CHAPTER 3

MATERIALS AND METHODS

3.1 Research Setting

3.1.1 Region

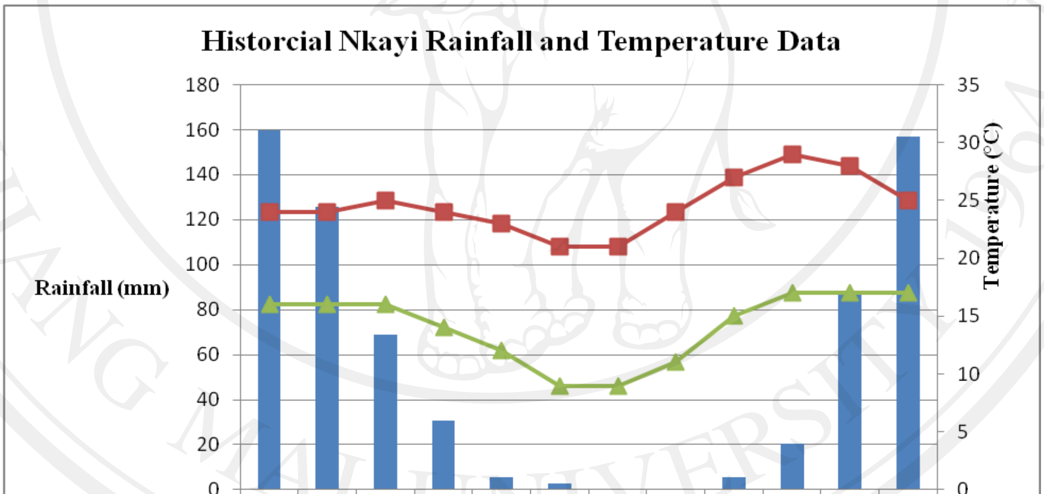
Within a 5 km area, nine research fields were located in Mantshololozane and Mathetshaneni Villages along the Shangani River in the Nkayi District of Matabeleland North Province in west central Zimbabwe (see Table 2 for coordinates). The Nkayi district has a population of 55,000 people and is subdivided into 22 wards with each ward comprising 5-8 villages (Mazango & Munjeri, 2009). Mantshololozane and Mathetshaneni Villages are in Ward 19 and located approximately 15 kilometers northwest of the city Nkayi, the district's administrative headquarters. The Matabele (Ndebele) minority ethnic group populates this area.

Figure 8: Zimbabwe country map with research site (3 sites within 5 km).

Source: Modified from Ezilon (2009)

3.1.2 Climate

Located in Natural Region IV (see Table 1 for Natural Region descriptions), average rainfall averages around 650 mm and is characterized by erratic distribution with significant periods of drought (FAO, 2006). The unimodal rainy season is confined to the summer months, mainly November through March (Figure 9). April to July is cool and dry while August to the start of rainy season is hot and dry (Raes et al., 2004). The altitude at the research site is approximately 1100 meters (Google Earth, May 22, 2012).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	160	126	69	31	6	3	0	0	6	20	87	157
Mean high (°C)	24	24	25	24	23	21	21	24	27	29	28	25
Mean low (°C)	16	16	16	14	12	9	9	11	15	17	17	17

Figure 9: Historical Nkayi rainfall and temperature Data.

[a] Rainfall data adapted from: Global Historical Climatology Network, 1930-1989, as cited in World Climate.

[b] Temperature data adapted from: World Weather Online, for 2000-2010.

3.1.3 Farming system

Farming consists primarily of smallholder crop and livestock systems where maize, sorghum (*Sorghum bicolor*), and pearl millet (*Pennisetum glaucum*) are the main cereal grains with cowpea (*Vigna* sp.), Bambara groundnut (*Voandzeia subterranean*), and groundnut (*Arachis hypogaea*) as the main legumes (Twomlow, et al., 2010). Maize yields are very low. In Matabeleland North, the average yield was 0.5 t/ha in 2011 and 0.7 t/ha in 2012 (Zimbabwe Minister of Agriculture, 2012). Livestock with goats, cattle, donkey, and sheep are raised on communal grazeland and additionally on crop residues during the dry season when shortfalls exist on grazeland. According to Masikati (2011), Nkayi farmers report maize stover to be the most commonly used crop residue for livestock grazing followed by groundnut. Due to communal grazing patterns, fields are fenced to protect crops from livestock.

