Appraising White Yam (Dioscorea Rotundata Poir) Performance And Fertility Status Of An Alfisol Under Yam - Based Intercropping

B. Osundare

Abstract: Empirical evidence from many parts of the world indicates that, intercropping, on a long – term basis, results in depletion of soil fertility and attendant reduced crop yields. Thus, the need arises to critically assess changes in nutrient status of soil under intercropping, in order to be able to fashion out an adequate fertilizer package, involving addition of organic and/or inorganic fertilizers to replenish the lost nutrients, hence, making intercropping sustainable. To partly meet the need, a two – year study was designed to evaluate the influence of yam – based intercropping on changes in fertility status of an Alfisol, tuber yield and yield components of white yam (Dioscorea rotundata Poir). The experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2012 and 2013 cropping seasons. The experiment was laid out in a randomized complete block design with three replications. The yam – based intercropping included: sole cropped yam (SCY), which served as the control; yam/cowpea (YC); yam/maize (YM); yam/cassava (YCa); and yam/maize/cassava (YMCa). The results obtained indicated existence of significant (P = 0.05) differences among the yam – based intercropping systems as regards their effects on chemical properties of Alfisol and yam tuber yield and yield components. At the end of 2012 cropping season, yam – based intercropping resulted in significant (P = 0.05) decreases in soil organic carbon (SOC) from 0.68 g kg^{-1} for SCY to 0.58, 0.52, 0.46 and 0.39 g kg^{-1} for YC, YM,YCa and YMCa, respectively. Similarly, at the end of 2013 cropping season, yam – based intercropping resulted in significant decreases in SOC from 0.64 g kg^{-1} for SCY to 0.55,0.48, 0.42, and 0.35 g kg^{-1} for YC, YM, YCa and YMCa, respectively. At the end of 2012 cropping season, yam – based intercropping significantly decreased total nitrogen from 0.50 g kg^{-1} for SCY to 0.55, 0.38, 0.44and 0.32 g kg^{-1} for YC, YM, YCa and YMCa, respectively. At the end of 2013 cropping season, yam – based intercropping significantly decreased total nitrogen from 0.47 g kg^{-1} for SCY to 0.52, 0.34, 0.40 and 0.27 g kg^{-1} for the respective YC, YM, YCa and YMCa. Across the two years of experimentation, mean values of yam tuber yield, adduced to yam – based intercropping systems were 7.00, 7.16, 5.94, 5.46 and 4.12 t ha^{-1} for the respective SCY, YC, YM, YCa and YMCa

Key words: Alfisol, appraise, fertility, status, yam

INTRODUCTION

White yam (Dioscorea rotundata Poir), is a long duration crop, which is suitable for intercropping with other crops that can mature within 2 – 3 months before yam canopy closes. Thus, about 60 percent of the white yam grown in southwestern Nigeria is intercropped with crops, such as maize, cassava and other vegetables (Alarape, 2012; Arista, 2014).Yam/maize/cassava intercropping has been reported to give the highest amount of calories per hectare (Aina, 2014), and the most widespread mixed cropping in the derived savanna and rainforest zones of southwest Nigeria (Alarape, 2012; Aina, 2014). Previous studies (Alarape, 2012; Irwin, 2014; Arista, 2014) had established that, crop mixtures take up higher amount of nutrients per unit land area than sole crops. Irwin (2014) and Arista (2014) reported that one hectare of crop mixtures took up 40 – 60% more nutrients than $2^{1/2}$ hectares of corresponding sole crops. In general, as a result of higher aggregate nutrient uptake, due to combined demands of individual intercrops in crop mixtures, there is usually the problem of soil fertility depletion under intercropping (Alarape, 2012; Apir, 2013).

- *B. Osundare*
- *Department of Crop, Soil, and Environmental Sciences*
- *Ekiti State University, Ado – Ekiti, Nigeria*
- *biodunosundare@yahoo.com +2348057212838*

Apir (2013) and Cesemus (2014) opined that, the rate of soil fertility depletion under intercropping increased with increasing number of individual crops in the mixture. To avert the problem of soil fertility depletion that attends intercropping, Oris (2013) and Header (2014) recommended inclusion of at least, one legume in crop mixtures, in addition to adequate organic and/or inorganic fertilization. Although, in Southwestern Nigeria, many studies had been carried out on improvement of productivity of yam – based intercropping, with a view to making it sustainable. However, there is still dearth of published scientific data and information on changes in nutrient status of an Alfisol under yam – based intercropping. To this end, this study was designed to evaluate changes in nutrient status of an Alfisol and tuber yield of yam under yam – based intercropping.

