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SOIL AND IRRIGATION WATER QUALITY ASSESSMENT FOR MAIZE PRODUCTION IN BUHLE FARM IN HOWICK, KWAZULU-NATAL PROVINCE, SOUTH AFRICA

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ABSTRACT

The continuous monitoring of soil health and irrigation water quality influences the crop yield and the quality of agricultural produce. In this study, various physicochemical parameters were measured to monitor the soil profile, irrigation water and maize quality harvested from the Buhle farm located in Howick in the KwaZulu-Natal Province of South Africa to ensure steady high quality food supply for the consumer. The maize crop was sampled from the maize stalk, the corresponding soil samples were collected from the upper surface of the soil (0-15 cm surface layer) using the soil auger and the irrigation water sample was taken from the irrigation tanks using polyethylene sample bottles. The physicochemical parameters considered for irrigation water were pH, electrical conductivity, alkalinity and chloride due to their ability to affect water quality which consequently affect crop growth and quality. The soil physicochemical parameters considered were moisture content, pH, electrical conductivity, texture, total nitrogen and nutrients (protein, fat, fibre, starch, total mineral matter and elements). These parameters determine the soil quality, water content, the ratio of absorbed and lost energy, concentration of ions and elements present which in turn affect or promote the yield and quality of crops. Maize was analysed for nutritional content and medicinal health-promoting compounds to assess the influence of soil and irrigation water on the maize quality and consequently the health of the consumers. The concentrations of total nitrogen (N), phosphorus (P) and potassium (K) in soil, which were translated into high soil fertility were 2700, 19 and 222 mg kg^{-1}, respectively. The results obtained were within the required specification for high quality maize production. The levels of sodium, sodium adsorption ratio and electrical conductivity in the irrigation water were 0.05 mg L^{-1}, 2 and 1.81 µS m^{-1}, respectively, indicating safe water of low salinity. Maize was high in starch (58.6%) while fibre, protein and fat contents in the maize were 23.4, 9.01 and 4.55%, respectively, indicating suitability for consumption. Furthermore, the total anthocyanin, total flavonoids and total phenolic acid content of the maize were 8.5, 49.5 and 100 mg L^{-1}, respectively. Overall, this study showed the presence of health-promoting compounds in the maize crop which is associated with its high quality for consumption. The validity of the analysis methods was tested using certified reference materials. The concentrations of the reference materials were not statistically different from the certified values, attesting to the validity of the analysis methods.

Key words: Soil profile, water quality, soil fertility, nutrition, antioxidants

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INTRODUCTION

Soil is an important natural resource that living things depend on for growth to meet their daily needs. As a growth medium for crop production, the soil has the ability to retain moisture and nutrients [1]. This natural resource is vitally important for agricultural sector. Soil quality is the capacity of a soil to function within ecosystem and land-use boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health [2]. The composition of soil includes mineral particles, a biological system of living organism as well as organic matter and these are differentiated into horizons [3]. Interaction of the biological, physical and chemical components of the soil determines its quality and health [4]. Soil quality is assessed for agro-ecosystems where the main, service is productivity. Therefore, knowledge about soil characteristics is essential to predict crop quality and yield.

High soil fertility promotes high nutritious crops enriched with starch, fibre, protein, macronutrients and fat along with micronutrients such as vitamin B complex, ß-carotene, magnesium, zinc, phosphorus and copper which are all essential for human health and development. Soil fertility is essential for plant growth and yield as indicated by nitrogen (N), phosphorus (P), potassium (K), micronutrients and adequate soil moisture. Organic carbon is a significant soil property which determines the level of soil productivity in agriculture [2, 5]. Thus, soil nutrients deficiency results in limited crop yield [6]. Soil pH is a primary chemical property that controls the concentration and plant adsorption of solutes in the soil [7]. Soil moisture promotes nutrients absorption by plants and it is much related to soil texture and soil structure [8]. Soil texture is the relative proportion of clay, sand, and silt particles in the soil volume and it influences soil aeration, soil-water relation, nutritional status and plant root penetration [9]. Soil temperature effects the biological, chemical and physical interactions related to crop growth [5, 10]. Soil electrical conductivity (EC) measures amounts of ions in the soil solution and correlates with soil properties that affect cation exchange capacity, drainage condition, organic matter level, salinity and soil characteristics [11]. The concentration and composition of soluble salts in the irrigation water determine its quality for human and livestock consumption as well as irrigation of crops. Water quality, therefore, is an important component with regard to sustainable use of water for irrigation in agriculture, especially when salinity development is expected to be a problem in an irrigated agricultural area [11].