3.1.4 Soil

Poorly structured sandy soils, loamy sands, and sandy loams are typical dryland soils of southern Africa (Mupangwa et al., 2006). 70% of Zimbabwe's soils are sandy soils with Cambic Arenosols and Ferric Luvisols as dominant soil types in the Nkayi District according to the World Reference Base for Soil Resources (WRB) classification (FAO, 2006) (Figure 10). An earlier more detailed soil map, dated 1979, is available through the European Digital Archive on Soil Maps (EuDASM) (Panagos et al., 2011). The dominant soil in the research area belongs to the Fersiallitic group and is described as follows: "mainly moderately shallow, grayish brown, coarse grained sands throughout the profile, to similar sandy loams, over reddish brown sandy clay loams; formed on granitic rocks.” (Department of the Surveyor General, 1979).

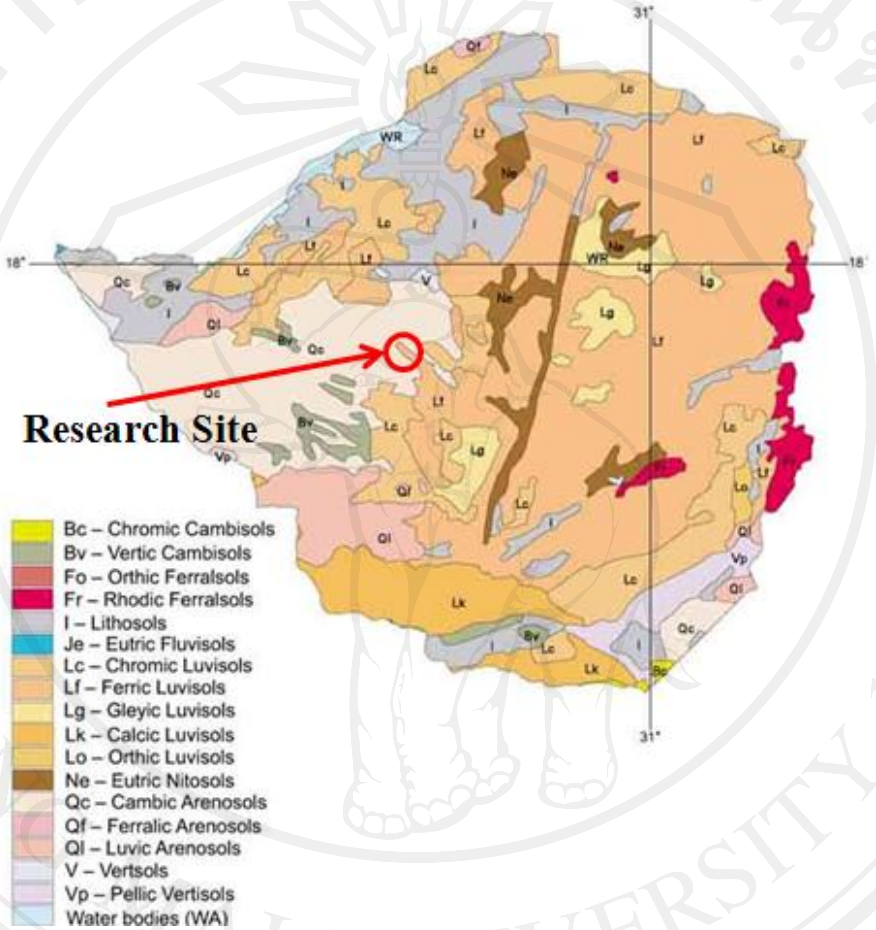


Figure 10: Soil Map of Zimbabwe according to WRB

[a] Source: DSMW-FAO-Unesco as cited in FAO, 2006

A soil profile was dug centrally located in the research area (18°55'S and 28°47'E) and the soil classified as a Haplic Cambisol (WRB, 2007) with a clay-poor sandy loam texture (50-90% sand, 10-50% silt, 0-10% clay) (Figure 11).

