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SOIL QUALITY OF A CROPLAND AND ADJACENT NATURAL GRASSLAND IN AN ARID REGION

Nurullah ACİR[1*], Hikmet GÜNAL[2]

[1]Kırşehir Ahi Evran University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Kırşehir, Turkey e-mail: nurullah.acir@ahievran.edu.tr

[2]Tokat Gaziosmanpasa University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Tokat, Turkey e-mail: hikmetgunal@gmail.com

Abstract: Maintaining and improving the quality of soils are vital to provide the food and fiber demands of increasing human population and support the sustainability of the ecosystem services. The aim of this study was to assess the effects of land use change on soil quality and related functions of natural grassland and adjacent cropland which has been used as grassland till 2008. Rotation of forage crops including rye, triticale, barley and second crop silage corn has been applied in the cropland after the conversion from rangeland. Manure (50 ton ha^{-1}) was applied to all croplands at the beginning of the crop production. A total of 200 surface soil samples (0-20 cm) were collected in June 2012, 68 of which were from cropland and 132 from natural grassland. Soil samples were analyzed for bulk density, aggregate stability, available water content, water-filled pore space, total organic carbon, pH, electrical conductivity (EC), sodium adsorption ratio, plant available phosphorus and extractable potassium concentrations to determine the soil quality index using Soil Management Assessment Framework method. Nutrient cycle, water relations, physical stability and support, filtration and storage, and resilience and resistance sub-functions were examined under the soil quality. Indicators defining the soil functions were determined using expert opinion and principal component analysis (PCA), and weights for each indicator were assigned by using simple additive and weighted additive methods. The aggregate stability included in the data set with the expert opinion was removed from the data set by the PCA approach. Total organic carbon, sodium adsorption ratio and EC were the most frequently used indicators to define soil functions in the study area. Soil quality assessment determined by PCA and expert opinion methods produced significantly different results. The mean sodium adsorption ratio values of cropland and natural grassland were 4.30 and 7.19, and the EC values were 2.48 and 3.66 dS m^{-1}, respectively. High sodium adsorption ratio decreased the soil quality in both lands. In addition, lower total organic carbon and higher EC values in natural grassland were other causes of low soil quality. Manure addition, crop rotation and irrigation in cropland increased the total organic carbon and decreased the sodium adsorption ratio and EC values compared to the natural grassland. Therefore, contrary to the expectations that converting rangelands into the croplands leads to negative changes in soil functions, conversion of natural grassland to cropland in study area, improved the soil quality. The simplicity and quantitative flexibility of soil management assessment framework allowed to compare and assess the effects of rangeland conversion into cropland.

Keywords: Soil management assessment framework, Soil quality, Principal component analysis, Expert opinion

1. INTRODUCTION

Soil is a habitat for thousands of organisms and also fulfills an important function in the preserving air and water quality recycling and filtering organic and inorganic residues. The capacity of a soil to perform various functions such as environmental protection and productivity is a consequence of the complex interactions of physical, chemical and biological properties of soils (Seybold et al., 1997). The ability of soils to perform the functions is adversely affected by land use activities (Hammac et al., 2016). The increase in the world population causes intensive land and input uses to maintain food safety, which lead to severe environmental quality concerns (Bagherzadeh & Gholizadeh, 2018). Therefore, conserving and improving the ability of soils to fulfill the functions is crucial providing important ecosystem services, such as sustainable food production, biodiversity, carbon sequestration, water retention and flood control (Kibblewhite et al., 2012).

Soils have an important role in provisioning services of the agricultural ecosystems, such as food and fresh water, along with regulating such as climate regulation, supporting services such as nutrient cycling and cultural services such as recreational, and aesthetic benefits (Duru et al., 2015). Soil quality which is considered as a regulating service can be improved using conservative agricultural practices to maintain the qualities of soil, air and water on-farm and in the surrounding agro ecosystems (Andrews et al., 2004).

Rangeland is an important agroecosystem type in arid and semi-arid regions that covers about 40% of the land surface area of the world (Suttie et al., 2005), supports indigenous vegetation (Havstad et al., 2007) provide several ecosystem services depending upon their management (Raiesi et al., 2017). Rangelands in many arid and semi-arid regions of the world have been reported facing with severe soil degradation and subsequent decrease in soil quality due to continuing decrease in organic matter content, soil structure stability and losses of nutrients. Conversion of rangelands to croplands, extensive grazing and erosion are the most commonly stated causes of decline in soil quality in arid and semi-arid regions (Snyman et al., 2005; Li et al., 2013; Ayoubi et al., 2014; Mahyou et al., 2016).

Reliable methods are needed to assess the effects of land use change, intensive agricultural practices, crop rotations etc. on soil functions (Wienhold et al., 2009). Data sets in the assessment methods should be composed of the minimum number of chemical, physical and biological soil properties that will allow the measurement of the realization rate of soil functions (Doran & Parkin, 1996; Karlen et al., 2003). Determining and monitoring the soil quality by establishing minimum data sets will enable early detection of the problems causing a reduction in the functioning ability of soils. Abnormalities detected in one or more of the quality indicators in the generated data sets is an indication of disruptions in the provision of ecosystem services. Therefore, monitoring the variability in soil quality as well as the individual functions and indicators is extremely important to take necessary precautions before the further degradation of natural resources (Budak et al., 2018).

Recent developments in statistical theories revealed a spatial correlation between the values of a variable within a sampled location, and that this correlation can be quantified to predict the value at an unsampled location (Lark & Minansy, 2018). Geostatistical methods are used successfully in determining the spatial dependence and prediction of unsampled locations. Understanding the temporal and spatial variations of soil properties is important to assess the effects of agricultural activities on environmental quality (Gunal et al., 2012; Goenster-Jordan et al., 2018).

The intensive influx of refugees in addition to the rapid increase of the population caused a serious increase in food and fiber demands in many countries, which resulted in pressure for the expansion of croplands and intensification of land use for crop and forage production (Günal et al., 2015). Intensive agricultural activities reported leading to considerable depletion of the ecosystem services (Williams & Hedlund 2014), however, the moderate-intensity and conservative systems can provide satisfactory conditions for sustainability in crop production, while sufficiently maintaining environmental quality (Stavi et al., 2016). This study was carried out to evaluate the quality of soils in cultivated lands, which were recently opened to agriculture, and adjacent natural grassland using nonlinear scoring curves developed by Andrews et al., (2004) under Soil Management Assessment Framework (SMAF). The SMAF emphasizes the dynamic soil quality which is influenced by the current management practices as well as the inherent soil quality that reflects the basic soil formation factors such as climate, topography and parent material. The SMAF has been considered as a user-friendly tool in many soil quality assessments conducted in overall the world (Pulido et al., 2017; da Luz et al., 2019; Gura & Mnkeni, 2019; Valani et al., 2020). However, despite the important functions in provisioning some of the ecosystem services, soil quality in terms of environmental protection is a challenging question for rangelands and the adjacent croplands which were converted from the rangelands.

