Journal of Soil Science and Environmental Management

Volume 5 Number 5 August, 2014
ISSN 2006-9782

Academic Journals

ABOUT JSSEM

The **Journal of Soil Science and Environmental Management (JSSEM)** is published monthly (one volume per year) by Academic Journals.

Journal of Soil Science and Environmental Management (JSSEM) is an open access journal that provides rapid publication (monthly) of articles in all areas of the subject such as Biological control of rot-inducing fungi, Post harvest losses of rice from harvesting to milling, Genetic variability studies between released varieties of cassava, Seed borne pathogens on farmer-saved sorghum etc..

The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in JSSEM are peer-reviewed.

Contact Us

Editorial Office:	jssem@academicjournals.org
Help Desk:	helpdesk@academicjournals.org
Website:	http://www.academicjournals.org/journal/AJAR
Submit manuscript online	http://ms.academicjournals.me/

Editors

Dr. Willie Peijnenburg
RIVM – Laboratory for Ecological Risk assessment
Leiden University, Centre for Environmental sciences
Bilthoven,
The Netherlands.

Dr. Geoffrey Kironchi
Department of Land Resource Management & Agricultural Technology
University of Nairobi,
Kenya.

Prof. Gamal Abdel-Nasser Khalil
Soil Science Dept.
College of Food and Agricultural Sciences - King Saud University
P.O. BOX 2460 - Riyadh 11451,
Saudi Arabia.

Dr. Anil vyas
Department of Botany,
J.N.V. University
A-282, Shastri Nagar.

Editorial Board

Dr. Elijah Ohimain
North Carolina A & T State University, Greensboro
Carver Hall Room 207,
Department of Natural Resources and
Environmental Design,
School of Agriculture and Environmental Science,
USA.

Dr. Mohamed Rashad Abd El-Fattah
Arid Lands Cultivation and Development Research
Institute,
Mubarak City for Scientific Research and
Technology Applications,
Egypt.

Dr. Gamal Abdel-Nasser Khalil
King Saud University P.O. BOX 2460 – Riyadh
11451,
Saudi Arabia.

Dr. V. Krishna Murthy
Pes Institute of Technology,
Ring Road, BSK III Stage, Bangalore-560 085,
Karnataka State,
India.

Dr. ANIL VYAS
Department of Botany,
J. N. V. University, A-282, Shastrinagar,
India.

Dr. Anthony O. Ano
National Roots and Tubers Research Institute
Umudike, Umuahia, Abia State,
Nigeria.

Dr Moacir de Souza Dias Junior
Universidade Federal de Lavras (Federal University
of Lavras)
Departamento de Ciência do Solo (Soil Science
Department)
Brazil.

Dr. Luki Subehi
Ndonesian Institute of Sciences,
Research Centre for Limnology
Cibinong Science Centre 16911 -
Indonesia.

Dr. Goswami Shreerup
P.G. Department of Environmental Science,
F.M. University , Gyana Vigyana Vihar,
Balasore-756020, Orissa,
India.

Dr. Tanushree Bhattacharya
Institute of Science and Technology for Advanced
Studies & Research
ISTAR, Near V.P. Science College, Motabazar, Vallabh
Vidyanagar,
Anand, Gujarat 388120"
India.

Dr. Suklayan Chakraborty
V. Patel College of Pure and Applied Scienes,
India.

Dr. Ulviyya Samadova
Institute of Soil science and Agrochemistry of
Azerbaijan National,
Azerbaijan.

Dr. Luís Carlos Timm
Federal University of Pelotas
Address Campus Universitário s/n – Capão do Leão-
RS,
Brazil.

Dr. Willie Peijnenburg
RIVM – Laboratory for Ecological Risk assessment
Leiden University, Centre for Environmental sciences
Bilthoven,
The Netherlands.

Dr. Dedeke Gabriel Adewumi
University of Agriculture, Abeokuta, Ogun State,
Nigeria.

Dr. M J Singh
Punjab Agricultural University, Punjab
India.

Mr. Willis
University of Western Australia
Australia.

Journal of Soil Science and Environmental Management

Table of Contents: Volume 5 Number 5 August 2014

ARTICLES

Research Articles

Modeling of ^{137}Cs and ^{60}Co transport in calcareous soils by groundwater 52
Ramzi M. Shihab

Effects of three tree species on microclimate and soil amelioration in the central rift valley of Ethiopia 62
Agena Anjulo Tanga[1]*, Tilahun Fromssa Erenso[2] and Bekele Lemma[3]

academicJournals

Vol. 5(5), pp. 52-61, August, 2014
DOI 10.5897/JSSEM13. 0415
Articles Number:CEE756C47212
ISSN 1996-0816
Copyright ©2014
Author(s) retain the copyright of this article
http://www.academicjournals.org/JSSEM

Journal of Soil Science and Environmental Management

Full Length Research Paper

Modeling of ^{137}Cs and ^{60}Co transport in calcareous soils by groundwater

Ramzi M. Shihab

Soil Science and Water Resource Department, College of Agriculture Tikrit University, Iraq.

Received 1 August, 2013; Accepted 25 July, 2014

The fate of transport of radionuclides is one of the most important factors to be considered for the safety assessment of repositories of radioactive wastes in porous media. Laboratory batch and column experiments were investigated to assess the transport of ^{137}Cs and ^{60}Co in calcareous loam and clay soils leached with groundwater (GW) using convection-dispersion equation model (CDE). Fractionation of Cs and Co in eight sequential fractions in the soils was also measured. Results showed that the distribution coefficient (*Kd*) values for ^{137}Cs found to be much more as compared to ^{60}Co. It was ranged from 20 to 395 ml/g, depending on soil and radionuclide characteristics. The CDE model provided a fairly good fit to the experimental breakthrough curves (BTCs) of both solutes. The retardation factor (*R*) was 821 and 118 for ^{137}Cs, while it was 65 and 88 for ^{60}Co, for both soils, respectively. The dispersion coefficient (*D*) was 2.0 and 2.8 for Cs, and 0.6 and 0.7 cm^2/min for Co for loam and clay soils, respectively. The silt+clay was the major soil fraction in retaining Cs followed by sand fraction, for both soils, while the carbonate was the major soil fraction in retaining Co followed by silt+clay, Fe oxides, and sand for loam soil, and silt+clay, sand and Fe oxides for clay soil. No large change was observed in ^{137}Cs retaining with leaching. The leaching consistently reduced the magnitude of ^{60}Co bound to carbonate and increased fraction bound to silt+clay.