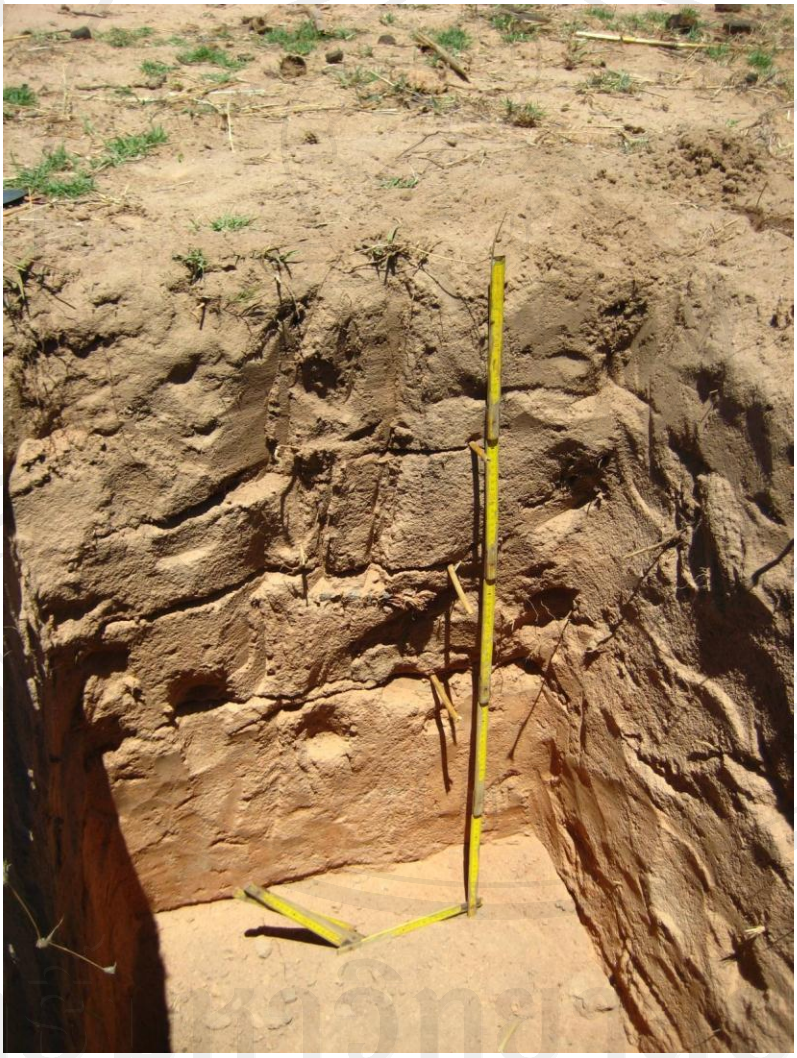


Figure 11: Soil profile: Haplic Cambisol with clay-poor sandy loam texture.

3.2 Field Selection

Fields visits to the Nkayi District were initiated during September of 2011 to locate a suitable research site(s). Consultation, translation services, and visits were facilitated through three NGOs— Foundations for Farming, German Agro Action, and Operation Trumpet Call. Data was collected from different farmers to determine appropriate fields. Data included information about current farming systems, crop and field history, fertilization (rate and type of amendments), and yield data. Selection criteria included: 1) fields where CF was practiced continuously for 3-5 years and 8-10 years, 2) reasonable confidence based on farmer input that the same planting stations had been maintained, 3) fields were in close proximity (preferably within a 5 kilometer area), 4) fields had similar soil conditions, and 5) fields had similar management patterns especially within their respective farming systems—CF or conventional tillage.