In this study, functions related to environmental protection were assessed by using the SMAF. In addition, spatial analysis was carried out to map changes of the soil quality within the study area, problems were identified, and solutions were proposed.

2. MATERIAL AND METHODS

2.1. Study Area

The study was carried out in a 2.650 ha land located in 1 km south of Kızılca Village of Bor District in Niğde Province, Turkey and situated in 6150.650-623.350 east-west longitude and 4.177.700-4.187.680 north-south latitude according to European 1950 UTM geographic coordinate system. The altitude of the study area varies between 1043 m and 1060 m and the average slope is around 0.6% (Fig. 1). The study area was not used for agricultural production until September, 2008 and used as natural grassland. The natural rangelands have been overgrazed by sheep for a long time with quite low efficiency due to the high salinity and sodicity. In 2008, crop production started in a part of the land after constructing center pivot irrigation systems. Natural rangelands and adjacent croplands in the study site was differed from each other only due to the land use and concequently vegetation changes. Both lands had been exposed to the same soil forming factors and were derived from calcerous shallow marine deposits (Budak, 2012).

The study area has a local steppe climate which is considered as BSk in the Köppen-Geiger climate classification (Anonymous, 2020). Long term average annual temperature of the study area is 11.08°C and annual precipitation is 333 mm. The highest average long-term rainfall is in May with 48.3 mm and the lowest average rainfall is in August with 3.9 mm. Most of soils have been classified as Petrocalcic Calcixerepts according to Soil Survey Staff (2014) and Petric Calcisol according to IUSS Working Group WRB (2015).

2.2. Crop production

The most important problems constraining agricultural production in the study area are insufficient surface drainage, high salt, boron and exchangeable sodium contents, as well as inadequate irrigation water. Crops grown in the area varied depending on the severity of the aforementioned problems. Rye was the initial crop due to the high tolerance to salt and high boron contents. Triticale and barley, moderately tolerant to salinity, were cultivated after the harvest of rye. Silage corn was planted as the second crop following the triticale and barley which were harvested for silage or hay. The precipitaion of the region is not enough to produce the plants in the crop rotation. Therefore, plants are being irrigated as needed. Addition water as leaching fragment is applied in each irrigation event to remove salt and boron in root zone. The amount of irrigation water during the growing season of rye, tritical and barley was 2225 kg ha^{-1}, and 8500 kg ha^{-1} for silage corn, in addition to the natural pracipitation.

Reduced tillage systems were applied to prepare seedbed for rye, tritical, barley and corn in croplands. Manure (50 ton ha^{-1}) was used in croplands to help remediation of the problems and provide additional nutrients to the crops. The amount of fertilizers used for each of the crop in rotation was 150 kg ha^{-1} diammonium phosphate, 200 kg ha^{-1} ammonium sulphate, 150 kg ha^{-1} ürea (46% N) and 10 kg ha^{-1} zinc sulphate for rye, triticale and barley; and 200 kg ha^{-1} ammonium sulphate, 400 kg ha^{-1} ürea (46% N), 300 kg ha^{-1} composite (20% N, 32+ P_2O_5, 15% SO_3), 2 tons ha^{-1} elementel sulphure, 20 kg ha^{-1} zinc sulphate and 2 kg ha^{-1} EDDHA for second crop silage corn.

2.3. Soil Sampling and Laboratory Analysis

The study area was divided into 400 x 400 m grid squares and a total of 150 soil samples was taken