Food security and quality remains a global concern for humans and livestock and that is highly dependent on soil health. Maize (Zea mays L) is the most stable and

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important agricultural crop in South Africa. About 73 million tons of maize are produced annually in South Africa [12]. However, this volume can increase with continuous monitoring of the soil health and irrigation water quality trends in South African farming and consequently steady food supply [13]. In this regard, maize quality and yield in Buhle farm is influenced by solar radiation, tillage method and unmonitored soil health and irrigation water quality. Therefore, it is imperative to monitor soil conditions, water and maize quality for the benefit of the consumer and consequently, providing knowledge on improving the system management and sustainability for this field. In this context the objective of this study was to assess the soil and irrigation water with the aim of evaluating their effect on the quality of maize quality harvested from Buhle farm located in Howick, KwaZulu-Natal Province.

MATERIALS AND METHODS

Study area and sample collection

Soil and maize samples were collected from the Buhle experimental field, located in Howick, KwaZulu-Natal Province, South Africa (Figure 1). Buhle Farm is an agricultural field where studies on maize, tubers and agronomic crops production are conducted for the KwaZulu-Natal community. The exact sampling locations can be found through the usage of the Global Positioning System (GPS), represented by the co-ordinates -29.523633, 30.247441. The location is known for its high temperatures in summer (wet season) which normally range from 21°C to 38°C, while these usually drop in winter (dry season) ranging from 10°C-28°C. On average, precipitation is approximately 569 mm annually. For the purpose of the present study, maize crop was taken from the maize stalk, the corresponding soil samples were collected from the upper surface of the soil (0-15 cm surface layer) using the soil auger. A 100 mL of irrigation water sample was taken from the irrigation tanks using polyethylene sample bottles. Maize and soil samples were stored in polyethylene bags while water samples were stored in polyethylene bottles during transportation from the field to the laboratory. The sample collection point was 10 km from the laboratory. Samples were stored at 4ºC until analyses were conducted, in triplicate.

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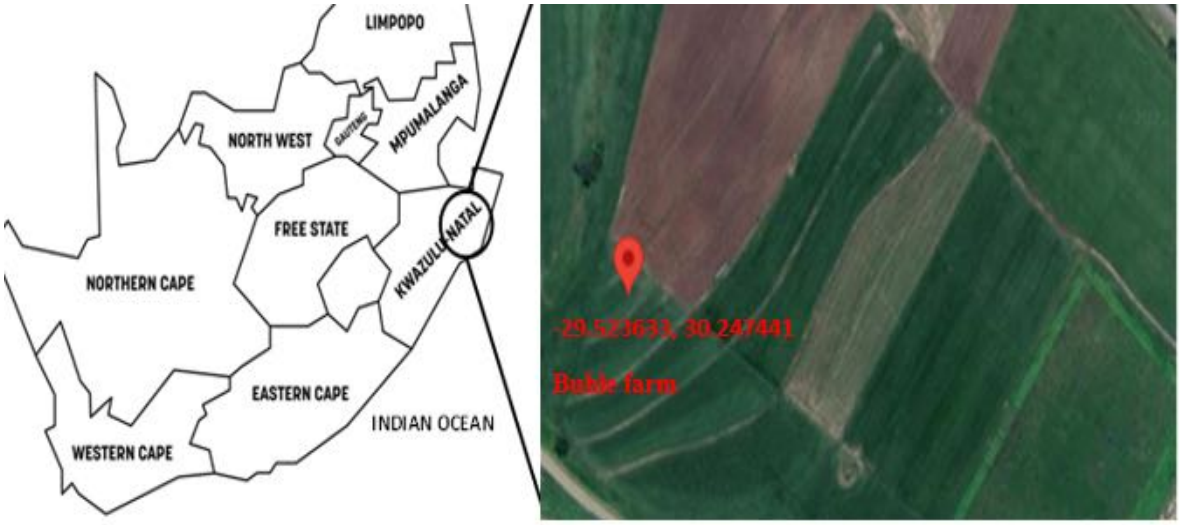