Materials and Methods

Study site: An experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2012 and 2013 cropping seasons. The soil in the study site belongs to the broad group Alfisol (SSS, 2002). The soil was highly leached, with low to medium organic matter, deep red – clay profile, with top sandy loam texture. The study site had been under continuous cultivation of a variety of arable crops, among which were cassava, maize, melon, cocoyam, sweet potato, prior to the commencement of this study.

Collection and analysis of soil samples: Prior to planting, ten core soil samples, randomly collected from 0 – 15 cm soil depth, were bulked inside a plastic bucket to form a composite sample, which was analyzed for chemical properties. At the end of each year cropping, another set of soil samples was collected in each treatment plot and analyzed. The soil samples were air – dried, ground, and passed through a 2 mm sieve. The processed soil samples and residues of the weed species were analyzed in accordance with the soil and plant analytical procedures, outlined by the International Institute of Tropical Agriculture (IITA) (1989).

Experimental design and treatments: The experiment was laid out in a randomized complete block design with three replicates. The different yam – based intercropping systems included: sole cropped yam (SCY); yam/cowpea (YC); yam/maize (YM); yam/cassava (YCa); and yam/maize/cassava (YMCa). Each plot size was 3 m x 3 m.

Planting, weeding, collection and analysis of data: Planting was done on March 1 and March 3 in 2012 and 2013, respectively. Stem – cuttings (20 cm long each) of early maturing cassava variety, Tropical Manihot Series (TMS) 30572, obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were planted at 1 m x 1 m (10,000 cassava plants ha^{-1}). Three seeds of Oba Super1 maize variety, treated with Apron Plus, were planted at 75 cm x 25 cm, but later thinned to two seedlings per stand (106,667 maize plants ha^{-1}), three weeks after planting (WAP). Similarly, three cowpea seeds were planted per stand at 60 cm x 30 cm, but later thinned to two seedlings per stand (55,556 cowpea plants ha^{-1}), 3 WAP. Weeding was carried out manually at 4, 8, 12 and 16 WAP, using a hoe. At harvest (12 months after planting, MAP), data were collected on yam tuber yield and yield components. All the data were subjected to analysis of variance, and treatment means were compared, using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

RESULTS

Soil nutrient status before cropping

Table 1 shows the initial nutrient status of soil in the experimental site prior to 2012 cropping

Table 1: The chemical properties of Alfisol prior to 2012 cropping season.

Soil properties	Values
pH	6.2
Organic carbon (g kg^{-1})	0.90
Total nitrogen (g kg^{-1})	0.60
Available phosphorus (mg kg^{-1})	0.66
Exchangeable bases (cmol kg^{-1})	
Potassium	0.58
Calcium	0.62
Magnesium	0.60
Sodium	0.55
Exchangeable Acidity	0.32
Effective Cation Exchangeable Capacity (ECEC)	2.67

Chemical properties of Alfisol as affected by different yam – based intercropping systems after 2012 and 2013 cropping seasons.