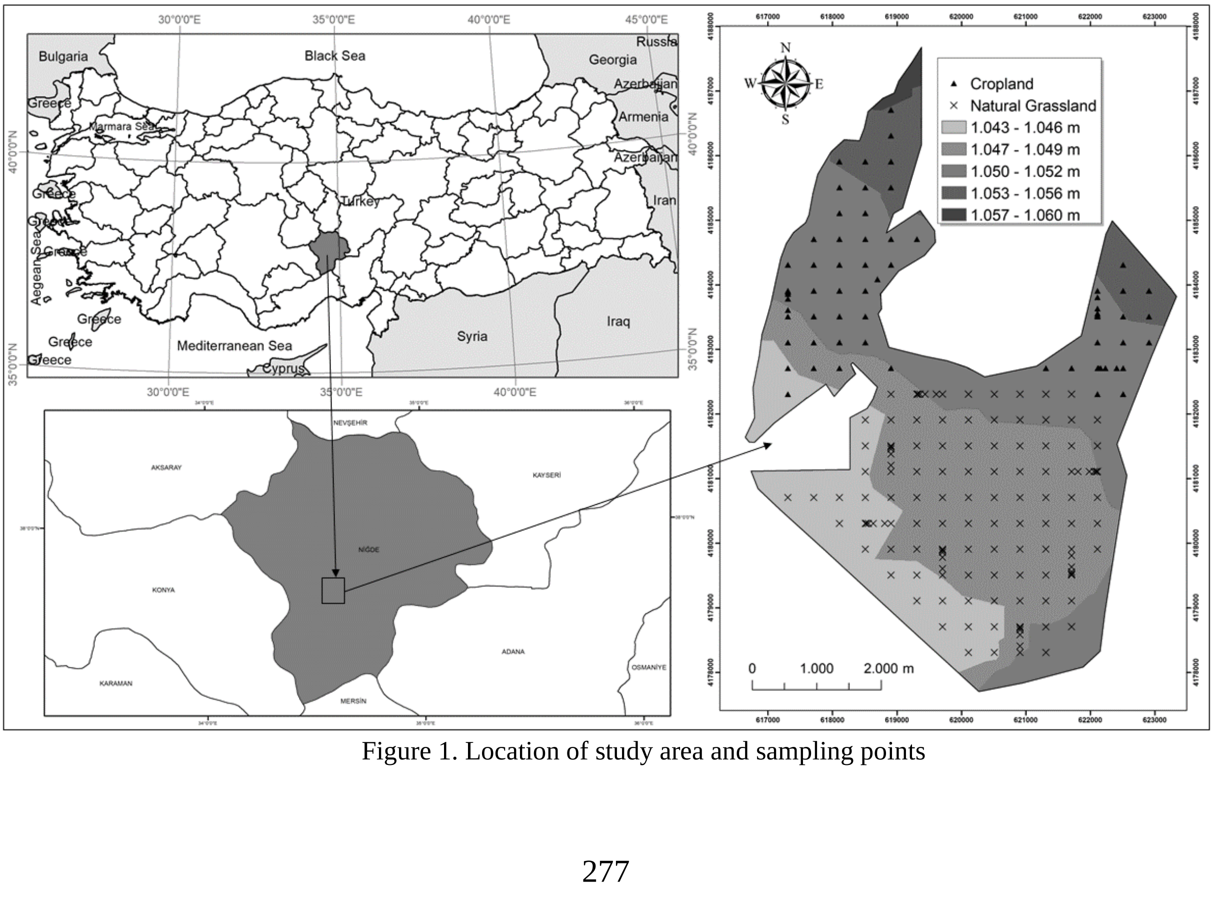

Figure 1. Location of study area and sampling points

from the corners of each grid point in June 2012. In order to determine the variability in distances less than 400 m, 10 transects were placed between the grid corners and a total of 50 samples were taken from 5, 20, 50, 125 and 300 m distances (Fig. 1). Disturbed and undisturbed soil samples were collected from 0-20 cm depth of each sampling point. Undistrurbed soil samples were used to determine bulk density (Blake & Hartge, 1986) and total porosity. Total porosity (TP) was calculated by the following equation;

$$TP= 1-\rho b/\rho p \qquad (1)$$

where; ρb is the bulk density of soil and ρp is the particle density (accepted as 2.65 g cm^{-3}). Root and gravel particles were removed from the disturbed soil samples which were sieved through a 2 mm sieve prior to analysis. Aggregate stability was determined by wet sieving method described by Kemper & Rosenau (1986) within the 2–1 mm size fraction. Available water content was calculated from the amount of water held between field capacity and wilting point using pressure plate sets (Klute, 1986).

Soil organisms suffer under both water deficient and excess water conditions. Aerobic biodegradation of organic material in soil environment can not occur under less than 10% water filled pore space, while Fichtner et al., (2019) indicated that bacterial colonies reach optimum growth at about 60% water filled pore space (Sims et al., 1993). Water filled pore space (WFPS) was calculated by the ratio of volumetric water content obtained by multiplying the water held in the field capacity by bulk density to the total porosity. WFPS was calculated by the following equation (Eq 2);

$$WFPS\ (\%\ or\ cm^3\ cm^{-3}) = VWC/TP \qquad (2)$$

where; VWC is the volumetric water content of soil and TP is the total porosity. Organic matter was determined using the modified Walkley-Black method (Nelson & Sommers, 1982). Plant available phosphorus was analyzedthe method of Olsen (1954) and extractable potassium was determined according to Thomas (1982). The sodium adsorption ratio was determined by using method described in Soil Survey Staff (1996), pH and electrical conductivity was according to Rhoades et al., (1999). Total organic carbon was calculated from the carbon in soil organic matter (Tabatabai, 1994). Since particle size distributon is an inherent characteristic that cannot be changed in a short time; clay, sand and silt contents in the databases in Budak (2012) were used in this study.

2.4. Environmetal Protection Quality of Soils

Soil Management Assessment Framework (SMAF) approach was used in assessing the soil qualities and related functions of soils (Andrews et al., 2004). In SMAF, the effects of various environmental factors are included in scoring the indicators defining the soil functions. Organic matter content, soil texture, amount of annual precipitation, average temperature, slope, mineralogy, weathering class, crop rotation, sampling time and soil analysis method are the factors considered in the scoring of an indicator (Karlen et al., 2008). Nutrient cycling, water relations, physical stability and support, filtering and buffering, resilience and resistance sub-functions have been defined under the soil quality (Fig. 2) (Andrews et al., 2004). The SMAF has three separate stages; proper selection of indicators that may best represent soil functions and overall quality, indicator interpretation (scoring) and integration of indicators into an index. Since low precipitation and high salinity are the major constrains in the land uses, soil organic carbon, aggregate stability, pH, electrical conductivity, sodium adsorption ratio, plant available phosphorus, extractable potassium, available water content, water filled pore space and bulk density were selected as the soil quality indicators.

The minimum data sets (MDS) that define the soil functions have been created by using expert opinion and principal component analysis (PCA).

The PCA was preferred to determine the best indicators defining the relevant function and reduce the dimension of data minimizing the information loss. Kaiser-Meyer-Olkin sphericity test was performed before the PCA to decide whether the data were suitable for the PCA. The lower limit in Kaiser-Meyer-Olkin test was accepted as 0.50 (Tabachnick et al., 2007). Principal components (PC) with eigenvalues ≥1.0 were assumed to be the indicators (Brejda et al., 2000) representing rangeland and adjacent cropland soils. Indicators that are within 10% of the highest loading value in each PC were included in the MDS. When there was more than one variable in a PC, the correlation between the indicators was examined to determine the highly correlated variables and eliminate the redundancy. If linear correlations were>0.50, the indicator with the higher factor loading was retained as indicator of the MDS (Andrews et al., 2002).