Figure 1: Location map of the study sites in Buhle Farm, Howick, South Africa

Chemicals and reagents

Hydrochloric acid (HCl), Sulphuric acid (H_2SO_4), nitric acid (HNO_3), potassium chromate (K_2CrO_4), silver nitrate ($AgNO_3$), hydrogen peroxide (H_2O_2), sodium hexametaphosphate $(NaPO_3)_6$, HPLC-grade acetone were purchased from Merck (Pty) Ltd, South Africa. Milli-Q water purification system (Millipore, Bedford, MA, USA) was used for water purification.

Analysis of irrigation water

Alkalinity analysis

Irrigation water analyses were performed according to the Official Analytical Chemists (AOAC) official methods [14]. The pH and EC were measured using conductivity/pH meter (CPC-505 Elmetron, SA).

Alkalinity was determined by titration of a 20mL water sample with 0.02 N H_2SO_4 using methyl orange indicator and alkalinity was calculated using equation (1).

$$\text{Alkalinity}\left(\frac{\text{me}}{\text{L}}\right) = 1000 \text{ x N x (volume of H2SO4)} - \text{mL (blank)} \quad (1)$$

where N is the concentration in normality of H_2SO_4.

Chloride analysis

Chloride content was also determined by titration. However, this was done using a precipitation titration procedure where 1mL of K_2CrO_4 was added to each alkalinity-titrated sample. The resulting mixture was then titrated with 0.02 N $AgNO_3$ until a

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slight reddish precipitate of silver chromate (Ag_2CrO_4) was formed. The chloride content was calculated using equation (2).

$$\text{Chloride (me/L)} = 1000\text{x N x (mL (AgNO3)} - \text{mL (blank)} \quad (2)$$

where N as in 1 above is the normality of the titrant.

Analysis of minerals in Irrigation water

Macro and micro plant nutrient element analysis of irrigation water samples were conducted using a mixture of 1mL of 1% (v/v) HNO_3 and 1mL of 0.1 % (v/v) lanthanum chloride ($LaCl_3$) in 500mL of irrigation water sample. The HNO_3 and $LaCl_3$ were added to the irrigation water samples to preserve and release the elements in the irrigation water. The resulting mixture was filtered using a 99mm Whatman No1 qualitative filter paper. Five millilitres of the filtrate was then transferred into a 25mL volumetric flask and diluted and made up to volume with deionized water. The elements in the diluted sample were measured and quantified using Inductive Coupled Plasma–Optical Emission Spectroscopy, ICP-OES (Agilent, 5800 ICP-OES, SA).

Soil analysis

Moisture content

One (1) gram of the soil sample was weighed into a pre-dried weighing dish and placed in a convection oven set at 105°C and dried for two hours and thereafter allowed to cool to room temperature in a desiccator. The dish containing the oven-dried sample was weighed to the nearest 0.1g and the mass recorded. The above steps were repeated until a constant weight was achieved. The percentage moisture was calculated using equation 3.

$$\text{Moisture (\%)} = \frac{\text{Mw}}{\text{Ms}}\text{x } 100 \quad (3)$$

where Mw is the mass of water in soil = (Wet mass of soil- dry mass of soil), and Ms, is dry mass of soil = (Wet mass of soil -mass of water in the soil, Mw).

