year, where the rest of the year is left uncropped. To overcome some of the problems in the region, FAO in collaboration with the Indonesian Agency for Agriculture Research and Development (IAARD) introduced the concept of conservation agriculture since 2014 with the aim to improve soil quality and crop productivity of the dryland.

The sustainability of the agricultural system, especially in developing countries, is closely related to the changes in soil quality, especially on upland agriculture (Sumarno 2012). Poor agricultural practices threaten the sustainability of the existing system to function, including for agriculture production due to degradation of soil quality. Soil quality is the capacity of soils to function within an ecosystem and is an indicator of environmental quality, biological productivity, plant and animal health, and sustainable land management (Karlen *et al*. 1997, Arshad and Martin 2002, Rachman *et al*. 2017). Implementing conservation agriculture model on upland agriculture with dry climates such as in NTB is believed to improve soil quality. Conservation agriculture combines three approaches simultaneously, which include minimum disturbance of soil (minimum tillage), the return of crop residues into farmland as mulch, and crop rotation temporarily or spatially (FAO 2015). The practice is very different from the common practice of farmers in Indonesia who is always till the soil and burn the crop residues on the field after harvest.

Hence, this study evaluates the changes in soil quality after four years of conservation agriculture implementation.

Materials and Methods

Experimental Site Description

This study was conducted in Gunung Malang Village, Pringgabaya District, East Lombok Regency, West Nusa Tenggara Province (116o 40’47.14" E, 8o 26’52.55" S) where conservation agriculture practices have been implemented continuously for four years. The annual temperature in the study site ranging from 22^{o}C to 33^{o}C, and that the mean annual precipitation is 1209 mm, occurring mostly from December to April, while the rest of the year is dry. The surface soil texture is loam with slope ranging from 5 to 10%. Selected soil chemical and physical properties of the soil surface are summarized in Table 1. The soil organic matter content is very low (<1%) caused mainly by poor farming practices where farmers burn their crop residues after harvest and the dependence of farmers on chemical fertilizers to maintain crop productivity.

Table 1. Selected soil chemical and physical properties of the study site before the application of conservation agriculture, Gunung Malang in 2014

Tabel. 1. Sifat kimia dan fisik tanah di lokasi penelitian sebelum pertanian konservasi diterapkan, Gunung Malang, 2014

Soil parameter	Unit	Value
Sand	g $100g^{-1}$	49.3 (5.1)[1]
Silt	g $100g^{-1}$	40 (4.1)
Clay	g $100g^{-1}$	10.8 (2.2)
pHw	-	6.6 (0.3)
Organic matter	g $100g^{-1}$	0.93 (0.22)
CEC	$cmol_c$ kg^{-1}	10.05 (2.33)

[1] Numbers in parentheses are the standard deviation of the mean of four

Maize is the main annual crop grown in the Pringgabaya District with productivity between 3 to 6 ton ha^{-1}. The majority of farmers in the village grows maize in the upland area once a year during the rainy season from December to March and continued with bean crops during the second growing season when the rain begins to decrease. A small number of farmers planted maize in the second season with the help of irrigation water pumped from the well. After harvesting the second crop, the land is basically left without crops due to very dry soil conditions. During the soil sampling of this study in June 2017, the field was bare with maize residues as mulch on the soil surface for the conservation agriculture plots and no mulch for the farmer (conventional agriculture) plots.

A B

Figure 1. Conservation agriculture model with small permanent pit (A) and strip tillage/ripping (B) methods for seed placement

Gambar 1. Model pertanian konservasi dengan metode lubang permanen (A) dan olah tanah strip (B) untuk peletakan benih

In the beginning of 2014, conservation agriculture (CA) practices were introduced into villages through demonstration plots. The CA model introduced including PIT and RIP models (Figure 1). As a comparison, the conventional farmers practice (LP) was also sampled. The description of each farming model is as follows:

(1) PIT : CA with permanent pit (40 x 40 x 20 cm), corn seeds were sown on each corner of the pit, the distance between pits is 40 cm where the biomass of harvested corn was laid as mulch. No-tillage was applied after establishing the pit except for mixing the organic compost with the soil inside the pit.