In the second stage, the indicator values were converted to unitless scores ranging from 0 to 1.0 using three nonlinear scoring curves (Andrews et al., 2004) which are" more is better", "less is better" and "midpoint is the optimum". In the last stage, indicator scores were combined into a single comparative index value. Two different methods, simple additive (Eq. 3) and weighted additive (Eq. 4), were used to obtain the final index values.

$$SQI_{SA} \sum_{i=1}^{n} \frac{Si}{n} \qquad (3)$$

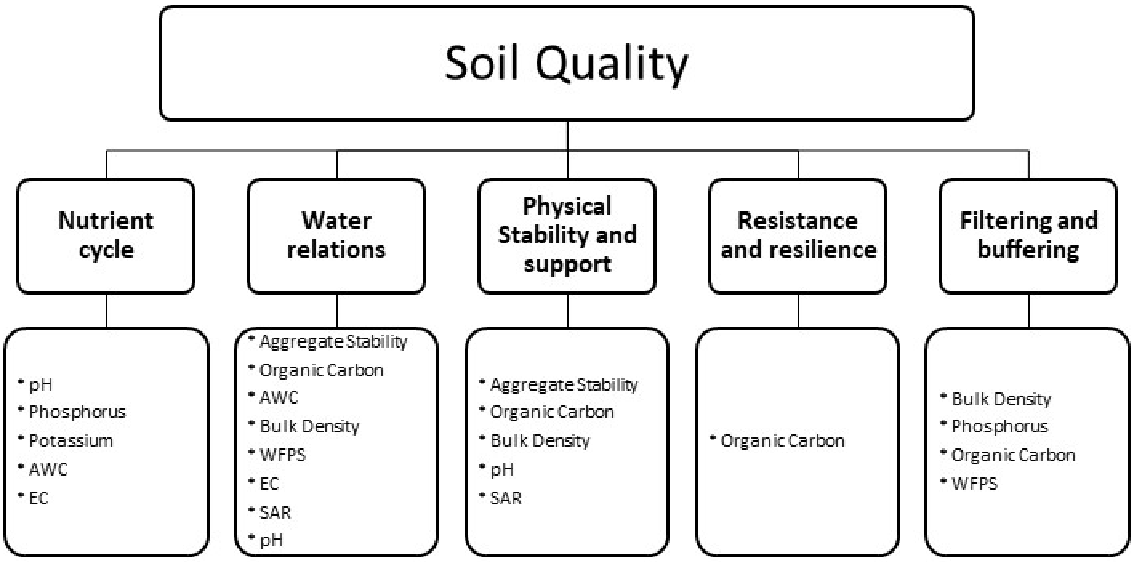

Figure 2. Flowchart to assess the soil quality

The additive index value was calculated by adding the scores of indicators in MDS and dividing the sum to the number of indicators.

$$SQI_{WA} \sum_{i=1}^{n} WiSi \qquad (4)$$

where; *Si* is the indicator score, *n* is the number of indicators and *Wi* is the weight of the indicator. The weights of indicators in PCA were derived from the amount of percent variation explained in the data set. Total variation in each PC was divided to the total variation of PCs with eigenvalues ≥ 1.0 (Ray et al., 2014). The weighted indicator scores were summed up to obtain weighted additive index value.

2.5. Geostatistic Analyses

Geostatistical analysis was conducted to explain the spatial patterns for the distribution of soil quality index values within the study area and to predict the index values for the unmeasured locations. Ordinary kriging technique was used for spatial interpolation (Goovaerts, 1999) of soil quality. Before the spatial analysis, normal distribution of the data was tested and appropriate transformations were performed for the parameter that did not have the normal distribution. GS+ 7.0 was used to analyze the spatial structure and to define the semivariograms. The trend of the variables (soil qualiyt index values obtained by expert opinion and PCA) were checked and the maps were produced after removing the trends of the variable.

2.6. Statistical Analyses

Descriptive statistics (minimum, maximum, mean, standard deviation, coefficient of variation and skewness) of soil properties, indicator scores, the index values of functions and soil index values were calculated using SPSS (SPSS 21) software. The data were tested for normal distribution before the statistical anlaysis. The data were transformed as necessary to meet the normality assumptions of the t-tests. The indicator scores, function scores and soil quality index values between croplands and natural grasslands were compared using independent t-test. Paired t-test was used to compare functions and soil quality index values derived with different methods. Natural rangeland was considered as a control and the values for indicators, functions and indexes were used for comparison with those from the cropland to determine th extend of land use change effect soil quality.

3. RESULTS AND DISCUSSION

3.1. Descriptive statistics of soil properties

Descriptive statistics of some physical and chemical chracteristics of cropland and natural grassland soils were given in Table 1. The most important problems constraining the crop production in both lands are the high salinity and high sodium content determined in some places. Mean sodium adsorption ratio value of cropland and natural grassland was 4.30 and 7.19, respectively, which is values, espacially in natural grassland as high as 53.66 at some locations (Table 1).

Seasonally waterlogging due to the limited drainage on almost completely flat conditions led to accumulation of salts in rangeland soils. Whereas lower salinity in croplands compared to the adjacent rangelands is probably due to leaching fragment applied in irrigation. The findings of Yao et al., (2013) are in accordance with our findings on higher salinity under under native soil than soils under cultivation conditions. High ratio of sodium which is known with dispersing effect causes deterioration of soil structure, decreases infiltration and hydraulic conductivity and increases erosion risk (Navarro-Pedreño et al., 2007). Therefore, soils with high sodium adsorption ratio values do not fully function and require a long time and high cost to be remediated.

Mean electrical conductivity (EC) in cropland and natural grassland was 2.48 and 3.66 dS m^{-1}, respectively. Similar to the sodium adsorption ratio values, the EC values reached 9.41 and 15.14 dS m^{-1} which are considered highly saline environment in some places of the cropland and natural grassland. Sand content varied between 13.1 and 61.6%, with an average of 39.8% and clay content was between 22.0 and 55.9% with a mean value of 35.3% (Table 1). The coefficient of variation (CV) is often used to express the variability of a property across a land. The attribute is considered less variable when CV is less than 15%, moderately variable when CV is between ≥15 and ≤35% and highly variable when CV is >35% (Wilding 1985). Plant available water content, EC, available phosphorus, exchangeable potassium, and sodium adsorption ratio values were highly vairable (CV >35%) in cropland (Table 1). Likewise, sand content, aggregate stability, EC, total organic carbon, phosphorus and sodium adsorption ratio values were highly variable in natural grassland.