At the recommendation of Foundations for Farming, the selection process centered around the area of Mantshololozane Village and CF Farmer Sifiso Mpofu, one of the earliest CF adopters in the region. Within 0.5 km of Sifiso's 9 year CF field, ten 4 yr. CF maize fields existed that fulfilled the selection criteria, existing on the same soil type with similar management histories. From these ten fields, three 4-yr CF fields were selected based on observations from field visits where planting stations could easily be found, farmers' input and interest to participate in the study, and recommendations from Sifiso Mpofu on what he knew to be similar management histories. Selection of three conventionally ploughed fields emphasized proximity to CF fields, similar soil type, typical farmer practice of the area where ploughing was their dominant land preparation method (though all conventional farmers in the study had small CF plots near their homes), and farmer input and willingness to participate in the study. Two conventional fields were within 0.5 km of Sifiso Mpofu's field and the third, approximately two km away in Mathetshaneni Village. The main challenge was finding three eight or older CF fields in close proximity with similar soil conditions. Several nearby farmers on similar soil type began in 2001-2, but only Sifiso Mpofu had consistently practiced CF in the same stations without reverting to ploughing for some years. This led to inclusion of two eight year CF fields with observable differences in soil texture and color, mainly a slight increase in clay and darker red color. This difference was reflected in the chemical analyses later done at Hohenheim University which resulted in dismissing these two fields from the overall statistical analysis (Appendix A). The soil was also classified as a Haplic Cambisol but with a clay-rich sandy loam (40-60% sand, 20-50% silt, 15-25% clay) compared to a clay-poor sandy loam for the other fields. Due to the inability to locate other eight-nine year CF fields on the same soil type, the sample size for CF8 was reduced to one field—CF8-1. See Table 2 for a further description of all nine individual fields.

Interviews were initiated with each of the selected farmers in the study. A translator was present at most interviews where the participant was not comfortable with English. For the full list of interview questions see Appendix B. Fields were measured for total maize area and for total crop area for the 2010-11 season.

Table 2: Individual field descriptions

Field	Farming method	Coordinates	Village	Soil Texture
REF-1	Ploughing	18°55'18.53"S 28°47'34.05"E	Mantshololozane	Clay-poor sandy loam
REF-2	Ploughing	18°55'15.90"S 28°47'46.63"E	Mantshololozane	Clay-poor sandy loam
REF-3	Ploughing	18°56'24.88"S 28°47'56.72"E	Mathetshaneni	Clay-poor sandy loam
CF4-1	CF (4 yrs.)	18°55'21.73"S 28°47'39.21"E	Mantshololozane	Clay-poor sandy loam
CF4-2	CF (4 yrs.)	18°55'25.35"S 28°47'41.68"E	Mantshololozane	Clay-poor sandy loam
CF4-3	CF (4 yrs.)	18°55'26.63"S 28°47'40.32"E	Mantshololozane	Clay-poor sandy loam
CF8-1	CF (9 yrs.)	18°55'21.23"S 28°47'55.25"E	Mantshololozane	Clay-poor sandy loam
CF8-2	CF (8 yrs.)	18°53'58.46"S 28°46'56.75"E	Mantshololozane	Clay-rich sandy loam
CF8-3	CF (8 yrs.)	18°54'11.20"S 28°47'0.43"E	Mantshololozane	Clay-rich sandy loam

The first conventional field (REF-1) field was under continuous ploughing for 21 years, REF-2 for 26 years, and REF-3 for 23 years. The four year CF fields (CF4-1, CF4-2, and CF4-3) were farmed under CF for four years. The farmers were part of a farmer-initiated and led group comprising 10 CF farmers. The land was formerly a ploughed field from 1950-1979 and then used for communal grazing until 2007 when the CF plots were developed. The 8+ CF field in the study (CF8-1) was originally ploughed between 1998-2001 before being converted to CF. The area sampled was under CF for nine years. CF8-1 and CF4-3 farmers were from the same household, Sifiso and Julia Mpofu.