(2) RIP : CA with strip tillage or ripping, corn seeds were sown along the strip, the distance between strips was 40 cm where the biomass of harvested corn was laid as mulch. No-tillage but small opening along the strips to facilitate the placement of seed.

(3) LP : local practice in which the soil was ploughed to a depth of 15 cm at each planting season. No harvested corn biomass was returned to the field.

Soil Sampling and Analysis

Soil samples for soil chemical and physical property analyses were collected in June 2017 on each of the treatment plots. Three sampling positions within each plot were selected representing Position A, B and C. Position A is inside the pit or rip, Position B is 0-10 cm from the edge of the pit or rip, and Position C is 10-20 cm from the edge of the pit or in the middle between two pits or rips (Figure 2).

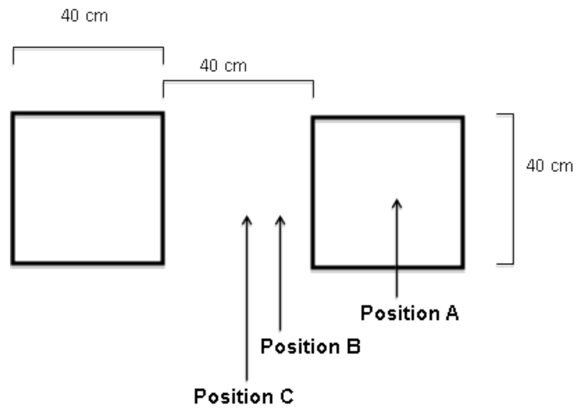

Figure 2. Schematic sketch of conservation agriculture with permanent pit (PIT) illustrating the dimension of pit and sampling positions (Position A, inside the pit; Position B, 0-10 cm from the edge of the pit; and Position C, 10-20 cm from the edge of the pit)

Gambar 2. Sketsa pertanian konservasi dengan lubang permanen (PIT) menunjukkan dimensi lubang dan lokasi pengambilan contoh (Posisi A, di dalam lubang; Posisi B, 0-10 cm dari sisi lubang; dan Posisi C, 10-20 cm dari sisi lubang)

Composite soil samples were collected from the soil surface (0-15 cm) from each position with four replicates. Composite soil samples were analysed for soil texture (pipette methods), pH (1:2.5 soil:water ratio, measured using a pH meter), C-organic (Walkley and Black Method), N (Kjeldahl), P_2O_5 (Olsen), K_2O (Morgan), and CEC (cation exchange capacity).

Intact soil cores were collected using a core sampler (76-mm inside diam and 40-mm length). Soil cores were taken from 2 depths 0 to 4-cm, 10 to 14-cm. Three soil cores from each depth with three replicates were collected for bulk density, porosity, water availability, and permeability measurements. The samples were labeled, sealed in plastic bags and placed in cases for transport to the laboratory. Soil water retention at matric potentials of 0.001, 0.01, 0.033, and 1.5 MPa were measured using a pressure plate apparatus (Sudirman *et al*. 2006). Intact soil cores were used to measure water retention at field capacity (FC) at 0.033 MPa. The potential available water capacity (AWC) of the soil was calculated as the difference in volumetric water content at 0.033 and 1.5 MPa. Bulk density (BD) was determined from oven-dried samples (Blake and Hartge 1986, Agus *et al*. 2006).

The principal component analysis (PCA) was used to determine the minimum data set (MDS) for calculating the soil quality index (Andrews *et al*. 2002, Li *et al*. 2013, Supriyadi *et al.* 2017). The analysis was conducted on untransformed data. Principal components (PCs) that received high eigenvalues (>1) were assumed to best represent variation in the systems (Andrews *et al*. 2002, Masto *et al*. 2008, Mukherjee and Lal 2014).