Table 1. Descriptive statistics of soil properties in cultivated and natural grassland

	Sand %	*Clay %*	*BD g cm^{-3}*	*AS %*	*WFPS %*	*AWC %*	*pH*	*EC dS m^{-1}*	*TOC %*	*P mg kg^{-1}*	*K mg kg^{-1}*	*SAR*
						Croplands (n=68)						
Minimum	13.1	22.0	1.00	25.70	34.11	4.93	8.02	0.43	0.44	3.09	41.20	0.38
Maximum	61.6	55.9	1.52	93.90	68.30	24.22	9.26	9.41	2.74	39.80	413.90	25.67
Mean	39.9	35.3	1.21	69.30	52.29	12.22	8.44	2.48	1.25	15.90	156.20	4.30
SD	10.5	8.4	0.12	19.20	7.41	4.51	0.28	2.26	0.42	7.35	71.36	4.79
CV	26.4	23.7	9.55	27.60	14.17	36.88	3.37	91.10	33.29	46.10	45.70	111.30
Skewness	-0.13	0.60	0.57	-0.60	-0.35	0.51	0.71	1.79	0.75	1.06	1.19	2.62
						Natural Grassland (n=132)						
Minimum	3.89	30.0	1.00	17.68	35.31	3.37	8.04	0.41	0.17	1.40	48.12	0.10
Maximum	49.3	81.1	1.54	96.07	94.13	21.69	9.47	15.14	2.45	40.69	337.57	53.66
Mean	18.9	61.3	1.23	64.17	58.91	11.02	8.70	3.66	0.97	11.93	148.70	7.19
SD	10.1	11.9	0.14	23.02	10.63	3.72	0.25	3.48	0.40	6.49	47.58	7.92
CV	53.7	19.34	11.31	35.88	18.04	33.79	2.91	95.18	41.12	54.44	32.00	110.14
Skewness	0.84	-0.62	0.27	-0.25	0.46	0.26	-0.31	1.06	0.92	1.44	0.61	2.53

* BD: bulk density; AS: aggregate stability; WFPS: water filled pore space; AWC: available water content; EC: electrical conductivity; TOC: total organic carbon; P: phosphorus; K: potassium; SAR: sodium absorption ratio; SD: standard deviation; CV: coefficient of variation

Table 2. Descriptive statistics of indicator scores in cropland and natural grassland

	BD g cm^{-3}	*AS %*	*WFPS %*	*AWC %*	*pH*	*EC dS m^{-1}*	*TOC %*	*P mg kg^{-1}*	*K mg kg^{-1}*	*SAR*
					Cropland (n=68)					
Min.	0.30	0.82	0.42	0.16	0.46	0.00	0.11	0.51	0.46	0.00
Max.	0.99	1.00	0.95	0.91	0.78	1.00	1.00	1.00	1.00	0.97
Mean	0.73	0.99	0.76	0.61	0.63	0.81	0.72	0.98	0.88	0.79
SD	0.19	0.04	0.16	0.19	0.08	0.37	0.23	0.07	0.13	0.25
CV	26.6	3.8	20.5	31.1	12.2	45.9	32.8	7.0	14.2	31.1
Skewness	-0.31	-3.67	-0.18	-0.33	-0.24	-1.58	-0.84	-5.45	-1.32	-2.59
					Natural Grassland (n=132)					
Min.	0.25	0.49	0.49	0.11	0.40	0.00	0.04	0.09	0.51	0.00
Max.	0.99	1.00	0.95	0.97	0.78	1.00	1.00	1.00	1.00	0.99
Mean	0.62	0.95	0.75	0.65	0.61	0.74	0.48	0.94	0.90	0.63
SD	0.24	0.11	0.10	0.20	0.07	0.42	0.28	0.13	0.10	0.36
CV	38.8	11.8	12.7	30.5	11.4	56.5	58.3	13.6	11.1	57.0
Skewness	0.10	-2.49	-0.38	-0.62	0.31	-1.12	0.31	-3.72	-1.22	-1.00
Independent t-test	*	*	*	ns	ns	*	*	*	*	*

BD: bulk density; AS: aggregate stability; WFPS: water filled poor space; AWC: available water content; EC: electrical conductivity; TOC: total organic carbon; P: plant available phosphorus; K: extractable potassium; SAR: sodium absorption ratio; Min: minimum; Max: maximum; SD: standard deviation; CV: coefficient of variation *The difference between land uses is imporant at P<0.05 level of significance. ns: non-significant

The total organic carbon content varied between 0.44 and 2.74% in cropland with an average of 1.25%, while the total organic carbon in natural grassland varied between 0.17 and 2.45% with an average of 0.97% (Table 1). The results obtained in natural grassland are in accordance with the findings of Abrol et al., (1988) who stated that organic carbon conent of soils with high exchangeable Na content is low. The conservative tillage system with incorporating the crop residue in soil, application of manure and an apropriate crop rotation caused an increase in organic carbon conent of soils in cropland.

3.2. Descriptive statistics of soil quality indicator scores

The concept of soil quality is related to the fulfilment of several soil functions that requires to determine a wide range of physical and chemical properties (Pulido et al., 2017). The scores of physical and chemical indicatorsof soils in cropland and natural grassland were given in Table 2. The difference in aggregate stability, bulk density, water filled pore space, total organic carbon, plant available phosphorus, potassium, EC and sodium adsorption ratio indicator scores between natural rangelands and croplands was statistically significant ($P<0.05$) (Table 2). The highest mean score in both lands belonged to the aggregate stability indicator which was 0.99 for cropland and 0.95 for natural grassland. The lowest aggregate stability score in cropland was 0.82 while the aggregate stability score in natural grassland which had higher sodium adsorption ratio values (Table 1) was 0.49 (Table 2). High sodium content of soils prevented the formation of stable aggregates in natural grassland. Poor physical properties in natural grassland impaire aeration and reduce water supply. The decrease in infiltration rate may also induce wind and water erosion in the area. Dispersion of soil aggregates due to the high exchangeable sodium content causes soil crust which leads to waterlogging on lower (Keren, 2005). The available water content and pH indicator scores were statistically similar between cropland and grassland. The mean EC indicator score was 0.81 and 0.74 in cropland and grassland while the lowest EC score in both lands was 0.0 due to severe salinity at some locations. High salinization of soils negatively affects the provisioning services of soil, agricultural production and environmental health (Rengasamy, 2006). Mineral fertilizers and manure added to the cropland increased phosphorus content and hence score in cropland (0.98 and 15.90 mg kg^{-1}) compared to the natural grassland (0.94 and 11.93 mg kg^{-1}) (Tables 1 and 2). The most significant difference between the two lands was observed in total organic carbon scores which was 0.72 in cropland and 0.48 in natural grassland. In general, conversion of rangelands to croplands is expected to decrease the soil organic carbon content due to the reduction of above and belowground biomass inputs (Guo et al., 2009). Similarly, Shepherd et al., (2001) indicated that tilllage increases disintegration of aggregates due to the loss of soil organic matter with increasing microbial activity. However, incorporation of crop residues with reduced tillage and manure addition to the cropland increased the total organic carbon contents and caused the formation of more stable aggregates compared to the natural grassland.