Key words: Transport parameters, ^{137}Cs, ^{60}Co, fractionation, dispersion, calcareous soils.

INTRODUCTION

The release of radioactive materials and fallout to soils has become important task with the advent of nuclear industry. Radionuclides reach groundwater (GW), plants and humans through several paths after their release to the environment. Therefore, the study of radionuclides transport through the soil is an important issue in the safety assessment of nuclear waste repositories and the potential for contamination. These materials can be immobilized in soil components by different mechanisms such as adsorption. It has been recognized that the adsorption process to the soil matrix could limit the transport of radionuclides in the groundwater system (Haque et al., 2011). The mobility of radionuclides is associated with physiochemical characteristics of soil.

The presence of radionuclides like ^{137}Cs and ^{60}Co in the terrestrial environment may be conditioned by nuclear power reactors, nuclear weapon test and nuclear accident. They are part of the major contributors to the

---

*Corresponding author. E-mail:ramzishihab@yahoo.com

Author(s) agree that this article remain permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

radionuclides inventory at low-level liquid waste disposal facilities (Serne et al., 1996). The interaction of radionuclide with the constituents of soil has been recognized as one of the most important processes determining the migration of radionuclide to groundwater. Migration of Co and Cs radionuclides in soil/groundwater system is important for safety disposal radioactive waste containing of these nuclides. Investigations on the behavior of radioactive Cs and Co in soil are addressed in many publications (Xiangke et al., 1999; Hakem et al., 2000; Shihab et al., 2001; Solovitch-Vella and Garnier, 2006; Itakura et al., 2010; Seliman et al., 2010, 2012). Those publications determined some factors affecting the movement of radiocesium or/and radiocobalt in soil.

Mathematical models are integral component of radionuclide transport in soil. An accurate understanding of this transport is required to successfully formulated and use these models. Palagyi and Stamberg (2010) found that the modified convection dispersion equation (CDE) gives rather better results for transport of ^{125}I, ^{137}Cs, and ^{85}Sr in granitoidic rock and soil columns than the classical one. Limited information on the Cs and Co transport parameters such as dispersion coefficient (*D*), retardation factor (*R*), and column Peclet number (*P*) as well as distribution of these radionuclides in soil exists in the literature.

The presence of carbonate in the soil may lead to increase its sorption capacity for radionuclides from radioactive waste and thus decreases their transport. Fahad et al. (1989) had indicated that soil carbonate is an important constituent in the retaining of applied ^{137}Cs. Although, the carbonate fraction of soil plays a key role in the sorption-desorption processes, the effect of carbonate on Cs and Co transport and distribution among soil constituents are still disputable.

The main objective of present study was to investigate the background or feature of calcareous soils in association with groundwater to fit the target radionuclide waste disposal. This was done by (1) evaluating the applicability of convection-dispersion equation model in describing transport of ^{137}Cs and ^{60}Co to understand the impact of leaching with groundwater on radioactive materials disposal under static and dynamic conditions, (2) estimate the transport parameters in undisturbed soil columns, and (3) determine the association of radionuclides with soil constituents using fractionation technique.

MATERIALS AND METHODS

The soils used in this study were calcareous and alluvial loam (soil 1) and clay (soil 2). These soils were taken from two locations surrounding the site of temporary storage of the low level radioactive liquid waste (LW), (formerly, Nuclear Research Center, Iraqi Atomic Energy Commission). Its location is within 33°12′14″N 44°30′49″E. Some characteristics of the soils are given in Table 1, which determined by using standard procedure (Page et al., 1982; Klute, 1986).

Batch experiments

The distribution coefficient (*Kd*) (radionuclide sorbed on soil/radionuclide in solution) of ^{137}Cs and ^{60}Co were determined by the batch technique on samples taken from the surface soil (0-50 cm). The samples were mixed, air dried and ground to pass through a 2 mm sieve. One gram from each sample was equilibrated with the GW (EC= 6.5 dS/m, pH= 7.8 and containing of Ca=275, Mg=314, Na=1067, K=7.0, Cl=1525, SO_4=887, and HCO_3=177 mg/L), for 24 h in a 50 ml centrifuge tubes at 25°C. Borehole was drilled, penetrated the aquifer of the site, and used for obtaining samples of GW. The equilibrating solution was a carrier solution of specified radionuclides in 10:1 liquid to solid ratio. The concentration of nuclide in solution was 10^{-6} mol/L, prepared in GW taken from the aquifer of the same site, and labeled with 0.37 MBq (10 µCi/ml) of CsCl and $CoCl_2$. After equilibrium time, the mixture was then centrifuged for 15 h at 3500 rpm and a aliquot of 10 ml was pipetted from the supernatant solution. Activity of ^{137}Cs and ^{60}Co was measured in the 1 ml solution sample in 2 ml stoppered plastic vials, using a well-type NaI(Tl) detector (LKB,1282 Compugamma, Sweden). The instrument was programmed to count pulses corresponding to energy peak of 0.66 and 1.33 Mev for ^{137}Cs and ^{60}Co, respectively.

Preliminary experiments were used the two soils, two concentrations (10^{-10} and 10^{-6} mol/l), two ratios of liquid to solid (1:1 and 50:1), and four shaking times (2, 15, 24, and 48 h) to select the suitable shaking time. It was found that the sorption equilibrium was attained in 15 h for most cases (data not presented). For this reason a shaking of 15 h was adopted throughout the batch experiments. The amounts of radionuclide retained by sample were determined by subtracting the amounts of radionuclide remaining in the equilibrium solution from the amounts initially added. The Kd was calculated according to the following equation:

$$Kd = \frac{q}{c} = r\left(\frac{Ao}{r - Al}\right)/Al \tag{1}$$

Where: *Kd* = distribution coefficient (L^3 M^{-1}), q = moles of radionuclide/g soil, c = moles of radionuclide/ml liquid, r = liquid to solid ratio, Ao = total radionuclides applied (count rate), Al = radionuclide remaining in solution (count rate).