Tables 2 and 3 show chemical properties of Alfisol as affected by yam – based intercropping after 2012 and 2013 cropping seasons. At the end of 2012 cropping season, yam – based intercropping resulted in significant (P = 0.05) decreases in soil pH from 5.7 for SCY to 5.1, 3.9, 4.5 and 3.4 for YC, YM,YCa and YMCa, respectively. At the end of 2013 cropping season, yam – based intercropping resulted in significant (P = 0.05) decreases in soil pH from 5.3 for SCY to 4.8, 3.5, 4.1 and 3.0 for YC, YM,YCa and YMCa, respectively. At the end of 2012 cropping season, yam – based intercropping resulted in significant (P = 0.05) decreases in soil organic carbon (SOC) from 0.68 g kg^{-1} for SCY to 0.58, 0.52, 0.46 and 0.39 g kg^{-1} for YC, YM,YCa and YMCa, respectively. Similarly, at the end of 2013 cropping season, yam – based intercropping resulted in significant decreases in SOC from 0.64 g kg^{-1} for SCY to 0.55,0.48, 0.42, and 0.35 g kg^{-1} for YC, YM, YCa and YMCa, respectively. At the end of 2012 cropping season, yam – based intercropping significantly decreased total nitrogen from 0.50 g kg^{-1} for SCY to 0.55, 0.38, 0.44and 0.32 g kg^{-1} for YC, YM, YCa and YMCa, respectively. At the end of 2013 cropping season, yam – based intercropping significantly decreased total nitrogen from 0.47 g kg^{-1} for SCY to 0.52, 0.34, 0.40 and 0.27 g kg^{-1} for the respective YC, YM, YCa and YMCa. At the end of 2012 cropping season, yam – based intercropping significantly decreased available P from 0.59 mg kg^{-1} for SCY to 0.52, 0.38, 0.57 and 0.32 mg kg^{-1} for the respective YC, YM, YCa and YMCa. At the end of 2013 cropping season, yam – based intercropping significantly decreased available P from 0.55 mg kg^{-1} for SCY to 0.47, 0.33, 0.53 and 0.25 mg kg^{-1} for the respective YC, YM, YCa and YMCa. At the end of 2012 cropping season, yam – based intercropping significantly decreased exchangeable K from 0.52 cmol kg^{-1} for SCY to 0.47, 0.35, 0.41 and 0.20 cmol kg^{-1} for the respective YC, YM, YCa and YMCa. At the end of 2013 cropping season, yam – based intercropping significantly decreased exchangeable K from 0.48 cmol kg^{-1} for SCY to 0.42, 0.32, 0.37 and 0.17 cmol kg^{-1} for the respective YC, YM, YCa and YMCa. At the end of 2012 cropping season, yam – based intercropping significantly decreased exchangeable Ca from 0.56 cmol kg^{-1} for SCY to 0.51, 0.40, 0.46 and 0.29 cmol kg^{-1} for the respective YC, YM, YCa and YMCa. At the end of 2013 cropping season, yam – based intercropping significantly decreased exchangeable Ca from 0.53 cmol kg^{-1} for SCY to 0.48, 0.37, 0.43 and 0.26 cmol kg^{-1} for the respective YC, YM, YCa and YMCa. At the end of 2012 cropping season, yam – based intercropping significantly decreased exchangeable Mg from 0.54 cmol kg^{-1} for SCY to 0.48, 0.37, 0.42 and 0.25 cmol kg^{-1} for the respective YC, YM, YCa and YMCa. At the end of 2013 cropping season, yam – based intercropping significantly decreased exchangeable Mg from 0.51 cmol kg^{-1} for SCY to 0.45, 0.33, 0.40 and 0.21 cmol kg^{-1} for the respective YC, YM, YCa and YMCa. At the end of 2012 cropping season, yam – based intercropping significantly decreased exchangeable Na from 0.47 cmol kg^{-1} for SCY to 0.42, 0.30, 0.36 and 0.22 cmol kg^{-1} for the respective YC, YM, YCa and YMCa. At the end of 2013 cropping season, yam – based intercropping significantly decreased exchangeable Na from 0.43 cmol kg^{-1} for SCY to 0.37, 0.25, 0.31 and 0.17 cmol kg^{-1} for the respective YC, YM, YCa and YMCa.

Table 2: Chemical properties of Alfisol as affected by yam – based intercropping after 2012 cropping season.

Treatments (Yam – based intercropping)	pH	Org. C ($g\ kg^{-1}$)	Total N ($g\ kg^{-1}$)	Av. P ($mg\ kg^{-1}$)	Exchangeable bases ($cmol\ kg^{-1}$)			
					K	Ca	Mg	Na
SCY	5.7a	0.68a	0.50b	0.59a	0.52a	0.56a	0.54a	0.47a
YC	5.1b	0.58b	0.55a	0.52b	0.47b	0.51b	0.48b	0.42b
YM	3.9d	0.52c	0.38d	0.38c	0.35d	0.40d	0.37d	0.30d
YCa	4.5c	0.46d	0.44c	0.57a	0.41c	0.46c	0.42c	0.36c
YMCa	3.4ce	0.39e	0.32e	0.32d	0.20e	0.29e	0.25e	0.22e

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). SCY = Sole cropped yam; YC = yam/cowpea; YM = yam/maize; YCa = yam/cassava; YMCa = yam/maize/cassava.