Since the units used to express the value of each soil parameters and their effect on soil quality are different, the transformation of each soil property values were necessary using scoring and weighing techniques. Scoring was conducted on each key indicator using a linear scoring function method (Andrews *et al*. 2002). Indicators were ranked in ascending or descending order depending on whether a higher value was considered “good” or “bad” in terms of soil function. The principle of "more is better" applied for Av K, N, and AWC which means the greater the value the better, thus the highest observation score is given a score of 1. Another principle is to use the principle of "higher is better" up to an optimum level, then apply the principle of "lower is better". The soil parameters included in this category is pH. The soil quality index (SQI) was then calculated using the following formula (Karlen and Stott 1994, Fernandes *et al*. 2011, Mukherjee and Lal 2014):

SQI = {(weight 1) * (Sub weight * RDC)} + {(weight 2) * (Sub weight – WSC)} + {(weight 3) * (Sub weight * NSC)}

Where RDC is the root development capacity, WSC is the water storage capacity, and NSC is the nutrient supply capacity. Weight 1, 2, and 3 are the respective numerical weights for each soil function assigned based on the major constraint of maintaining soil quality in the area in relation to crop productivity. Since the major limiting factor for crop growth in the area is water availability, therefore the highest weight (0.40) was assigned to WSC and the lowest is (0.25) was given to RDC. Sub weights are the weighted factor of each soil parameter based on PC analysis. The weighting factor value for each indicator was calculated by dividing the amount of variation of each PC with the maximum total variation of all PCs selected to determine the MDS.

Results and Discussion

Effects of Conservation Agriculture on Selected Soil Properties

The CA Model had a statistically significant different effect ($P < 0.01$) on bulk density (BD), soil organic carbon (SOC), and available P (AvP; Table 2). Interaction of CA Model and sampling Position had a significant different effect on BD and SOC. The lowest bulk density (0.87 ± 0.07 Mg m^{-3}) was obtained on the first soil depth (0-10cm) of position A under the PIT and the highest (1.36 ± 0.03 Mg m^{-3}) was on the second depth (10-20 cm) of Position C under the RIP (Figure 3). Application of continuous zero tillage for four years on PIT and RIP increased the near-surface bulk density (0-10 cm) of Position A by about 7.6%, 14.9% for Position B and 33.7% for Position C from the initial bulk density value (baseline BD=0.92 Mg m^{-3}). It is interesting to note that even thought Position B received the same treatment as Position C, however, the bulk density was significantly lower in Position B than C (Table 2). We speculate that this fact was affected by the expansion of corn root into Position B from Position A which had loosening effects to lower bulk density. Lower bulk density value may enhance water infiltration, soil porosity, soil fauna activity, and root development (Kemper *et al.* 2012, Amien *et a*l. 2014, Rachman 2016) which are important on semi arid environment.

Available pore water is the range of soil pores ranging from 0.2 to 8.6μ where water is stored that can be utilized by plants for growth. The greater the percentage of available water pore distribution in the soil, the greater the availability of water for plant growth. The CA Model and Position had no significant difference on available water capacity (AWC; Table 2). However, there is a trend that position A had the highest AWC followed by position B and the lowest was in position C on both depth, 0-10 and 10-20 cm soil depth (Figure 4). The AWC at the first soil depth tended to be higher than at the second depth. The highest available pore water (18.06 ± 0.76% vol) was obtained in position A of the PIT and the lowest (12.55 ± 1.85% vol) was in position C of the RIP. These results indicate that the conservation agriculture with permanent pits filled with a mixture of soil composted green manure provides more water than other models for plants during the dry season. In addition, the growth of corn roots in position A positively affects the surrounding zones as indicated by improved AWC in position B than in C. Application of harvested corn residues into position C as surface mulch has not been able to increase the AWC.