Column experiments

Undisturbed soil columns were sampled in Perspex tubes 0.5 m long and 0.05 m inner diameter. A steady state saturation water content condition in the soil columns was established before application of radionuclides (the soil columns were saturated with GW from the bottom). Each soil column was spiked with 1.48 MBq (40 µCi) for ^{137}Cs and ^{60}Co (carrier free). The soil columns then were leached with GW until ^{137}Cs and ^{60}Co until very small activity of ^{137}Cs and ^{60}Co was detected in the effluent. The GW was supplied through Marriotte technique maintaining a constant level of 2 cm throughout the leaching period, Table 2 presents physical parameters of soil columns. During the leaching process samples of effluent were daily collected by a fraction collector and measured for ^{137}Cs and ^{60}Co, using a well-type NaI(Tl) detector (LKB, 1282 Compugamma, Sweden) with aid of dual-label program. Data of ^{37}Cs and ^{60}Co from batch and column experiments were corrected for background, dead time, decay and the contribution of high energy ^{60}Co in the low energy ^{137}Cs (spill over). At the end of leaching, the soil columns were sectioned every 2 cm. Soil from each section was air dried, ground and passed through a 2.00 mm

Table 1. Some characteristics of soils.

Character	Soils	
	Soil 1	Soil 2
Textural class	loam	clay
Clay (g/kg)	256	393
Silt (g/kg)	463	303
Sand (g/kg)	281	304
ECe[a] (dS/m)	1.0	1.1
pH	7.9	7.8
Equiv.$CaCO_3$ (g/kg)	324	325
OM [b] (g/kg)	14.0	11.4
CEC[c] ($cmol^+$/kg)	13.0	23.4
Soluble ions (mg/L)		
Ca^{2+}	178	108
Mg^{2+}	31.3	31.0
Na^+	13.6	28.3
K^+	17.9	8.6
Cl^-	266	337
SO_4^{2-}	52.9	67.2
Clay minerals (%)		
Dominant 50-90	S(M)[d]	S(M), Ch
Major 20-50	Ch	HM, P
Minor 5-20	P, HM	I
Trace < 5	K, V	V, K

[a]electrical conductivity of soil pest extract, [b]organic matter, [c]cation exchange capacity, [d] S=Smectite; M=Montmorillonite; Ch=Chlorite; P= Palygorskite; HM= Hydrous Mica; I=Illite; K=Kaolinite; V=Vermiculite.

Table 2. Physical parameters of soil columns for ^{137}Cs and ^{60}Co.

Parameter	^{137}Cs		^{60}Co	
	Soil 1	Soil 2	Soil 1	Soil 2
Soil column length, L (m)	0.5	0.5	0.5	0.5
Bulk density, ρ (Mg/m^3)	1.44	1.36	1.44	1.36
Porosity (%)	45.7	48.6	45.6	48.7
Sat.vol.water content, θ (cm^3/cm^3)	0.452	0.481	0.450	0.482
Pore volume, V (cm^3)	443.0	471.4	441.0	472.4
Pore water velocity, v (cm/min)	0.023	0.027	0.022	0.028

sieve. Two grams from each section were taken to measure the activity of ^{137}Cs and ^{60}Co in the same plastic vials in the case of effluent.

Fractionation experiments

The upper 2 cm layer from each soil column was mixed thoroughly for fractionation of the remained unleached ^{137}Cs and ^{60}Co (major part of the two radionuclides had been accumulated in the upper 2 cm soil layer). Ten grams were taken and separated into the following 8 sequential fractions, water soluble, exchangeable, associated with carbonate, organic matter, Mn oxides, Fe oxides, sand, and silt+clay. The first seven fractions except for carbonate were taken following Shuman (1985). The carbonate and silt+clay fractions were taken following the procedure described by Fahad (1988). The carbonate fraction was obtained by washing the sample extracted for exchangeable form with 40 ml deionized water for 3 min and 150 ml 1.0 M NaOAc of pH 5 was added. The soil sample was shaken for 24 h centrifuged at 6000 rpm, and measured for Cs and Co. The silt+clay fraction was separated by sedimentation. The residual sample (sand + silt + clay) was treated with 10 ml of 5% sodium hexametaphosphate and 140 ml of deionized water, shaken for 24 h and sieved through 50 µm sieve to separate sand from silt+clay. The silt+clay suspension was then transferred to 1.0 L cylinder and filled to mark. Based on Stocks' law of particle sedimentation in fluids, sample of 25 ml was pipetted at depth of 10 cm at time zero for silt+clay. The same procedure of fractionation was repeated on soil samples received same activity of ^{137}Cs and ^{60}Co and incubated for the same time of leaching near saturation water content at 25±1°C. All results reported for batch, column and fractionation experiments are average of triplicate determinations expressed on a moisture free basis.

Theory of transport

The basic transport equation is called convection dispersion equation (CDE) (Skagges and Leij, 2002).

$$R\left(\frac{\partial c}{\partial t}\right) = D\left(\frac{\partial^2 c}{\partial x^2}\right) - v\left(\frac{\partial c}{\partial x}\right) \qquad (2)$$

Where R is the retardation factor, c is the volume averaged solute concentration, t is time, x is distance, and v is water velocity, approximated by ratio q/Θ, where q is the volumetric flux density and Θ is volumetric water content. Equation 2 can be solved analytically for initial boundary conditions:

$$c(0,t) = c_o \text{ and } \frac{\partial c}{\partial x}(\infty, t) = 0 \qquad (3)$$

By assuming that solute distribution inside the column is not affected by an outflow boundary or effluent collection system, and considering the column to be part of an effectively semi-infinite system. Also, by assuming that the concentration is continuous at $x=L$ (length of soil column ($0 \leq x \geq L$), the following equation can be used for solute transport in soil column in one direction for the relative concentration of effluent (c/c_o) in terms of pore volumes, V leached through the column and column Peclet number, P (van Genuchten and Wierenga, 1986):

$$\frac{c}{c_o} = \frac{1}{2} erfc[(\frac{P}{2\sqrt{RV})})^{\frac{1}{2}} (R - V)] + 1/2 \exp(P) erfc[(\frac{P}{2\sqrt{RV})})^{\frac{1}{2}} (R + V)] \qquad (4)$$

$$and \quad P = vL/D \qquad (5)$$

where c/c_o is the relative concentration and $erfc$ (x) is the complementary error function (1-erf (x)). In general D depends on pore structure, the solute velocity, and water content. The velocity dependence is often as:

$$D = \lambda v \qquad (6)$$

Where λ is the dispersivity (units of length).