Soil pH, EC and Particle size analysis (texture)

A soil sample was mixed with deionized water at 1:2.5 ratio and agitated using a shaker (Labcon, Durban) for 1 hour. The suspension was then filtered using Whatman No. 1 filter paper prior to analysis. The pH and EC electrodes were immersed into the filtrate for 10 minutes at 24 °C to measure the pH and EC.
For soil texture analysis, the soil sample was air dried at room temperature for 96 hours, ground and sieved through a 2mm sieve. About 20g of soil sample was weighed into a 1L beaker and wetted with small amount of deionized water. A

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30mL of 30 % hydrogen peroxide (H_2O_2) was added to the sample and allowed to settle at room temperature for 5 minutes. The sample contents were placed in a water bath at 100 °C and allowed to boil to remove any unreacted H_2O_2. A 20mL of dispersing agent was added to the mixture. The dispersing agent was prepared by mixing 20mL of 2% sodium hydroxide (NaOH) with 10mL of 10% sodium hexametaphosphate $(NaPO_3)_6$ and stirred for 10 minutes. The sample was decanted into 1L polyethylene measuring cylinder and filled up to the mark with deionized water and allowed to settle overnight. The following day, the soil sample was brought into suspension by applying 40 firm strokes (up and down) using a plunger. Sand and coarse silt were sampled at 100mm below the surface with the pipette using a 20mL glass pipette and the sample was discharged into the pre-weighed beaker. This was followed by sampling the fine silt at 75mm below the surface of the suspension in the cylinder with the pipette, representing the clay content and the sample was discharged into the pre-weighed beaker. Sample beakers were placed in an oven at 105°C to dry overnight. Texture class was determined using equation 4, 5, 6 and 7.

$$\%\ \text{Silt and Clay} = \left(\left(\frac{\text{mass containing dried silt} - \text{mass of empty beaker} - \text{blank}}{\text{mass of the original sample}}\right)(\text{moisture})\right) \quad (4)$$

$$\%\ \text{Clay} = \left(\left(\frac{\text{mass containing dried clay} - \text{mass of empty beaker} - \text{blank}}{\text{mass of the original sample}}\right)(\text{moisture})\right) \quad (5)$$

$$\%\ \text{Silt} = (\%\ \text{Silt} + \text{Clay}) - \text{Clay} \quad (6)$$

$$\%\ \text{Sand} = 100 - (\%\ \text{Silt} + \text{Clay}) \quad (7)$$

Total N and elemental analysis

For total N analysis, 1g of the soil sample was weighed into a ceramic boat and 0.5g of vanadium pentoxide was added as a combustion catalyst and placed into the ceramic horizontal furnace at 1100 °C with an autoloader and the percentage of nitrogen was measured. Samples were combusted in an induction furnace in the presence of oxygen to form water, carbon dioxide, sulfur dioxide, nitrogen oxides and nitrogen. Carbon dioxide and sulfur dioxide were removed, and nitrogen oxides was reduced to nitrogen. Total nitrogen was then measured using a thermal conductivity detector. Nitrogen-to-protein conversion factor was then used to calculate the total (crude) protein content of the sample.

For analysis of potassium, sodium and calcium, a 10g of the soil sample was weighed into a polyethylene beaker and mixed with 50mL of extraction solution. The extraction solution was initially prepared by mixing 8.6mL of 37 % HCl and 0.7 mL of 99.7 % H_2SO_4 and made-up to 1L with deionised water. The mixture was

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agitated for one hour at room temperature using a shaker (Labcon, Durban). The mixture was then filtered using Whatman No. 1 filter paper prior to ICP-OES analysis. For quantification, ICP was calibrated with the respective elements over the concentration range of 1-100 mg L^{-1}. In this study, the extraction solution was used as blank.