Table 3: Chemical properties of Alfisol as affected by yam – based intercropping after 2013 cropping season.

Treatments (Yam – based intercropping)	pH	Org. C ($g\ kg^{-1}$)	Total N ($g\ kg^{-1}$)	Av. P ($mg\ kg^{-1}$)	Exchangeable bases ($cmol\ kg^{-1}$)			
					K	Ca	Mg	Na
SCY	5.3a	0.64a	0.47b	0.55a	0.48a	0.53a	0.51a	0.43a
YC	4.8b	0.55b	0.52a	0.47b	0.42b	0.48b	0.45b	0.37b
YM	3.5d	0.48c	0.34d	0.33c	0.32d	0.37d	0.33d	0.25d
YCa	4.1c	0.42d	0.40c	0.53a	0.37c	0.43c	0.40c	0.32c
YMCa	3.0c	0.35e	0.27e	0.25d	0.17e	0.26e	0.21e	0.17e

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). SCY = Sole cropped yam; YC = yam/cowpea; YM = yam/maize; YCa = yam/cassava; YMCa = yam/maize/cassava.

Yam tuber yield and yield components

Yam tuber yield and yield components as affected by yam – based intercropping are presented in Table 4. Across the two years of experimentation, mean values of yam tuber yield, adduced to yam – based intercropping systems were 7.00, 7.16, 5.94, 5.46 and 4.12 t ha^{-1} for the respective SCY, YC, YM, YCa and YMCa. Similarly, mean values of yam tuber length, adduced to yam – based intercropping systems were 17.85,17.97, 15.99, 14.05 and 9.61 cm for the respective SCY, YC, YM, YCa and YMCa. Mean values of yam tuber diameter, adduced to yam – based intercropping systems were 12.95,13.10, 11.65, 9.97 and 8.04 cm for the respective SCY, YC, YM, YCa and YMCa.

Table 4: Yam tuber yield and yield components as affected by yam – based intercropping systems at harvest

Treatments (Yam – based intercropping)	Yam tuber yield ($t\ ha^{-1}$)			Yam tuber length (cm)			Yam tuber diameter (cm)		
	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean
SCY	7.10b	6.90b	7.00	18.00b	17.70b	17.85	13.01b	12.88b	12.95
YC	7.28a	7.03a	7.16	18.14a	17.80a	17.97	13.15a	13.04a	13.10
YM	6.00c	5.88c	5.94	16.10c	15.89c	15.99	11.71c	11.58c	11.65
YCa	5.50d	5.41d	5.46	14.17d	13.93d	14.05	10.11d	9.83d	9.97
YMCa	4.20e	4.03e	4.12	10.21e	9.00e	9.61	8.20e	7.88e	8.04

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). SCY = Sole cropped yam; YC = yam/cowpea; YM = yam/maize; YCa = yam/cassava; YMCa = yam/maize/cassava.

DISCUSSION

Relative to the control treatment, the significant decreases in pH of soil in the plots of those yam – based intercropping, after cropping, corroborate the findings of Alarape (2012); Arista (2014) and Cesemus (2014), who noted significant decreases in pH of an Alfisol under yam – based intercropping, after cropping. These observations can be ascribed to significant decreases in the exchangeable basic cations on the exchange sites of soil in the plots of those yam – based mixtures. The significant decreases in soil organic carbon (SOC), adduced to the yam – based intercropping, agree with the reports of Apir (2013); Cesemus (2014), who observed significant decreases in SOC beneath yam – based mixtures, after cropping. The highest total N value for yam/cowpea mixture, after cropping, is in line with the observations of Header (2014), who noted highest total N value under yam/cowpea mixture, compared to other yam – based mixtures. The highest total N value for yam/cowpea can be attributed to biological nitrogen fixation (BNF) by cowpea. The lowest available P value for yam/maize/cassava mixture, can be attributed to the lowest pH value of soil in the yam/maize/cassava plots.