Soil organic matter was affected by CA model ($P < 0.05$) while the position within the CA model had no significant effect on SOC (Table 2). Across positions, the highest SOC (1.27± 0.21%) was obtained in PIT followed

Table 2. The CA model and position means and probability values (P > F) from analysis of variance for bulk density (BD), available water capacity (AWC), pH, soil organic carbon (SOC), and available P (Av P) as affected by CA Model and Position four years after establishment of conservation agriculture system

Tabel 2. Rata-rata nilai dari model CA dan posisi dan nilai probabilitas (P > F) dari hasil ANOVA terhadap berat isi tanah (BD), kapasitas ketersediaan air (AWC), pH, bahan organik (SOC), dan ketersediaan P (Av P) yang dipengaruhi oleh Model CA dan Posisi empat tahun setelah diterapkannya sistim pertanian konservasi.

	BD	AWC	pH	SOC	Av P
	CA Model mean				
PIT	1.09	15.1	7.0	1.27	89.0
RIP	1.26	14.1	7.0	1.00	25.7
LP	1.04	13.5	6.4	0.76	26.8
	Position mean				
A	1.02	15.4	6.6	1.07	63.1
B	1.12	14.0	6.7	0.97	50.7
C	1.25	13.4	7.0	0.98	43.3
	Analysis of variance P > F				
CA Model	0.000	0.140	0.015	0.000	0.000
Position	0.000	0.062	0.147	0.209	0.302
CA Model X Position	0.005	0.263	0.949	0.017	0.243

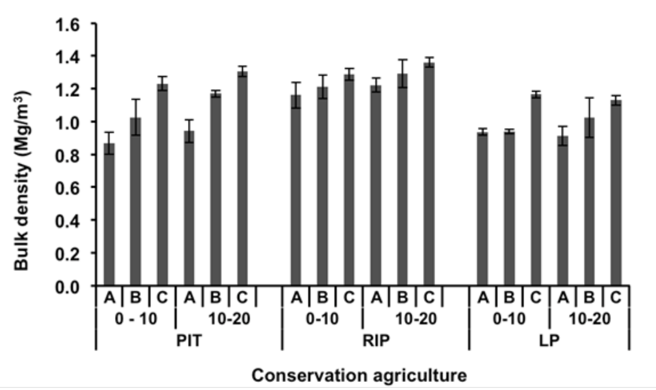

Figure 3. Effects of conservation agriculture model, soil depth, and sampling position on bulk density

Gambar 3. Pengaruh model pertanian konservasi, kedalaman tanah, posisi pengambilan contoh terhadap berat isi tanah

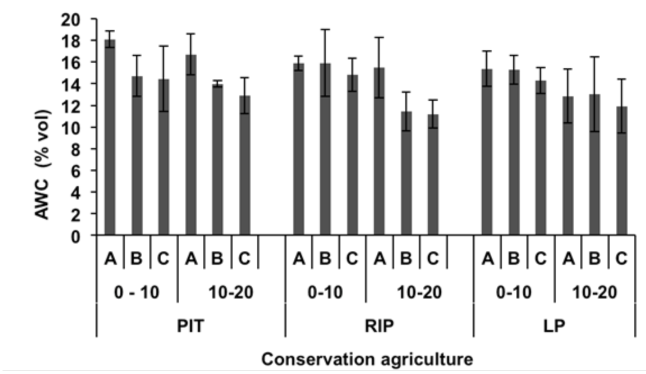

Figure 4. Effects of conservation agriculture model, soil depth, and sampling position on available water capacity (AWC)

Gambar 4. Pengaruh model pertanian konservasi, kedalaman tanah, dan posisi pengambilan contoh terhadap kapasitas ketersediaan air (AWC)

by RIP (1.00 ± 0.12%) and the lowest was in LP (0.76 ± 0.18%). The application of conservation agriculture had increased the SOC by 37% on PIT and 8% on RIP, while the LP lowered the SOC by 18% from the initial SOC value of 0.93 ± 0.22% (Figure 5). The higher SOC under PIT was mainly contributed by Position A of the PIT which had the highest SOC (1.51± 0.05%). Decayed corn root and the addition of compost into the pit have enriched the soil organic matter conttent of position A in the PIT. The reduction of SOC on LP was caused by the removal of crop residues out of the field mostly to feed the cattle or burned which is a very common practice in the area.