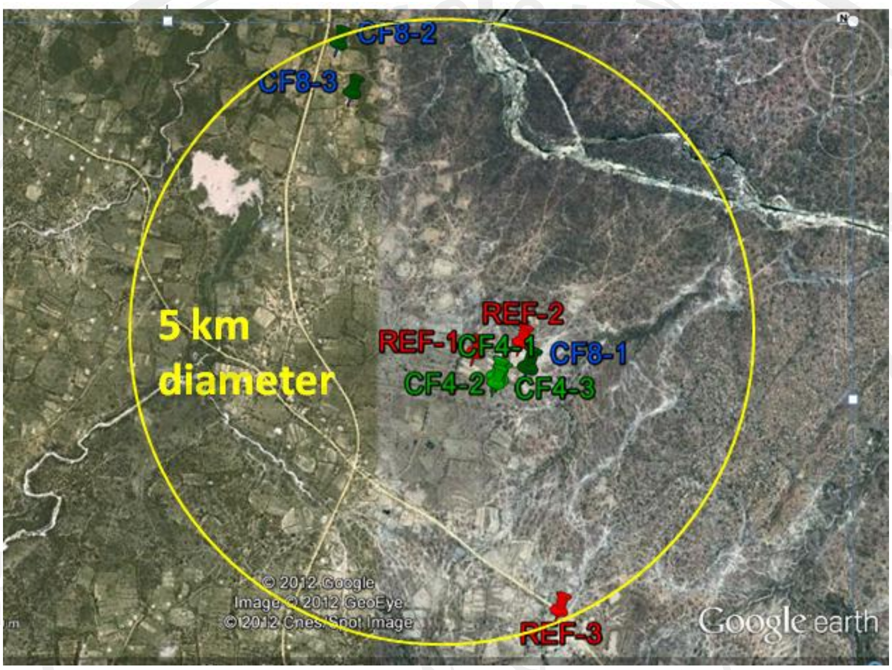


Figure 12: Location of nine research fields.

[a] Source: Modified from Google Earth

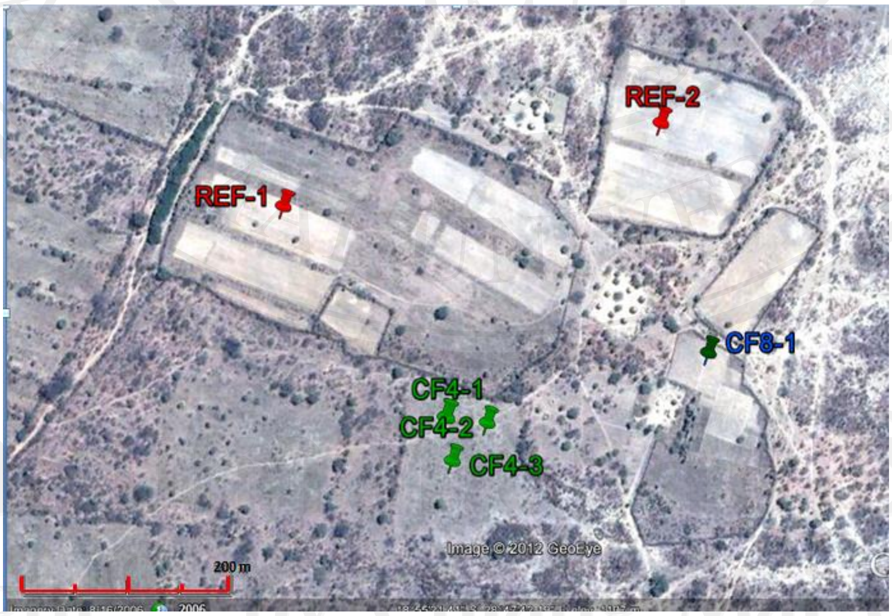


Figure 13: Closer view of six fields in the study. CF4-1, 2 and 3 fields are not visible since satellite photo is from 2006.