Parameters determination

Experimental retardation factor (R_{exp})

R_{exp} was calculated, by using Kd values (determined from batch experiments Equation 1), from the following equation:

$$R_{\text{exp}} = 1 + (\frac{\rho Kd}{\theta}) \qquad (7)$$

where ρ is bulk density of soil column. The conditions for batch experiments were similar as possible to those of the column experiments.

Peclet number and dispersion coefficient

Breakthrough curves (BTCs) of ^{137}Cs and ^{60}Co were constructed in which the relative concentration (c/c_o) was plotted as a function of GW pore volumes (V), one pore volume equals to liquid capacity of soil column (Table 2), passed through soil columns. Estimation for P and hence for D can be obtained by matching a series of theoretical curves calculated from Equation (4) with the experimental one. If a reasonably good agreement is achieved (higher correlation coefficient, r and root mean square error (RMSE) the curve is the best fit and parameter is based on that curve (trial and error). Then D was calculated from Equation (5). Data were analyzed by Mathcad software.

RESULTS AND DISCUSSION

Figures 1 and 2 presented observed and predicted BTCs as a function of pore volumes of ^{137}Cs and ^{60}Co of the two soils, respectively. There was good agreement between experimental and theoretical curves (best fit) with significant correlation coefficient (r) greater than 0.9 in all cases studied, and the RMSE was ranged from 0.035 to 0.058. Such fairly well fit indicates the suitability of Equation (4) and (5) to evaluate the respective BTCs of ^{137}Cs and ^{60}Co and hence to estimate and determine the relative transport parameters (Table 3). However, there was some scatter in the theoretical BTCs in terms of shape and position for both solutes reflect the influence of soil characteristics, pore structure, and ion type.

The theoretical non symmetrical sigmoid shape BTCs according to Equation (4) has shown that P number has a substantial influence on both position and value of c/c_o is seen in Figure 3. By increasing the P from 1 to 20 at constant R value (R=100), the curve position is shifted to the left. The position of BTCs depends on both P and R values and the BTCs shape, and the R value depends mainly on the P value (Palagyi and Vodickova, 2009). Also, from Figures 1 and 2 it can be seen that the investigated radionuclides are readily retained, and retention depends on type of soil and their chemical properties. The values of retention at the end of leaching were about 17, 25, 6, and 14% for ^{137}Cs and ^{60}Co of soil 1 and 2, respectively. The highest retention for ^{137}Cs and in less degree for ^{60}Co resulted in high values of Kd and R.

It seems that R values of ^{137}Cs are much higher than those for ^{60}Co (Table 3). Values of R were 821 and 118 observed for Cs and 65 and 88 for Co, indicates that

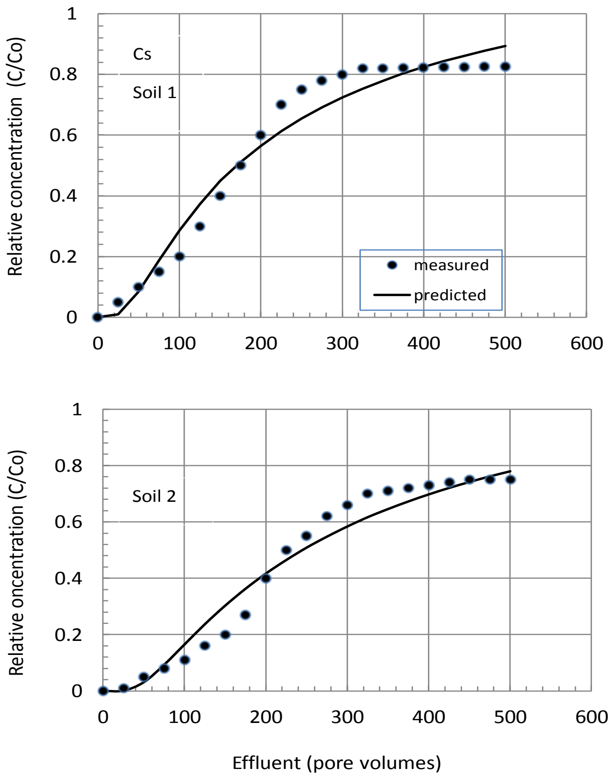

Figure 1. Experimental and theoretical breakthrough curves of ^{137}Cs retained on loam (soil 1) and clay (soil 2).

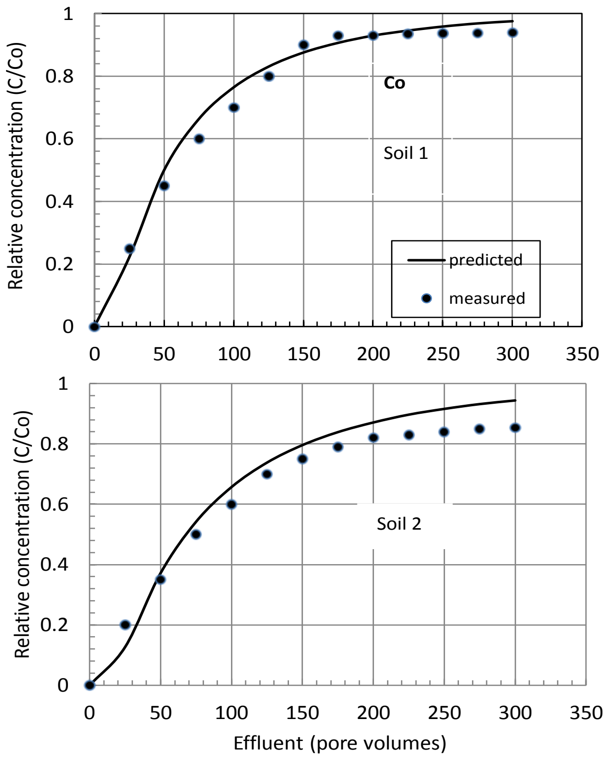

Figure 2. Experimental and theoretical breakthrough curves of ^{60}Co retained on loam (soil 1) and lay (soil 2).