Preparative work was slightly altered to allow for the analysis of other metals (P, Zn, Cu and Mn). In this case, a 2.5g soil sample was mixed with 25mL of the extraction solution. The extraction solution was prepared by mixing 0.25M NH_4CO_3, 0.01 M Na_2EDTA, 0.01 M NH_4F and 0.05 g L^{-1} Superfloc (N100). The pH was adjusted to 8 with 1 N NaOH. The mixture was agitated for 10 minutes at room temperature using a shaker (Labcon, Durban) and then filtered using Whatman No. 4, followed by a 4 times dilution. The resulting solution was analyzed on the ICP-OES.

Nutrient composition of maize

Protein and fat analysis

The LECO Truspec Nitrogen Analyser (LECO Corporation, Michigan, USA) was employed to measure the content of protein in the samples using Official Analytical Chemists (AOAC) Official Method 990.03. The measurements were conducted in triplicate. The analysis was done by placing each maize ground sample into a combustion chamber at 1100 °C with an autoloader and the percentage of protein was calculated using equation (8) as described in another study [14].

$$\%\ \text{crude protein} = \%\ \text{N} \times 6.25 \quad (8)$$

where %N is the amount of nitrogen present in the sample.

The Büchi 810 Soxhlet Fat extractor (Büchi, Flawil, Switzerland) was used for the determination of the fat content in the samples with petroleum ether as the extracting solvent. Triplicate analyses were conducted following the AOAC Official Method 920.39 and the percentage of crude fat was determined as explained in equation (9) [14].

$$\%\ \text{Crude fat} = \frac{\text{beaker+fat}-\text{beaker}}{\text{sample mass}} \times 100 \quad (9)$$

Analysis of Fibre

The sample (0.5g) was added into a scintered glass crucible. The marble/buffer beads and 50mL of neutral detergent solution (NDS) (50mL) were added to the glass crucible holder. The NDS was prepared with 124g ethylene diamine tetra-

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acetic acid, 45.3 g disodium tetraborate, 200g sodium lauryl sulphate, 67mL 2-ethoxy ethanol and 30.4 g disodium hydrogen phosphate. The crucible containing the sample was placed in a glass crucible holder which was thereafter placed into a digestion block set at 110 °C. A 1mL of termamyl (α-amylase) was then added and the container covered with stoppers for 70 minutes. Afterwards, the glass crucible was removed and placed on a draining rack to remove the suspension. The filtration unit connected to the vacuum system was used to suction the samples which were washed three times with boiling water. The sample and sides of the crucible were then rinsed with acetone and the samples were placed in a drying oven at 105 °C for 4 hours. The samples were then cooled in a desiccator, the crucible was weighed and the NDF of the sample was calculated using equation (10).

$$\% \text{ NDF} = \frac{(\text{crucible+dry residue})-(\text{crucible+ash})}{\text{sample mass}} \times 100 \quad (10)$$

Total mineral matter (ash) and elemental analysis

Ash was determined using the AOAC Method 942.05 [14]. The samples were weighed and placed in a furnace at 550 °C for 24 h. After the volatilisation of the organic matter from the samples, the elemental salts that remained as a residue of ash in the crucibles were calculated using equation (11).

$$\% \text{ ash} = \frac{(\text{mass of the sample+crucible after ashing})-(\text{mass of pre-dried crucible})}{(\text{mass of sample+crucible})-(\text{mass of pre-dried crucible})} \times 100 \quad (11)$$

The mineral elements were analysed using the Agricultural Laboratory Association of Southern Africa (ALASA) Method [15]. Samples were ashed at 550 °C in a furnace for 12 hours. The samples were dissolved in HCl followed by addition of HNO_3 and then analysed using the ICP–OES.