Particle size distribution of soils, mineralogical composition, total porosity and organic matter content have significant effect on bulk density of soils (Chaudhari et al., 2013). Higher mean bulk density was expected in cropland soils due to the higher sand content (39.9% in cropland) compared to the natural grassland soils (18.9%). However, the increase in organic matter content caused an increase in porosity and a decrease in bulk density in cropland. Therefore, the bulk density score e was higher in cropland compared to the score in natural grassland. The CV values reveled pronounced differences in the indicator score variability of available water content, EC, total organic carbon and sodium adsorption ratio in cropland and bulk density, available water content, EC, total organic carbon and sodium adsorption ratio in natural grassland (Table 2). The aggregate stability, pH, phosphorus and potassium scores were slightly variabile ($CV\leq 15.0\%$) in cropland and aggregate stability, water filled pore space, pH, phophorus and potassium scores had a small variability in grassland land. The skewness values of indicators (except bulk density, available water content and total organic carbon in natural grassland) were all negative that data is skewed left. The highest skewness values were obtaind for phosphorus and aggregate stability in both land types.

3.3. Soil Quality and Soil Functions

Soil functions such as filtering of pollutants, buffering nutrients by affecting the nutrient cycles, resistance to degradation and water relations have strong influence on water cycle on the earth surface, conservation of the environment with all living organisms against the contamination of water resources and the food chain and sustaining the food and fiber demands of the growing world population (Blum, 2005). Therefore, determining the soil quality status of a land is vital to initiate monitoring the effects of land uses on related soil functions. Establishing a reliable data set for each soil function is the first thing to achieve for monitoring activities.

The most relevent indicators for each soil function was determined by multivariate analysis such as PCA and expert opinion methods (Mukherjee & Lal, 2014; Budak et al., 2018). The Kaiser-Meyer-Olkin (KMO) test which used for PCA conformity of a data set was performed prior to establishing minimum data sets for soil quality (Table 3). The KMO test indicated that soil characteristics selected as indicators have acceptable variability (P<0.001) for PCA analysis.

Table 3. Kaiser-Meyer-Olkin test results for the indicators of soil quality

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.636
	df	45
	Sig.	0.000

The results of PCA showed four PCs with eigenvalues >1.0 and potential indicators of MDS, which defined 68.87% of the variability in the soil data. The sodium adsorption ratio, aggregate stability, EC, exchangeable potassium and total organic carbon were the selected indicators with high loading values (>0.5) in the PC1 (Table 4).

Table 4. The results of principal components analysis; principal components, eigenvalues and component matrix variables

(N=200)	PC1	PC2	PC3	PC4
Eigenvalues	2.93	1.57	1.34	1.05
Variance %	29.25	15.68	13.42	10.52
Cumulative Variance %	29.25	44.93	58.35	68.87
Eigen vectors				
Sodium Adsorption Ratio	**0.86**	-0.23	0.18	0.09
Aggregate Stability	**-0.78**	-0.19	-0.02	0.23
Electrical Conductivity	**0.67**	0.04	0.50	0.34
Extractable Potassium	**0.54**	0.03	0.26	-0.15
Total Organic Carbon	**-0.54**	-0.22	0.42	0.04
Water Filled Pore Space	-0.12	**0.81**	0.05	-0.11
pH	0.54	**-0.56**	-0.27	-0.26
Bulk Density	0.39	0.37	**-0.70**	-0.14
Available Water Content	0.28	0.40	-0.08	**0.69**
Available P	0.06	0.40	0.49	**-0.53**

From PC2, water filled pore space and pH were selected indicators for MDS. The bulk density from PC3 and available water content and available phosphorus from PC4 were the potential indicators of MDS with sufficient loading values. The correlation matrix between the variables was examined to apply the data reduction technique (Table 5). In order to remove a variable from the data set among the highly correlated variables, total values of the loading values under each PC or the sum of correlation coefficients were examined (Sharma et al. 2005). The sodium adsorption ratio indicator under PC1 showed a statistically significant correlation with EC, pH and aggregate stability (r = 0.69, r = 0.54, r = -0.56, respectively) which all had high factor loading values under PC1 (Table 5).

The EC that was considered as an explanatory indicator under the water relations function of soils had a lower factor loading value than sodium adsorption ratio, thus EC has been removed from the data set compiled using PCA. Salinity is an important indicator under nutrient cycle function especially in arid regions due to the adverse effect on plant growth and microorganisms (Andrews et al., 2004), Therefore, EC indicator was kept as an indicator in data set based on the opinions of the experts. Similarly, Brejda et al., (2000) indicated that EC is a useful soil quality indicator to define the effects of different land uses in the Southern High Plains. Nabiollahi et al., (2017) also reported that detrimental effect of salt on soil quality causes can be monitored by including the EC into MDS, and necessary soil management practices could be employed to improve and stabilize soil quality. Because of the importance, the EC indicator was included to the MDSs established by the expert opinions (Table 6). Despite a high correlation between sodium adsorption ratio and pH indicators, pH was kept in the data set because pH has significant influence on productivity especially in arid regions.

Table 5. Correlation matrix of soil quality indicators

	TOC	AS	pH	P	BD	EC	SAR	AWC	K	WFPS
TOC	1.00									
AS	0.42	1.00								
pH	-0.15	-0.27	1.00							
P	0.05	-0.14	-0.10	1.00						
BD	-0.38	-0.33	0.23	-0.04	1.00					
EC	-0.24	-0.44	0.07	0.09	-0.09	1.00				
SAR	-0.27	**-0.56**	**0.54**	0.02	0.16	**0.69**	1.00			
AWC	-0.11	-0.08	-0.07	-0.03	0.25	0.23	0.17	1.00		
K	-0.10	-0.38	0.22	0.12	0.09	0.28	0.34	0.14	1.00	
WFPS	-0.02	-0.07	-0.37	0.22	0.17	-0.02	-0.20	0.11	-0.03	1.00
Sum of Correlation	2.74	3.70	3.03	1.80	2.74	3.15	3.95	2.19	2.70	2.22

TOC: Total organic carbon AS: Aggregate stability SAR: Sodium adsorption ratio AWC: Available water content WFPS: Water filled pore space

Table 6. Weights for soil functions and indicators calculated by expert opinion and principal component analysis (PCA)