^{137}Cs had been highly retarded comparison with ^{60}Co. Although nearly 500 and 300 pore volumes passed through the soil columns the amounts of Cs and Co retained were very high as indicated by the high retardation factors (*R*). The values of *R* calculated by using data obtained from batch-isotherm experiments were very representative of the observed transport of ^{137}Cs and ^{60}Co in the soil columns experiments. There is close correlation between experimental and theoretical *R* values, which only slightly differ from each other ($R_{theo.}$ was obtained by BTCs fitting as above mentioned). The retention of these radionuclides, in accordance with the values of *Kd* is increasing in the order of ^{137}Cs > ^{60}Co. The *Kd* values were 257, and 395 for ^{137}Cs and 20, and 31 ml/g for ^{60}Co for soils 1 and 2, respectively (Table 3). It is clear that the *Kd* of ^{137}Cs is about 13 order of magnitude greater than for ^{60}Co in two soils.

The height values of *R* and *Kd* for Cs compared with Co had been obtained for two soils. The silt+clay content play large effect in retention process (Table 4). Clay content and type of clay minerals can play the role of natural barrier in the radionuclides migration (Bucur et al., 2000). Clay and silt have specific sites in their structures that strongly fixed the Cs ions. Cesium has low hydration energy, and if present at the site, it will lose the hydration shell and bind to the negatively charged mineral platelets, resulting in a closing of the site thus fixation the ion (Cornell, 1983). On the contrary, Palagyi et al. (2013) reported that ^{137}Cs sorption is irreversible despite of the fact that ^{137}Cs is prone to ion exchange and practically it forms no complexes.

It is obvious that ^{60}Co showed greater mobility than ^{137}Cs (Figures 1 and 2, Table 3). The ^{60}Co has relatively low sorption affinity to clay fraction. Based on series ofstudies Co was categorized as mobile, exchangeable, or irreversible sorbed in the sand sediment and water system (Mahara and Kudo, 1981). Also, mobile of ^{60}Co was found to consist of non ionic forms which do not contribute to ion exchange absorption onto soil matrix (Hossain et al., 2012). It is well known that cobalt hydrolyzes and form an insoluble hydroxide $Co(OH)_2$ in an alkaline solution. Therefore, under the conditions of the present study the migration rate of ^{60}Co in the soil columns faster than^{137}Cs.

Radionuclides leached with GW were transported through the soil columns with mechanisms of diffusion. It moved in direction of the higher concentration to lower concentration (Bucur et al., 2006). Dispersion in soil was mainly affected by the geometry of porous structure and by the radionuclide interaction with pore walls (Haque et al., 2011). The relation between *D* and *P* (Equation (5)) is another important factor for recognizing the effect of both diffusion and dispersion on solute mixing. Although, the effects of both diffusion and dispersion on solute mixing are difficult to be separated, Fried and Combarnous (1971) suggested that when *P* is more than 20, the diffusion is at minimum value. Data in Table 3 show that *P* ranged from 0.5 to 2.0. This indicates that diffusion

Table 3. Transport parameters of ^{137}Cs and ^{60}Co in undisturbed soil columns.

Parameter	**^{137}Cs**		**^{60}Co**	
	Soil 1	**Soil 2**	**Soil 1**	**Soil 2**
Kd (ml/g)	257.5	394.9	20.2	31.1
R_{exp}	821.4	1117.6	64.4	87.7
R_{theo}	770	1200	65	88
P	0.5	0.5	2.0	2.0
D (cm^2/min)	2.1	2.8	0.6	0.7
λ (cm)	0.01	0.009	0.037	0.039
Correlation coeff., r	0.983	0.985	0.995	0.995
RMSE	0.056	0.0.53	0.035	0.058

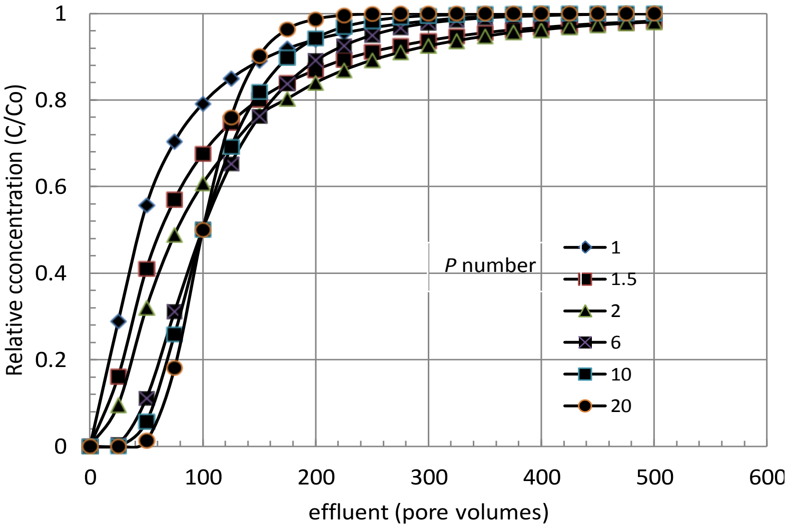

Figure 3. Effect of different values of P number on the position and shape of breakthrough curves at value of R=100.

may be the dominant process in transport of ^{137}Cs and ^{60}Co. On the other hand, D reaches values 2.1 and 2.8 cm^2/min for^{137}Cs and 0.6 and 0.7 cm^2/min for ^{60}Co for the loam and clay soils, respectively. Also, λ values were 0.01 and 0.01 cm for ^{137}Cs and 0.04 and 0.04 cm for ^{60}Co for the loam and clay soils, respectively (Table 3). Regardless soil type, the highest value of λ being for ^{60}Co and the lowest for ^{137}Cs. It is evident that the reduction in λ values attributed to high reduction in flow velocities (Table 2).