Analysis of starch

The starch content was determined by weighing 1g of the sample into a test tube and 5mL of 80 % ethanol added to the sample in the test tube. The mixture was vortexed and incubated at 80 °C for 30 minutes to completely evaporate the ethanol. Then 10mL of acetate buffer was added to the mixture in the test tube followed by 200µL of Termamyl α amylase enzyme. The mixture was vortexed and incubated for 30 minutes at 90 °C after which the mixture was allowed to cool. After cooling, 200µL of amyl glucosidase was added to the mixture in the test tube and gently shaken followed by incubation at 60 °C for 8 hours. The sample was diluted in a 200mL volumetric flask using deionized water and filtered through Whatman No. 1 filter paper. Five (5) milliliters of copper reagent was added to 3

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mL of the filtrate in the test tube followed by addition of the arsernomolybdate reagent (5 mL). The test tube was then shaken and allowed to stand for 90 minutes. The starch content of the sample was determined by UV absorption at 750nm wavelength and the starch content calculated using equation (12).

$$\% \text{ Starch } = \frac{0.4555 \times \text{Absorbance of sample} \times 0.9}{\text{sample weight} \times \text{ Absorbance of glucose standard}} \quad (12)$$

where the factors 0.4555 = starch to glucose factor and 0.9 = glucose to starch factor

Analysis of Antioxidants

About 30mg of samples was weighed and transferred into a 1 mL falcon tube and 400µL distilled water was added. The samples were boiled in a water bath at 100 °C for 30 minutes followed by addition of extraction buffer (2mL). The 100mL buffer was made by mixing 2mL distilled water, 94.8mL of 95 % EtOH and 3.2mL of 37 % HCl. The sample solutions were vortexed and agitated overnight on a shaker (Labcon, Durban). The samples were centrifuged at 13,000rpm for 15 minutes and the first supernatants were collected. One (1) milliliter extraction buffer was added to each sample pellet, vortexed and agitated for two hours. The samples were then centrifuged at 13,000rpm for 15 minutes and the supernatant was collected and mixed with the first one. A 3 mL of supernatant collected from each sample was centrifuged again at 13,000rpm for 30 minutes. The absorbance was measured spectrophotometrically (Cary 50, Germany) at 530nm, at 350nm and 280nm respectively for anthocyanins, flavonols and phenolic acids, using the extraction buffer as blank. The anthocyanin content was calculated as cyanidin 3-glucoside equivalents [molar extinction coefficient (ε) 26,900 Lm-1 mol^{-1}, MW 484.82], the amounts of flavonols and phenolic acids were calculated as quercetin 3-glucoside (ε 21,877 Lm^{-1} mol^{-1}, M.W 464.38) and ferulic acid (ε 14,700 Lm^{-1} mol^{-1}, MW 194.18) equivalents [16].

Methods validation and statistical analysis

The accuracy of the methods was validated by analysing certified reference materials (CRMs). Maize flour (FCNC21-AFE16) was purchased from Fera Science proficiency testing Ltd, soil CRM and water CRM were purchased from Merck (Pty) Ltd, South Africa.

The Statistical Package for Social Science (SPSS version 25.0 SPSS Inc, Chicago, IL, USA) was used for the analysis data. The standard deviations and mean values of the irrigation water, soil and maize samples were calculated for all replicate measurements. The significant differences in soil, irrigation water and maize

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samples were determined using Kruskal Wallis non-parametric test. Where significant differences in results were recorded, the Mann-Whitney U test was employed to determine the specific differences. Significance in the results was measured at the 5 % level.