There is no significant effect of CA Model and Position on pH, while available P were significantly affected by CA model. The concept of conservation tillage which is one component of conservation agriculture (Lal 2015, FAO 2015) has been reported by others to increase gradually soil organic matter content (Zikeli *et al*. 2013, Ghosh *et al*. 2015), nutrient supply (Kassam *et al*. 2013), available water capacity (Kassam *et al*. 2013, Aziz *et al*.

2013), soil aggregation (Nurida and Kurnia 2009). Zikeli *et al*. (2013) reported that conservation tillage significantly increased available K and P on surface soil (0-20 cm). The conservation tillage combines minimum disturbance of soil by any tillage practice with the return of crop residues into the field as surface mulch (Rachman *et al*. 2004, Busari *et al*. 2015), therefore, it will gradually improve the quality of degraded soil (Kassam *et al*. 2009, Derpsch *et al*. 2010), especially in arid and semi-arid environments (Mosaddeghi *et al*. 2009).

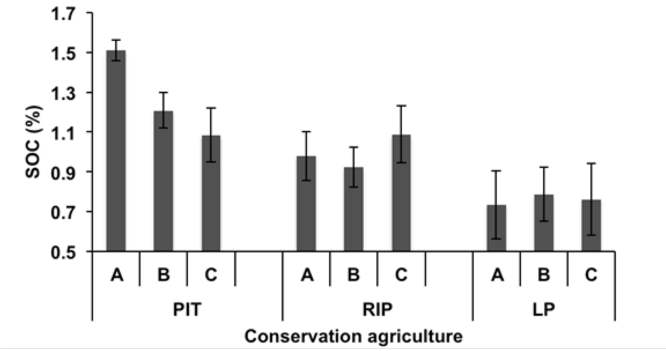

Figure 5. Effects of conservation agriculture model and sampling position on soil organic carbon (SOC)

Gambar 5. Pengaruh model pertanian konservasi, kedalaman tanah, dan posisi pengambilan contoh terhadap karbon tanah (SOC)

Soil Quality Evaluation

Table 3 shows the results of the principal component analysis (PCA). There were 15 PCs, but only the PCs with eigenvalues > 1 were analyzed (Supriyadi *et al*. 2017). Under a particular PC, each soil variable has a weighing index (WI) that represents the contribution of that variable to the composition of the PC. The 'highly weighted' variables, having WI > 0.300 were retained for further analysis to determine MDS (Mukherjee and Lal 2014). Based on that criteria, the selected variables as indicated by boldface values in Table 3 were SOC, Tot P, Av P, AWC, PR, and FC for PC-1, pH, Av K, BD, and WP for PC-2, pH, Tot N, CEC, and BS for PC-3, and Av P, AWC,

Table 3. Results of principal components analysis of soil quality indicators having significant differences between three positions with applied conservation agriculture. East Lombok 2017

Tabel 3. Hasil dari analisa komponen utama (principal components analysis) terhadap indikator kualitas tanah yang menunjukkan perbedaan nyata diantara tiga posisi pada perlakuan pertanian konservasi, Lombok Timur 2017