In the present study the clay content of soils 1 and 2 were 256 and 392 g/kg, respectively (Table 1). Increasing CEC will therefore increase the exchange sites. Comparison of both soils showed that soil 2 had higher CEC, whereas soil 1 had lower CEC. Since clay fraction has a high affinity for sorption of Cs and Co, soil 2 sorbed these two radionuclides higher than soil 1 (Figures 1 and 2). These results are in agreement with the reports of soil samples that contain clay minerals and resulted in large CEC for absorbing a large amount of dissolved ^{137}Cs (Kamel, 2010). When organic matter is higher, and clay minerals are not sufficient, the migration of radionuclide is higher (Dumat and Staunton, 1999; Rosen et al., 2006). This was not so in the present study, because the both soils have low organic matter (Table 1), therefore, the clay fraction plays large role in Cs and Co retention. Effect of length of soil column on travel time (tr) of ^{137}Cs and ^{60}Co are shown in Figure 4. The travel time under dynamic conditions was calculated according to the following equation:

$$tr = \left\lfloor \frac{L}{(v/R)} \right\rfloor \qquad (8)$$

Table 4. Fractionation of Cs and Co remained in the upper layer 2 cm of soil column at the end of leaching.

Soil fraction	% of total added			
	^{137}Cs		^{60}Co	
	Control	Leached soil columns	Control	Leached soil columns
	Soil 1			
Water soluble	0.3	0.3	0.3	2.3
Exchangeable	0.9	0.5	1.7	1.4
Carbonate	1.6	1.5	32.3	12.9
Organic	1.3	2.5	0.5	0.3
Mn oxides	1.0	0.9	4.5	3.0
Fe oxides	4.6	4.3	28.5	34.8
Sand	15.8	14.1	6.1	4.4
Silt+clay	74.5	75.5	26.5	41.0
	Soil 2			
Water soluble	0.2	0.3	0.4	3.7
Exchangeable	1.1	0.4	2.5	2.1
Carbonate	1.9	1.4	47.3	23.7
Organic	1.3	4.4	0.8	0.5
Mn oxides	0.2	0.1	0.7	0.5
Fe oxides	0.6	0.5	5.3	7.6
Sand	15.4	14.2	7.9	7.3
Silt+clay	79.2	78.2	35.2	54.6

The tr represents the theoretical time when the highest activity peak of ^{137}Cs and ^{60}Co appears from soil columns. Because of low GW velocities in the soil columns (Table 2), tr of radionuclides came up very long. Appearing of highest activity peak corresponding to the travel time of ^{137}Cs and ^{60}Co through the soil column, it can be said that the length of soil column affects on tr. However, differences observed in tr of both Cs and Co for a given soil are due to porous media sorption capacity, ionic strength of leaching solution, and nature of undisturbed soil columns. The values of travel time calculated by Equation (8) were 411, 1433 days for ^{137}Cs, and 100, and 112 days for ^{60}Co for loam and clay soils, respectively (Figure 4).

The above results indicate the travel time of Cs was very long compared to Co, and the presence of greater proportion of soil colloids (clay, Fe oxides, and humified organic matter) may increase tr from hundreds to thousands of years for arbitrary distance of 1000 m because ^{137}Cs are more effectively sorbed to the soil colloids. Hossain et al. (2012) found that thickness of soil layer has an effect on tr of ^{137}Cs and ^{60}Co through the soil layer. At a given column length (thickness of soil layer) ^{60}Co travel time was less comparison with ^{137}Cs. The results obtained are consistent with other results given in literature (Meier et al., 2003). This implies that in the presence of soil colloids a large reduction of nuclide travel times must be taken into account. That is the protective effect of porous media like the soil against the migration of radioactive contaminants to the biosphere can be low in the presence of colloids of soil.

Influence of Leaching with GW on fractionation of ^{137}Cs and ^{60}Co in soils

Fractionation of Cs and Co in the control samples as well as in samples of the upper 2 cm of both soils columns leached with GW is given in Table 4. For the control soils, it is clearly evident that major portion, 74 to 79% of applied Cs associated with sil+clay. The sand fraction was the second important soil constituent responsible for Cs retention. About 14% of total Cs was retained by the sand fraction in both soils. The retention percent of the Fe oxides was found to be 4.6% for soil 1 and 0.6 for soil 2. The retention percent of organic fraction was 1.3% for both soils. The rest of Cs added was bound to other fractions of soils.

The leaching increased the amount of Cs bound to organic fractions for both soils 1 and 2. Conversely, the exchangeable, carbonate, Mn oxides, and Fe oxides were found to decrease upon leaching. Comparing the fractionation data of Cs from control and soil columns leached with GW for soil 1 (256 g/kg clay) and soil 2 (392 g/kg clay) one can conclude that both soils appeared similar distribution of retaining ^{137}Cs.

The fact that the retention percent for two soils are

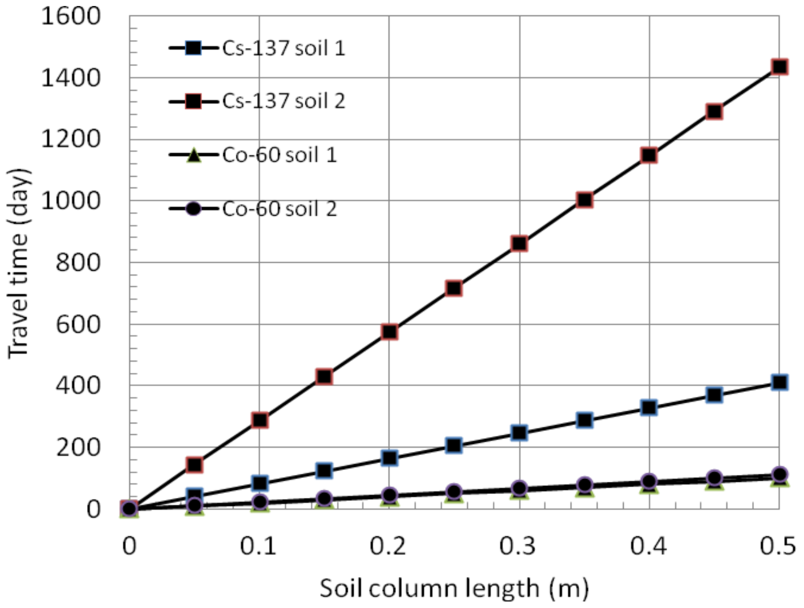

Figure 4. Travel time of ^{137}Cs and ^{60}Co as a function of distance from point of release (soil column length).