RESULTS AND DISCUSSION

Irrigation water

Water alkalinity/sodicity, salinity and presence of toxic ions are indicators of the quality of irrigation water. The pH, electrical conductivity, and total dissolved solids classify the concentration of soluble salts. In this study, the pH of irrigation was found to be 7.5, indicating weak alkalinity. Irrigation water pH ranging from 6-8 is considered suitable for irrigation purposes [18]. The measured electrical conductivity was 1.81 µS m^{-1} showing low content of soluble salts and thus high purity of water for irrigation purposes. The recommended electrical conductivity in irrigation water is <2.50 µS m^{-1} [17]. Due to the low content of soluble salts, irrigation water class was found to be C1-S1, which meant low salinity and low sodicity content. Previous studies reported 7.79 pH, 0.49 µS m^{-1} EC and 180 mg L^{-1} TDS [18]. The sodium (Na) hazard in water, represented by the sodium adsorption ratio (SAR) was 2, indicating low sodium toxicity to crop. The CRM values of water (Table 1) were not only found to be statistically different compared to certified values, but also confirmed the validity of the method used for analysis.

Soil quality

The soil and irrigation water quality can be used to predict crop quality and yield. Soil quality is equated with organic carbon, fertility and total nitrogen content. In this study, soil organic carbon was 4.4 %, which is in the range of organic carbon in agricultural soil (4-6 %), [19]. The concentration of nitrogen (2700 mg kg^{-1}) was found to be above the minimum total nitrogen content considered adequate in agricultural soil, which is 2000 mg kg^{-1} [20]. This is the most critical element obtained by plants from the soil and it is a constraint in crop growth. Organic carbon to nitrogen (C:N) ratio significantly attributes to microbial biomass which influence nutrients transformation and soil ability to store and recycle energy and nutrients [21]. The concentrations of P and K were found to be 19 mg kg^{-1} and 222 mg kg^{-1} (Table 2), respectively. Phosphorus is an important element present in any living cell and responsible for seed germination and promotes root growth while K plays a significant role in physiological process of the plant and resistance of the plant from the diseases [22]. Soil profile had high total cation of 11.93 cmol kg^{-1}, consequently, high cation exchange capacity (CEC), which determines the nutrient ion retention capacity movement of nutrients through the soil profile. This result is

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indicative of high fertility status of the soil associated with the high clay content (56.41%) [23]. Clay soil is more fertile due to its ability to retain nutrients. Due to the good quality of the soil profile in this study (Table 3), agricultural fertilizers were not applied for maize growth. The statistics analysis showed that the results obtained for the certified reference material are not significantly different from those of the certified values, verifying the precision and accuracy of the results reported in this study.

Nutrient content of maize

The major nutrient components in maize are carbohydrates [24]. The maize nutrient content results (Table 4) showed that starch was present in higher amounts (58.62%), which could be due to endosperm mutant known as amylose-extender that influences growth in the amylose proportion of the starch [25]. Protein content was 9.01 % which is comparable to 10.10 % reported by Nkosi et al. [26]. Protein is derived from plant cells of the crop and it is influenced by the plant's genotype and agronomic practices [27]. The maize flour CRM values obtained from the analysis in this study were comparable to those of certified values. The fat content (4.5 %) obtained in this study is comparable to the previously reported study in white maize, which was 4.06 % [28]. Presence of fat in maize is responsible for its flavour, texture and high palatability [29]. The fat in the maize kernel is in the germ of the maize kernel, and it is genetically influenced. The macro and micro minerals obtained in this work were 2.42 % and 1.79 %, respectively which is expected as the macro and micro nutrient elements in maize are generally lower compared with other cereal grains [29]. The soil is deficient in micronutrients particularly zinc and this is a global concern [30].

Analysis of Antioxidants

Antioxidants are important as they inhibit oxidation of free radicals in human cells, consequently, protecting the consumer from numerous degenerative diseases. The high phenolic compounds in maize found in this study (Table 5) directly indicate higher antioxidant strength [16]. The total phenolic acid showed high quantity (100.42 mg L^{-1}) which is beneficial to the consumer since phenolic acids have cancer prevention ability. The maize CRM showed high concentration of total flavonoids and total phenolic acid compared to the maize sample, while the total anthocyanin was higher in the maize sample than the CRM. However, there was no significant difference in all the concentrations obtained ($p<0.05$). These chemical compounds containing antioxidant properties have correlation with the biosynthetic pigments in crops [28].