Management Goal	Soil Function	Weight		Indicators	Weight	
		PCA	EO		PCA	EO
Soil Quality	NC	0.24	0.20	pH	0.15	0.20
				Phosphorus	0.10	0.20
				Potassium	0.27	0.20
				Available water content	0.13	0.20
				Electrical conductivity	0.35	0.20
	WR	0.35	0.20	Aggregate Stability	-	0.125
				Organic Carbon	0.20	0.125
				Available water content	0.09	0.125
				Bulk Density	0.12	0.125
				Water filled pore space	0.16	0.125
				Electrical conductivity	-	0.125
				Sodium adsorption ratio	0.32	0.125
				pH	0.11	0.125
	PSS	0.25	0.20	Aggregate Stability	-	0.20
				Organic Carbon	0.27	0.20
				Bulk Density	0.15	0.20
				pH	0.16	0.20
				Sodium adsorption ratio	0.42	0.20
	RR	0.07	0.20	Organic Carbon	1.00	1.00
	FB	0.09	0.20	Bulk Density	0.22	0.25
				Phosphorus	0.13	0.25
				Organic Carbon	0.36	0.25
				Water filled pore space	0.29	0.25

*PCA: Principal component analysis, EO: Expert opinion; NC: Nutrient cycle, WR: Water relations, PSS: Physical stability and support, RR: Resistance and resilience, FB: Filtering and buffering

Factor loading value sodium adsorption ratio was higher than that of aggregate stability indicator, therefore sodium adsorption ratio indicator was included in the physical stability and support and water relations functions, and the aggregate stability indicator was excluded from the MDS.

The potassium and total organic carbon, which had high factor loading values under the PC1, were kept in the MDS since they did not have a statistically significant correlation between each other and with the other indicators. Similarly, there were no significant correlations between water filled pore space and pH under PC2, and between available water content and phosphorus under PC4; thus, they all kept in the MDS. The bulk density was the only indicator under PC3 and was kept in the MDS.

Soil structure influences several physical, chemical and biological soil functions and associated ecosystem services. Water movement into a soil (infiltration), runoff across a field, and percolation or drainage are mainly driven by the type and the stability of the soil structure (Guimarães et al., 2017; Truman & Franzmeier, 2017). The aggregate stability was considered as an important indicator for water relations and physical stability and support functions, and thus was included to the MDS by the expert opinion. The MDSs created by both expert opinion and PCA and contribution of each indicator to soil function and functions to soil quality were given in Table 6.

Function scores of MDSs derived from the expert opinion and PCA and calculated by simple additive and weighted additive methods were significantly differed in all functions except the resistance and resilience function in the cropland and in the nutrient cycle and resistance and resilience functions in the natural grassland (Table 7). Total organic carbon was selected as an indicator significantly contributing to four of the five soil functions. Organic carbon holds soil particles together which increases the resistance to deterioration and reduces the negative impact of erosion. In addition, organic carbon prevents soil compaction and formation of undesirable physical conditions such as surface crust (Budak et al., 2018). Therefore, only the contribution of total organic carbon into water relations, physical stability and support, resistance and resilience and filtering and buffering functions 20, 27, 100 and 36%, respectively (Table 6). Similar to findings on high contribution of organic carbon into the overall soil quality, Raiesi (2017) stated that contribution of organic carbon in soil quality of cultivated and natural rangelands was 73% and followed by EC with 13% and arylsulfatase (10%).

Application of leaching fraction in each irrigation event caused leaching of salts and exchangeable sodium to lower part of soil profile and resulted in lower EC and sodium adsorption ratio values in cropland compared to the adjacent natural grassland. Therefore, quality score of water relations function was higher in cropland compared to the natural grassland.

Table 7. Comparison of soil quality index value and function scores obtained by simple additive and weighted additive methods in natural grassland and cropland

Functions and Quality Index	Simple Additive				Weighted Additive				Paired sample t-test between simple and weighted additive	Independent t-test between cropland and rangeland
	Min.	Max.	Mean	Skewness	Min.	Max.	Mean	Skewness		
	Cropland (n=68)									For simple additive
NC	0.59	0.91	0.78	-0.50	0.47	0.94	0.80	-1.25	*	**
WR	0.50	0.89	0.75	-0.76	0.38	0.88	0.73	-1.25	**	**
PSS	0.49	0.92	0.77	-0.97	0.30	0.93	0.74	-1.61	**	**
RR	0.11	1.00	0.72	-0.84	0.11	1.00	0.72	-0.84	Ns	**
FB	0.57	0.98	0.80	-0.39	0.49	0.98	0.77	-0.56	**	ns
SQ	0.54	0.93	0.76	-0.67	0.42	0.92	0.75	-1.02	*	*
	Natural Grassland(n=132)									For weighted additive
NC	0.56	0.90	0.77	-0.63	0.48	0.93	0.78	-0.95	ns	*
WR	0.38	0.85	0.68	-0.53	0.30	0.85	0.62	-0.60	**	**
PSS	0.32	0.92	0.66	-0.30	0.14	0.91	0.59	-0.52	**	**
RR	0.04	1.00	0.48	0.31	0.04	1.00	0.48	0.31	ns	**
FB	0.47	0.94	0.70	0.13	0.42	0.93	0.65	0.24	**	ns
SQ	0.43	0.89	0.66	0.17	0.33	0.87	0.64	-0.35	**	**

SA: Simple additive, WA: Weighted additive, NC: Nutrient cycle, WR: Water relations, PSS: Physical stability and support, RR: Resistance and resilience, FB: Filtering and buffering, SQ: Soil quality, **Difference is significant at P<0.01 level (2-tailed). *Difference is significant at P<0.05 level (2-tailed), ns: not significant