similar to each other indicates that the retention of Cs on calcareous soil is mainly determined by the composition of clay minerals. The dominant clay minerals in the two soils are montmorillonite (Table 1), since this type of clay minerals has a high affinity for sorption of Cs. Its affinity for Cs is due to very small hydration energy of the cation and higher electrostatic attraction between Cs and clay particles (Mirkhani et al., 2012). On other hand, the transport of Cs explained the limited replacing ability of the GW because the majority of applied Cs was tightly bound to silt+clay fraction. The amount of Cs released is 75 to 83% over 500 pore volumes using GW as leaching solution (Figures 1 and 2). Also, the *Kd* of Cs was high in the two soils (Table 2). This may also indicate that fixation (irreversible sorption) was the main mechanism responsible for Cs retention in the soils of montmorillonitic clay. These results are essentially consisting with the results discussed above for transport in soil columns. Bellenger and Staunton (2008) recently observed a strong irreversibility for Cs during desorption experiments from different minerals. Giannakopoulou et al. (2007) showed that clay content plays predominant role on sorption of Cs. Also, the results (Table 4) showed that for the control of both soils, carbonate retained 32 to 47% of ^{60}Co added, although substantial amounts were retained by the clay+ silt minerals, Fe oxides, and sand. Different patterns of Co distribution among soil fractions were obtained for the leached soil columns. The leaching consistently increased the amounts bound to silt+clay minerals, Fe oxides, and water soluble in both soils, whereas it either decreased the amount bound to carbonate (13 to 24%), sand, and Mn oxides fractions (in the case of soil 1) or slightly changed in the rest fractions. These results are compared with that obtained by others (Razaq et al., 1993; Kamel, 2002) for the release of ^{60}Co from the soil or from the marine sediments. The ^{60}Co radionuclide was bounded to the exchangeable and carbonate fraction. Also, similar results were reported before for Co desorption from soil constitutions (Backes et al., 1995; McLaren and Backes, 1998; Seliman et al., 2012). The amount of Co released out of both soils columns, respectively is 94 and 86% over 300 pore volumes using GW as a leaching solution (Figures 1 and 2). This indicates a smaller degree of reversibility compared to the amounts of Cs released under the same conditions. Also, this may indicates the highest ability of Co to release out of soil columns when it leached with GW compared with Cs.

The results of the present study (Table 4) showed that the substantial amounts of radionuclides especially for ^{137}Cs were retained by sand fraction. It is unexpected to observe this result since the sand is inert component and has small specific surface area. This is may be attributed to fact that sand in arid and semi-arid soils has considerable amounts of light minerals like calcite, feldspar, mica, and quartz which were responsible for Cs and Co retention. Also, the presence of Fe oxides could enhance the adsorption capacity of some minerals (Sipose et al., 2008). From the above results, one can conclude that the behavior of Co is the combined effect of diffusion and development of bound between the nuclide and adsorption sites.

The low replacing ability of GW for release the two radionuclides may due to the fact that ^{137}Cs and ^{60}Co were found to be influenced by the (i) composition of the soil, (ii) radionuclide characteristics, and (iii) presence of dissolved cations such as Ca, Mg and K in the soil – groundwater system to form coordination bonds. Some researchers attributed the slow desorption process of trace metals from soil constituents surfaces to different mechanisms such as recrystallization of metals into the mineral structure, diffusion into micropores, surface precipitation, change in the surface complex, and solid state diffusion into the crystal matrix (Glover, 2000).

The positive or negative effects on the obtained retention of ^{137}Cs and ^{60}Co data can be supposed mainly of the silt+clay, and sand content of the soil, as well as the carbonate and Fe oxides which especially in the case of ^{60}Co influence this process. Moreover, the very low concentration of tracer radionuclides and carriers, as well as the competition of major ions in the groundwater, including the isotopic exchange between the stable isotope in soil particles and radioactive isotope in the solution has to be considered in the retention of these radionuclides in soil samples (Soderlund et al., 2011).

Conclusions

The convection-dispersion equation (CDE) model allows predicting the transport of ^{137}Cs and ^{60}Co through soil. Also, CDE model provides estimates of the transport parameters of radionuclides. The transport of both radionuclides were slow in soil columns, in spite of the fact that ^{60}Co showed greater mobility than ^{137}Cs. These findings suggest that Cs and Co are strongly retained on soil fractions. The retention may be influenced by several factors, e.g., quantity and quality of clay minerals and other components of the soil. This study also showed that content of silt+clay was associated with the maximum values of *Kd*, *R*, and the minimum tr, *D,* and *P*.

Most of ^{137}Cs applied was distributed among major soil fractions followed the order silt+clay > sand > organic ≥ Fe oxides, while, ^{60}Co was distributed followed the order carbonate > silt+clay > Fe oxides > sand. Leaching however changed either the order or magnitude of fractions. This study exhibits the significance of radionuclides transport features in soil matrix through groundwater flow from the viewpoints of safety aspects of surface level disposal facility. Current risks appear to be low because such calcareous soils will tend to retain the large amount of radionuclides which might release from the burial site and reduce the potential migration of radionuclides to the environment. More thorough investigations regarding long-term is required to accurately estimate the amount of risk associated with contamination from the site.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

Author is grateful to Drs, A. A. Fahad AlTaii and H. A. Tawfeek for their assistance and useful comments.

REFERENCES

Backes CA, Mclaren RG, Rate AW (1995). Kinetics of cadmium and cobalt desorption from iron and manganese oxides. Soil Sci. Soc. Am. J. 59:778-785.http://dx.doi.org/10.2136/sssaj1995.03615995005900030021x

Bellenger JP, Staunton S (2008). Adsorption and desorption of 85Sr and 137Cs on reference minerals, with and without inorganic and organic surface coating. J. Environ. Radioact. 99:831-840.http://dx.doi.org/10.1016/j.jenvrad.2007.10.010 PMid:18295381

Bucur C, Popa A, Arsene C, Olteanu M (2000). Diffusion coefficients of critical radionuclides from radioactive waste in geological medium. Proc. WM'00 Conf., Feb. 27-Mar.2, Tucson, AZ.

Bucur C, Olteanu M, Pavelescu M (2006). Radionuclide diffusion in geological media. Rom. J. Phys. 51:469-478.