Principal components	PC1	PC2	PC3	PC4	PC5
Eigenvalue[a]	**4.992**	**3.821**	**1.889**	**1.108**	0.923
Proportion	0.333	0.255	0.126	0.074	0.062
Cumulative	0.333	0.588	0.713	0.787	0.849
Eigen vectors[b,c]					
pH	0.160	**-0.322**	**-0.375**	-0.063	-0.292
Soil organic carbon (SOC)	**0.307**	-0.209	0.238	0.015	0.029
Total N (Tot N)	0.203	0.140	**<u>-0.518</u>**	-0.212	0.132
Total P (Tot P)	**0.332**	-0.212	0.158	-0.284	0.175
Available P (Av P)	**<u>0.374</u>**	-0.102	0.122	**-0.326**	0.247
Total K (Tot K)	0.120	-0.276	0.259	-0.214	-0.568
Available K (Av K)	0.230	**<u>-0.400</u>**	0.001	-0.050	0.023
Cation exchange capacity (CEC)	0.253	0.254	**-0.382**	-0.264	-0.061
Base saturation (BS)	-0.019	-0.292	**<u>-0.447</u>**	0.281	0.086
Bulk density (BD)	-0.224	**<u>-0.386</u>**	-0.142	0.127	-0.108
Available water capacity (AWC)	**<u>0.339</u>**	0.071	0.022	**0.495**	-0.250
Permeability (PERM)	0.290	-0.007	0.143	**<u>0.382</u>**	0.494
Porosity (PR)	**<u>0.326</u>**	0.184	-0.154	0.075	-0.105
Field capacity (FC)	**0.320**	0.246	0.058	**0.320**	-0.330
Wilting point (WP)	0.013	**0.379**	0.117	-0.228	-0.181

[a] Boldface eigenvalues correspond to the PCs examined for the index
[b] Boldface factors are considered highly weighted index
[c] Bold-underlined factors correspond to the indicators included in the MDS

PERM and FC for PC 4. Further analysis of selected variables was conducted using Person Correlation to determine if the variables were highly correlated (Table 4). If the variables were significantly correlated as indicated by r-value > 0.6 and P-value <0.01, then the one with the highest WI was retained in the MDS, and all others were eliminated to avoid redundancy.

Following that procedure, three variables under PC1 (Av P, AWC, and PR), two variables under PC2 (Av K and BD), two variables under PC3 (N and BS) and one variable under PC4 (PERM) were selected in the final MDS as indicated by bold-faced and underlined values in Table 3. The calculation of soil quality index was done by firstly classifying the soil indicators into three groups based on the function of the soil i.e. water storage capacity (WSC), nutrient supply capacity (NSC), and root development capacity (RDC). Soil indicators included in the WSC were AWC and PERM, soil indicators in NSC were Av P, Av K, Tot N and BS, and BD and PR in the RDC. The highest weight was given to WSC (0.40) followed by NSC (0.35) and RDC (0.25), since the main limiting factor for crop growth in the semi-arid environment as in the study site is water shortage for >8 months. The next limiting factor is the soil nutrient availability since farmers in the upland area apply a very limited amount of both chemical and organic fertilizers.

Table 5 shows the difference in soil quality index as influenced by the application of conservation agriculture for four years and position within the respective CA Model. The application of conservation agriculture with permanent pit (PIT) was able to improve the soil quality relative to other models (RIP and LP). Better soil quality was found on Position A and B under PIT, Position A under RIP and Position A and B under LP and lower soil quality was found in Position B and C for RIP and C for PIT and LP. Continuous planting of corn in Position A and allowing corn roots and stalks to decay in that area gave a positive effect on soil quality improvement both in Position A and B. While there was no improvement on soil quality on Position C indicating that planting secondary crop as crop rotation in Position C with zero tillage did not give sufficient improvement on soil chemical and physical

Table 4. Pearson correlation coefficient (r) and level of significant for all soil variables tested