This is because, the availability of P in the soil, depends on the pH of the soil medium, with available P decreasing with decreasing pH (Aveta, 2014). The decreasing available P phenomenon, associated with increasing acidity or decreasing pH, is due to the conversion of P into unavailable forms under acid soil conditions, as a result of fixation by micro – nutrients, such as Fe and Al, which abound in acid soils (Aveta, 2014; Header, 2014). After cropping, the available P value, adduced to yam/ cassava mixture was significantly higher than that for yam/maize mixture, suggesting that, the quantity of available P removed from the soil system by cassava during the growing period was lower than that removed by maize. The non – significant difference in available P value between sole cropped yam and yam/cassava mixture, confirm the observations of Oris (2013) and Kim (2013), who reported non – significant difference in available P value between sole cropped yam and yam/cassava mixture, after cropping. This observation implies that, the inclusion of cassava in yam/cassava mixture, did not result in significant removal of P from the soil, that is, the quantity of P removed from the soil was low. Kim (2013) and Aveta (2014) had earlier reported low P uptake in cassava. The low correlation between soil P and plant – content and yield, testifies to low uptake of P by cassava (Aveta, 2014). One factor that can be implicated for the low P uptake by cassava is that of mycorrhizal association, which provides as much as 15 ppm P to the soil from fixed P by soil mycorrhiza Apir (2013); Kim (2013). The practical implication of the low P uptake by cassava is that, P perhaps, is not a limiting nutrient element in mineral nutrition of cassava, hence, a high root yield of cassava can still be obtained in a soil of inherently low P, provided other essential nutrients are not limiting. The significant decreases in total N, available P and the exchangeable cations, observed in the plots of yam – based mixtures, after cropping, can be attributed to significant decreases in SOC values recorded in the plots of yam – based mixtures. This is because, soil organic matter (SOM) has been reported as a reservoir of other plant nutrients. That is, other plant nutrients are integrally tied to it, and hence, the maintenance of SOM is paramount in sustaining other soil quality factors (Oris, 2013; Aveta, 2014). The lowest values of all the plant nutrients, adduced to yam/maize/cassava mixture, after cropping, was due to the highest aggregate uptake of those nutrients under yam/maize/cassava mixture, due to the combined demands of yam, maize and cassava for the nutrients. These observations suggest that, soil nutrient reserve would deplete faster under intercropping than sole cropping, unless a commensurable fertilizer input is embarked upon. The lower values of SOC/SOM, and other plant nutrients, recorded in plots of yam – based mixtures at the end of 2013 cropping season, as against what obtained at the end of 2012 cropping season, further confirm the assertion of Boker (2014), that SOM declines under continuous cultivation, with or without fertilizer application. The lower SOC value for 2013 than its 2012 counterpart, can be explained in the light of higher rate of oxidation of SOM during 2013 cropping season due to effects of continuous tillage. This is because, the continuous cultivation or tillage during 2013 cropping activities may have caused further exposure of previously inaccessible and preserved SOM to action of the soil microbial biomass (Beare et al., 1992; Angers et al., 1993). So, the higher rate of oxidation of SOM during 2013 cropping activities, due to continuous tillage, can be implicated for the lower SOC value, recorded at the end of 2013 cropping season. This is because part of the carbon content of the organic matter may have been oxidized or converted into CO_2 gas, and consequently, more organic carbon is lost in the form of carbon dioxide – C emission from the soil system during 2013 cropping season. In view of the declined soil fertility that usually attends continuous cultivation, to forestall this problem of declined soil fertility, and hence, achieve sustainability of crop production on a continuous basis, the recommendation of appropriate SOM management techniques, such as incessant and copious manure additions, return of plant residues to land under continuous cultivation is imperative. The significantly higher values of tuber yield and yield components of yam interplanted with cowpea than those of the sole cropped yam, corroborate the findings of Alarape (2012); Aladeleye (2013), who noted that yam interplanted with cowpea significantly out – performed sole cropped yam. These observations suggest that, the presence of cowpea in yam/cowpea mixture was not detrimental to yam, implying yam's tolerance of cowpea, if and when they are combined. The significantly higher yield and yield components of yam interplanted with cowpea, compared to its sole cropped counterpart, can be attributed to beneficial effects of the presence of cowpea on yam. One way in which the presence of cowpea in yam/cowpea mixture may have been beneficial to yam is that of cowpea improving soil N status, through biological nitrogen fixation. Asides, in yam/cowpea mixture, the complete ground coverage, provided by cowpea, which may have minimized incident of run – off, erosion, leaching and excessive water evaporation from the soil, as well as increased soil organic matter content, resulting from decomposition of cowpea residues, can be implicated for the observed significant tuber yield difference between yam interplanted with cowpea and its sole cropped counterpart. The significantly higher tuber yield and yield components of sole cropped yam than those of yam in yam/maize, yam/cassava and yam/maize/cassava mixtures, can be ascribed to inter – specific competition among yam, maize and cassava in the mixtures, for below – and above – soil growth factors or resources (air, nutrients, water, light). The tuber yield and yield components of yam in yam/maize and yam/cassava mixtures, were significantly higher than those of yam in yam/maize/cassava mixtures, suggesting greater detrimental intercropping effects on yam in yam/maize/cassava mixture than what obtained in yam/maize and yam/cassava mixtures.