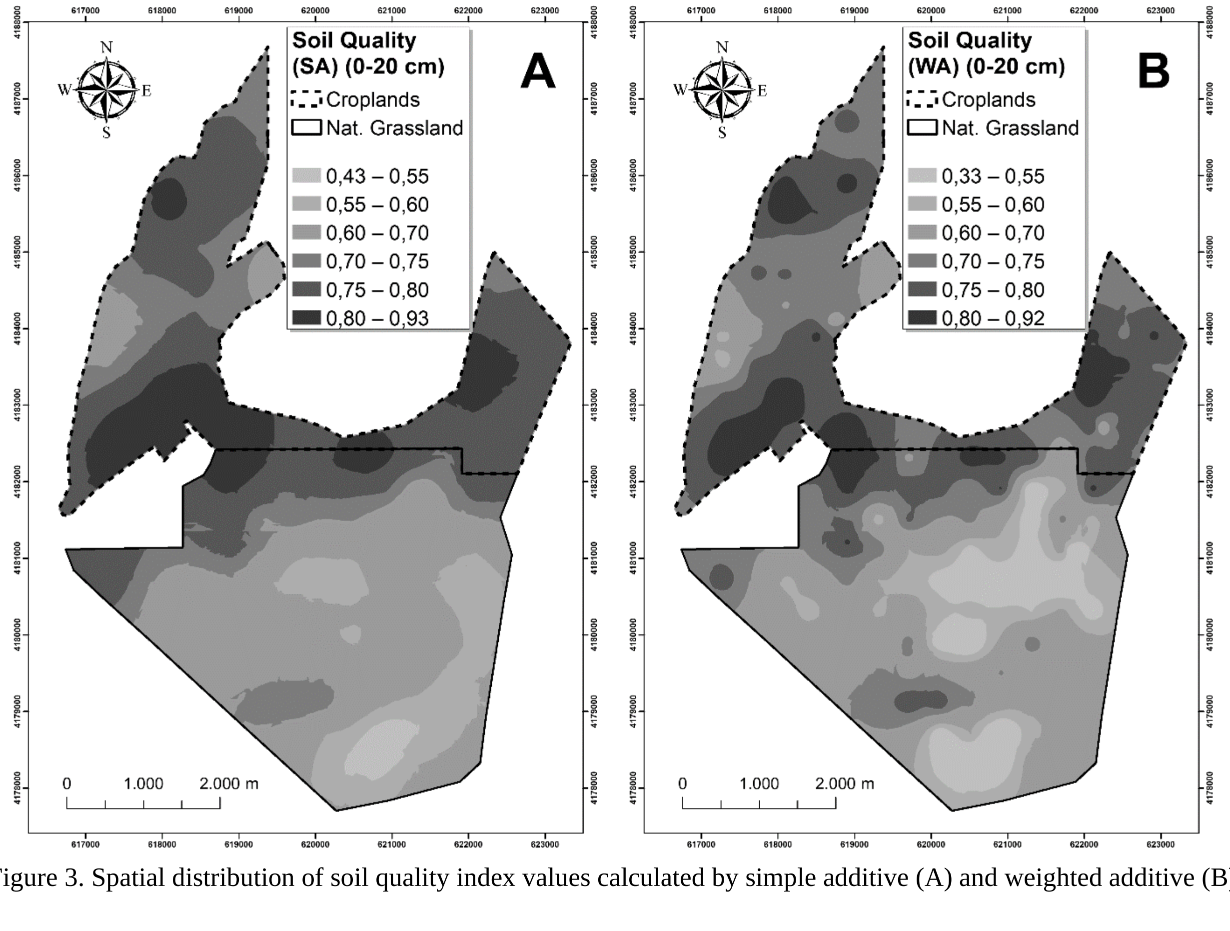

Figure 3. Spatial distribution of soil quality index values calculated by simple additive (A) and weighted additive (B)

Marzaioli et al., (2010) classified soil quality index (SQI) values as low quality with SQI <0.55, moderate quality with 0.55 <SQI <0.70 and high quality with SQI> 0.7. The soil quality maps of the study area prepared by both simple additive and weighted additive methods show that soil quality in cropland is predominantly of high quality compared to the natural grassland (Fig. 3). High sodium adsorption ratio and EC values and low total organic carbon content in the natural grassland caused poor soil quality. Raiesi (2017) defined the high soil salinity in natural rangelands as an important constrain in productivity and suggested that the level of salts might decrease after conversion to croplands. Therefore, salt and exchangeable sodium content of soils in natural grassland should be decreased, whereas organic carbon content needs to be increased to sustain the soil quality and improve the provisioning of ecosystem services.

4. CONCLUSIONS

Rangelands are considered important natural resources due to the potentials to provide several ecosystem services through productive and high quality of soils. However, rangeland soils particularly in arid regions are very fragile for intensive grazing and conversion to agricultural production (Pulido et al., 2017). Therefore, this study was conducted to determine a minimum data set including soil physical and chemical indicators to assess soil quality of a cropland and adjacent natural grassland in an arid region. Contrary the reports of previous studies (Han et al., 2008; Bestelmeyer et al., 2015; Raiesi, 2017), the results indicated that conversion of natural grassland to cropland significantly improved the soil quality and related soil functions of natural grassland.

The differences in soil quality index values calculated by using the minimum data sets derived from principal component analysis and expert opinion methods were in accordance with the findings of Vasu et al. (2016). The soil quality of cropland was high calculated by using the minimum data set determined by both approaches, whereas the soil quality of natural grassland was low or moderate. The difference in soil quality index values between cropland and natural grassland can be attributed to the agricultural practices such as application of manure, crop rotation, incorporation of crop residues and irrigation started in 2008.

Salinity and sodicity in natural grasslands in addition to the extensive grazing constrain the production of biomass which resulted in low total organic carbon content. High values of sodium adsorption ratio, which is a severe constrain for agricultural activities, decreased functioning potential to sustain soil quality in natural grassland. In addition to sodium adsorption ratio, the EC is the second major limiting indicator for the functioning ability of soils in natural grassland. Similarly, Nabiollahi et al., (2017) indicated that high values of EC and sodium adsorption ratio values decreased the overall soil quality, while higher mean weight diameter, cation exchange capacity and lower EC, sodium adsorption ratio and bulk density values in no-saline soils have led to high soil quality. Therefore, cultural practices such as the use of gypsum, sulfuric acid, elemental sulfur, leaching and addition of organic amendments such are needed to decrease the sodium adsorption ratio and electrical conductivity values, thereby increase the organic matter content and aggregate stability of soils. Regular addition of organic materials such as manure to the both lands will have a direct or some indirect positive impacts on the other soil quality indicators, which will help to improve soil quality.

Soil quality assessment allowed to quantify the effects of land use conversion on several soil functions and overall soil quality. The results concluded that total organic carbon, sodium adsorption ratio and electrical conductivity are the most important indicators, which can be used to monitor soil functions and soil quality of rangelands in arid regions after conversion to croplands. Finally, the integrated soil quality assessment approach used in this study can effectively be used to quantify the impacts of converting natural rangelands into croplands in arid and semi-arid regions.

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