Tabel 4. Koefisien korelasi Pearson (r) dan tingkat signifikansi terhadap semua variabel tanah yang diuji

	pH	SOC	N	Tot P	Av P	Tot K	Av K	CEC	BS	BD	AWC	PERM	PR	FC
SOC	0.246													
N	0.273	0.078												
Tot P	0.417*	0.690**	0.134											
Av P	0.305	0.653**	0.260	0.896**										
Tot K	0.391*	0.484*	-0.265	0.410*	0.313									
Av K	0.665**	0.647**	-0.009	0.698**	0.603**	0.506**								
CEC	0.167	-0.005	0.835**	0.139	0.358	-0.147	-0.101							
BS	0.619**	0.023	0.133	-0.006	-0.083	0.001	0.401*	-0.108						
BD	0.413*	-0.107	-0.320	-0.087	-0.362	0.137	0.301	-0.615**	0.530**					
AWC	0.175	0.476*	0.265	0.333	0.384*	0.130	0.226	0.378	-0.078	-0.371				
PERM	0.053	0.449*	0.095	0.468*	0.530**	0.006	0.301	0.141	0.045	-0.391*	0.539**			
PR	0.153	0.253	0.443*	0.304	0.464*	-0.079	0.150	0.624**	-0.050	-0.529**	0.574**	0.386*		
FC	-0.012	0.307	0.282	0.239	0.337	0.012	-0.028	0.506**	-0.271	-0.619**	0.875**	0.432*	0.702**	
WP	-0.375	-0.262	0.035	-0.155	-0.042	-0.267	-0.532**	0.275	-0.459*	-0.601**	-0.053	-0.087	0.327	0.414

Table 5. Soil quality index of soil conservation agriculture practices in East Lombok, Indonesia

Tabel 5. Kualitas tanah dari praktek pertanian konservasi di Lombok Timur, Indonesia

Soil function	Weight 1	MDS	PC weight	Total weight	Score index								
					PIT			RIP			LP		
					A	B	C	A	B	C	A	B	C
WSC	0.40	AWC	0.423	0.169	0.81	0.72	0.59	0.82	0.61	0.59	0.59	0.63	0.57
		PERM	0.094	0.038	1.00	1.00	0.80	1.00	1.00	0.95	0.85	1.00	1.00
RDC	0.25	BD	0.324	0.081	1.00	0.82	0.52	0.65	0.54	0.40	1.00	1.00	0.71
		PR	0.423	0.106	1.00	0.88	0.69	1.00	0.87	0.80	1.00	1.00	0.84
NSC	0.35	Av P	0.423	0.148	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Av K	0.324	0.113	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Tot N	0.160	0.056	0.03	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
		BS	0.160	0.056	1.00	1.00	1.00	1.00	1.00	1.00	0.87	0.89	1.00
		Soil quality index (SQI)			0.68	0.64	0.56	0.65	0.59	0.57	0.63	0.64	0.60

properties used to determine the soil quality index. The application of conservation agriculture concept on semi-arid environment may take longer than four years to significantly improve soil quality as also indicated by previous studies (Kassam *et al*. 2009, Mosaddeghi *et al*. 2009, Derpsch *et al*. 2010). The amount of crop residues returned as surface mulch as one package of conservation tillage concept (Rachman *et al*. 2004, Busari *et al*. 2015) may not be sufficient to rapidly improve soil condition due to rapid decomposition process under warm environmental conditions.

Conclusions

The selected minimum data set to calculate soil quality index (SQI) of the site where conservation agriculture had been implemented for four years were available water capacity, porosity, available P, bulk density, available K, Total N, base saturation, and permeability, which represent 79% of variation. The SQI of the permanent pit system was slightly better than ripping and farmers' local practices.

After four years under conservation agriculture (CA) practices, the soil quality at Position A (SQI = 0.63-0.68), inside the pit or strip where corn was continuously grown and corn residues were returned had shown a greater improvement in soil quality as compared with other positions. The least soil quality improvement (SQI = 0.56-0.60) was found at Position C located at about 10-20 cm from the edge of the pit or strip, indicating that crop rotation component in the CA model had a relatively small effect on improving soil condition.

The improvement of soil bulk density, available water capacity and organic carbon content at Position A may benefit the crops planted in the dry season as it will store more water and nutrient for crop uptake.

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