REFERENCES

[1] Aina, O. S. 2014.Study on yam – based intercropping in Southwestern Nigeria. Journal of Food and Agricultural Research.16:75 – 82.

[2] Aladeleye, M. T. 2013. Influence of organic and inorganic fertilizers on yam/cassava/maize intercrop in Southwestern Nigeria. Researches in Agricultural Sciences.26:333 – 339.

[3] Alarape, M. F. 2012.Soil fertility assessment under yam/cassava/maize intercrop. International Journal

of Agriculture and Rural Development. 23(2):321 – 328.

[4] Angers, D. A., N.Samson and A. Legege 1993. Early changes in water stable aggregate induced by tillage in a soil under barley production. Canadian Journal of Soil Science. 73: 51 – 59

[5] Apir, O. T. 2013. Responses of an acid Alfisol to increasing cassava population density in a yam/cassava mixture. Soil Fertility and Land Development.21:5 – 10.

[6] Arista, G. R. 2014. Interplanting tropical legumes with yam in Ghana. Journal of Soil and Environmental Sciences. 32:54 – 61.

[7] Aveta, L. A. 2014. Studies on P mineral nutrition of cassava. Plant Nutrition. 25:100 – 107.

[8] Beare, M.H., Parmelee, R.W and D.A. Crossley 1992. Microbiology and fauna interactions and effects of litter nitrogen and decomposition in agro – ecosystems. Ecology Monograph. 62:569 – 591.

[9] Boker, F. O. 2014. Assessment of organic matter status of an Alfisol under yam – based intercropping. Soil Fertility Research. 21(2):212 – 218.

[10] Cesemus, B. M. 2014. Assessing tuber yield of white yam (Dioscorea rotundata Poir) under fertilizer types and yam/maize/cassava intercrop. Crop Science Research. 33:87 – 94.

[11] Header, A. D. 2014. Improving fertility status of an Alfisol and maize grain yield performance through interplanting tropical legumes with maize. Advances in Soil Science.18(1):270 – 277.

[12] International Institute of Tropical Agriculture (IITA) 1989. Automated and semi – automated methods of soil and plant analysis. Manual Series, No 7, IITA, Ibadan, Nigeria.

[13] Irwin, B. I. 2014. Evaluating changes in soil fertility under cassava/maize/sweet potato intercrop in Cameroon. Plant and Soil Sciences. 23:322 – 328

[14] Kim, B. S. 2013. Growth and yield responses of cassava (Manihot esculenta Crantz) to NPK fertilizer application. Soil Fertility and Plant Nutrition. 21(2):251 -258.

[15] Oris, O.Y. 2013. Improving productivity of yam – based intercropping system. Crop Improvement. 8(2):1 – 6.

[16] Soil Survey Staff (SSS) 2003. Keys to soil taxonomy, SMSS Technical Monograph (8th edition). Natural Resource Conservation Services, United State Department of Agriculture, USA.