[a] Source: Modified from Google Earth

3.3 Experimental Design

The experimental design included three treatment groups: 1) reference (REF), representing conventional farmer practice of ploughing, 2) CF practiced 4 years (CF4), and 3) CF practiced 8-9 years (CF8). From each treatment group there were three fields making a total of nine fields. Soil sampling design for CF fields took place inside and outside of the basin (37.5 cm away from station based on 75 X 75 cm station spacing). Sampling occurred at two depths, 0-15 cm and 15-30 cm. For reference fields, soil sampling occurred on top of the ridge where maize is planted and in the adjacent furrow and at the same two depths (0-15 cm and 15-30 cm). Each set of four samples was replicated five times in each field (usually a minimum of 10 m apart), resulting in 20 total soil samples from each field. Soil was extracted using a soil auger with a 30 cm core depth.

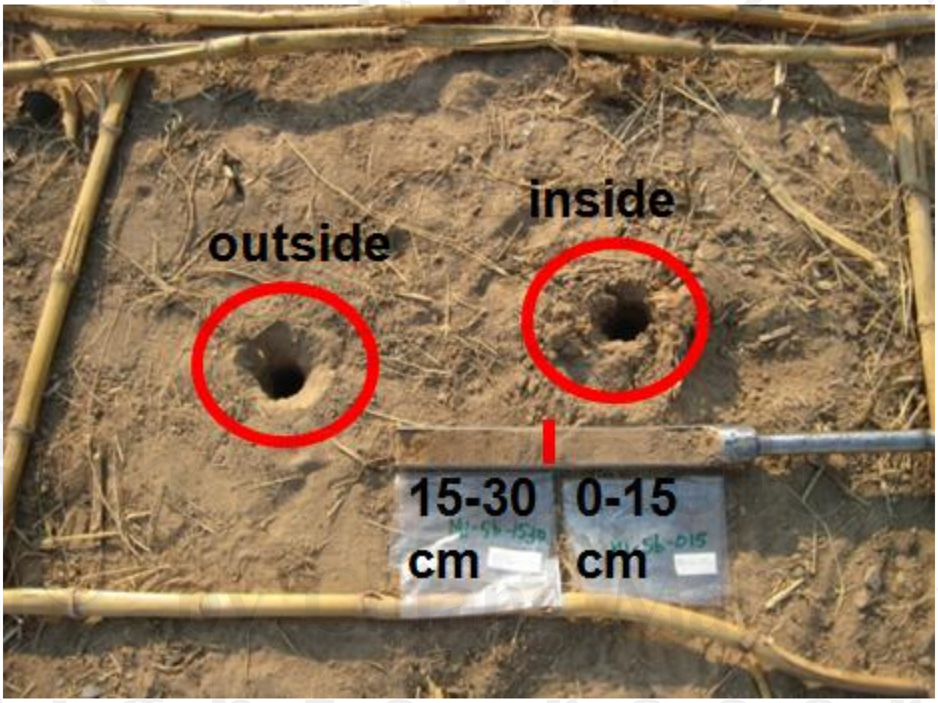


Figure 14: Sampling design in CF field: inside and outside planting station and at two depths.

Samples were not bulked but tested independently for soil fertility parameters. For each soil core sample location, a bulk density sample was taken in close proximity to each soil core sample following the same protocol—inside and outside CF stations, and along ridge and furrow for reference fields and at both depths. Infiltration was measured at the soil surface only adjacent to each soil sampling location.

3.4 Soil Analyses

3.4.1 Physical Parameters

Physical parameters, bulk density (BD) and infiltration (IN), were measured on-site in Zimbabwe. Infiltration was measured in the fields using double-ring infiltrometer where outer ring was 8.34 cm in diameter and inner ring 5.0 cm in diameter. Infiltration was measured at soil surface (0-15 cm depth only). Water was maintained in outer ring while water added to inner ring was measured every minute for a total of 10 minutes. Results are based upon the last 5 minutes, defined as the stationary infiltration rate. For bulk density, 100 cm^3 metal rings were used to extract soil from the middle of each sampling depth (0-15 cm, 15-30 cm). Samples were stored in plastic bags, air-dried, and then oven-dried before for final weighing.