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CONCLUSION

In this study, soil quality, irrigation water and maize crop quality planted in the Buhle farm was evaluated. The cation of interest for irrigation water was Na^+ and the results showed that the concentration was low (0.05 mg L^{-1}) and so it did not pose any sodium hazard. The low sodium adsorption ratio of 2 corroborated the results of sodium hazard of the water. The low EC (1.81 µS m^{-1}) is indicative of a safe water of low salinity. The soil texture high in clay content (56.4%), sand (40.6%) and slit (2.89%) indicated high fertility potential of the soil profile. It was then concluded that soil quality and irrigation water quality were suitable for producing good quality maize. The results of the analysis of key nutrition parameters of maize were consistent with the good quality soil and irrigation water. The results showed that the maize contained high amounts of total anthocyanin, total flavonoids and total phenolic acid compounds. These compounds are considered essential for good health and consumers can be assured of medicinal benefit from consuming this maize.

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Table 1: Irrigation water analysis and method validation

Parameter	Water CRM (certified)	Water CRM (obtained)	Irrigation Water sample	P value
pH	6.12	6.89	7.50	0.042
EC (µS m^{-1})	7	9	1.81	0.012
TDS (mg L^{-1})	41	50	113.00	0.021
Mg (mg L^{-1})	2.78	3.45	0.45	0.032
Na (mg L^{-1})	0.54	0.69	0.05	0.045
K (mg L^{-1})	0.41	0.64	0.25	0.011
Zn (mg L^{-1})	0.06	0.01	0.54	0.044
Mn (mg L^{-1})	0.06	0.02	0.11	0.031
P (mg L^{-1})	NA	0.01	0.08	0.009
N (mg L^{-1})	-	-	-	
SAR			2.05	
Water class			C1-S1	

NA-not analysed

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Table 2: Soil analysis and method validation

Parameter	Soil CRM (certified)	Soil CRM (found)	Soil sample	P value
pH	6.50	6.10	5.95	0.034
EC (µS m^{-1})	349.3	282.5	476.1	0.033
Mg (mg kg^{-1})	284	274	283	0.027
Na (mg kg^{-1})	0.34	0.12	0.06	0.051
K (mg kg^{-1})	289	314	222	0.045
Zn (mg kg^{-1})	3.5	3.90	27.7	0.036
Mn (mg kg^{-1})	66	75.00	23.0	0.021
P (mg kg^{-1})	10	11.0	19	0.030
N (mg kg^{-1})	NA	6400	2700	0.043
Texture class			Clay	

NA-not analysed

Table 3: Mechanical strength of the soil profile

Sample	Density	Exchangeable acidity cmol kg^{-1}	Total cation cmol kg^{-1}	Acid saturation (%)	Organic carbon (%)	Clay (%)	Sand (%)	Silt (%)
Soil	1.03	0.11	11.93	1	4.4	56.41	40.61	2.98

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Table 4: Nutrition analysis of the maize crop

Parameter (%)	Maize flour CRM (certified)	Maize flour CRM (found)	Maize sample	P value
NDF	25.72	26.42	23.43	0.032
Fat	5.79	6.49	4.55	0.042
Ash		1.32	1.67	0.021
Protein	8.42	9.24	9.01	0.021
Starch	61.42	60.21	58.62	0.032
Total macro minerals	-	3.52	2.42	0.012
Total micro minerals	-	1.03	1.79	0.030

Table 5: Phytochemical analysis of the maize crop

Parameter (mg L^{-1})	Maize CRM	Maize sample	P value
Total anthocyanin	5.21	8.52	0.051
Total flavonoids	66.02	49.52	0.048
Total phenolic acid	112.42	100.42	0.020

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