Figure 15: Double ring infiltrometer inside and outside CF station

Figure 16: Bulk density sampling at 0-15 cm.

3.4.2 Chemical Parameters

All chemical analyses (total C, total N, P, K, Exchangeable cations (K, Ca, Na, and Mg), pH and active C) were done at Hohenheim University, Germany. 100 g soil core samples were collected. At Hohenheim University, samples were oven-dried and sieved through 2mm mesh. The following laboratory procedures were used:

For total carbon (TC) and nitrogen analysis, subsamples were ground and measured in C/N elemental analyzer (Elementar, Hanau, Germany). Phosphorous and potassium were extracted in 0.03 N NH_4F and 0.025 N HCl_2 solutions according to Jackson (1958) as cited in 'Das kleine Bodenkochbuch, 2010'. P was measured with Cary 50 UV-Visible Spetrophotometer (Varian, Mulgrave, Australia). K was measured with Elex 6361 flame photometer (Eppendorf, Hamburg Germany). Exchangeable cations (calcium, potassium, sodium, and magnesium) were extracted in 1M NH_4-acetate solution as cited in 'Das kleine Bodenkochbuch, 2010'. Ca, K, and Na were measured with Elex 6361 flame photometer (Eppendorf, Hamburg, Germany). Mg was measured with Perkin-Elmer Model 3100 AAS (Atomic Absorption Spectrophotometer) (PerkinElmer, Norwalk, CT, USA). pH was measured in 0.01 $CaCl_2$ solution according to DIN (Deutsches Institut für Normung) 19684 as cited in 'Das kleine Bodenkochbuch, 2010'. Active carbon (AC) was measured according to the laboratory method developed and tested by Weil et al. (2003) outlined below:

1. Air-dry soil samples indoors
2. Sieve soil < 1 mm screen
3. 5 grams of soil in 20 ml of 0.02M $KMnO_4$ and 0.1M $CaCl_2$ solution
4. Shake vigorously 2 minutes with horizontal shaker at 120 rpm
5. Let stand for 10 minutes without disturbance, allowing settling of particles
6. Absorbance measured with Cary 50 UV-Visible Spetrophotometer (Varian, Mulgrave, Australia) at 550 nm.
7. Construct standard curve using 0.005M, 0.01M, and 0.02M of $KMnO_4$ standard solutions (absorbance= x-axis; concentration= y-axis)
8. To calculate active C, the formula, as cited by Weil et al. (2003), is described below:

Active C (mg kg^{-1}) = [0.02 mol/l - (a + b X absorbance)] X (9000 mg C/mol)

X (0.02 l solution/0.005 kg soil)

Where:

i) 0.02 ml/l is initial solution concentration

ii) *a* is intercept and *b* is slope of standard curve

iii) 9000 is mg C oxidized by 1 mol of MNO_4

iv) 0.02 l is volume of $KMnO_4$ solution reacted

v) 0.005 is kg of soil used

3.5 Statistical Analysis

Data was managed through EXCEL. Outlier data points were calculated using Grubb's test. Soil parameters were analyzed for statistical significance using ANOVA as a mixed model in SAS. Log transformations for normalizing data were used for the following dependent variables: TC, P, N, K, Ca, Mg, and IN. Square root transformation was used for AC. Untransformed data was used for Na, pH, and BD. Means were calculated as estimated marginal means (also known as Least Squares (LS) means) in SAS—"within-group appropriately adjusted means for the other effects in the model" (SAS, 2012). Graphs were made with estimated marginal means in SPSS. AC carbon correlations were run with untransformed data of TC, N, and BD using Pearson Correlation Coefficient.