Cornell RM (1983). Adsorption of cesium on minerals: A review. J. Radioanal. Nucl. Chem. 171:483-500.http://dx.doi.org/10.1007/BF02219872

Dumat C, Staunton S (1999). Reduced adsorption of cesium on clay minerals caused by various humic substances. J. Environ. Radioact. 46:187-200. http://dx.doi.org/10.1016/S0265-931X(98)00125-8

Fahad AA (1988). Fate of zinc applied to calcareous soils using 65Zn as a tracer. 1. Fractionation with time. Arid Soil Res. Rehabil. 2:217-225. http://dx.doi.org/10.1080/15324988809381176

Fahad AA, Ali AW, Shihab RM (1989). Mobilization and fractionation of 137Cs in calcareous soils. J. Radioanal. Nucl. Chem. 130:195-201. http://dx.doi.org/10.1007/BF02037713

Fried JJ, Combarnous MA (1971). Dispersion in porous media. Adv. Hydrosci. 7:665-671.

Gianakopoulou F, Haidouti C, Chronopoulo A, Gasparatos D (2007). Sorption behavior of cesium on various soils under different pH levels. J. Haz. Mater. 149:553-556. http://dx.doi.org/10.1016/j.jhazmat.2007.06.109 PMid:17720309

Glover LJ (2000). The influence of residence time and organic acids on the desorption of trace metals from goethite. M.SC. Thesis, Fac. Virginia Polytech. Instit. State Univ. Virginia.

Haque MM, Ghose S, Islam SMA (2011). A laboratory based study on the movement of radiocesium in some columns by gamma spectrometer. J. Bangladesh Acad. Sci. 35:141-151.

Hakem NL, Al Mahamadi I, Apps JA, Moridis GJ (2000). Sorption of cesium and strontium on Hanford soil. J. Radioanal. Nucl. Chem. 246:275-278. http://dx.doi.org/10.1023/A:1006701902891

Hossain MA, Shamsuzzaman M, Ghose S, Hossain AKM (2012). Characterization of local soils and study the migration behavior of radionuclide form disposal site of LILW. J. Environ. Radioact.105:70-75. http://dx.doi.org/10.1016/j.jenvrad.2011.10.016 PMid:22230023

Itakura T, Airey DW, Leo CJ, Payne T, McOrist GD (2010). Laboratory studies of the diffusive transport of 137Cs and 60Co through potential waste repository soils. J. Environ. Radioact. 101:723-729 http://dx.doi.org/10.1016/j.jenvrad.2010.04.015 PMid:20554096

Kamel NHM (2002). The behavior of 137Cs, 60Co and 85 Sr radionuclides in marine environmental sediment. Sci. World J. 2:1514-1526. http://dx.doi.org/10.1100/tsw.2002.290 PMid:12806132

Kamel NHM (2010). Adsorption models of 137Cs radionuclide and Sr(II) on some Egyptian soils. J. Environ. Radioact. 101:297-303. http://dx.doi.org/10.1016/j.jenvrad.2010.01.001 PMid:20167404

Klute A (ed.) (1986). Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, Agron. No. 9, 2nd edition, ASA, SSSA, Madison WI, USA. PMid:12267821

Mahara Y, Kudo A (1981). Fixation and mobilization of 60Co on sediments in coastal environments. Health Phys. 41:645-655. http://dx.doi.org/10.1097/00004032-198110000-00006 PMid:7309521

McLaren RG, Backes SA (1998). Cadmium and cobalt desorption kinetics from soil clays: effect of sorption period. Soil Sci. Soc. Am. J. 62:332-337.

http://dx.doi.org/10.2136/sssaj1998.03615995006200020006x

Meier M, Zimmerhackle E, Zeitler G (2003). Modeling of colloid-associated radionuclide transport in porous groundwater aquifer of the Gorlleben site, Germany. Geochem. J. 37:325-350. http://dx.doi.org/10.2343/geochemj.37.325

Mirkhani R, Roozitalab MH, Khaleghpanah N, Majdabadi A (2012). Sorption behavior of cesium and strontium in selected soils of semiarid and arid regions of Iran. J. Radioanal Nucl. Chem. 293:587-594. http://dx.doi.org/10.1007/s10967-012-1779-x

Page AL, Miller RH, Keeny Dr (eds.) (1982). Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, Agron. No. 9, 2nd edition, ASA, SSSA, Madison WI, USA.

Palagyi S, Vodickova H (2009). Sorption and desorption of 125I-, 137Cs+, 85Sr2+ and 152,154Eu3+ on disturbed soils under dynamic flow and static batch conditions. J. Radioanal. Nucl. Chem. 280:3-14. http://dx.doi.org/10.1007/s10967-008-7436-8

Palagyi S, Stamberg K (2010). Transport of 125I-, 137Cs+,and 85Sr2+ in granitoidic rock and soil columns. J. Radioanal. Nucl. Chem. 286:309-316. http://dx.doi.org/10.1007/s10967-010-0719-x

Palagyi S, Stamberg K, Vodickova H, Herick M (2013). Sorption of 125I, 137Cs+, 85Sr2+ and 152,154Eu3+ during their transport in undisturbed vertical and horizontal soil cores under dynamic flow conditions. J. Radioanal. Nucl. Chem. 395:1447-1458. http://dx.doi.org/10.1007/s10967-012-1924-6

Razaq IB, Fahad AA, Al-Hadethi AA, Ali AW, Tawfeek HA (1993). Uptake of gamma-emmitting activation products,65Co and 65Zn by successive cropping. Basrah J. Agric. Sci. 6:47-61.

Rosen K, Shand CA, Haak E, Cheshire MV (2006). Effects of clay content and wetting-and-drying on radiocesium behavior in a peat and a peaty podzol. Sci. Total Environ. 182:117-133.

Seliman AF, Borai EH, Lasheen YF, Abo-Aly MM, DeVol TA, Bowell BA (2010). Mobility of radionuclides in soil / groundwater system: comparing the influence of EDTA and four of its degradation products. Environ. Pollut. 158:3077-3084. http://dx.doi.org/10.1016/j.envpol.2010.06.035 PMid:20656386

Seliman AF, Borai EH, Lasheen YF, DeVol TA (2012). Remobilization of 60Co, 89Sr, 137Cs, 152Eu, and 241Am from a contaminated soil column by groundwater and organic ligands. Transp. Porous Med. 93:799-813. http://dx.doi.org/10.1007/s11242-012-9983-2

Serne RJ, Felmy AR, Cantrell KJ, Krupka KM, Campbell JA, Bolton H, Fredrickson JK (1996). Characterization of radionuclides-chelating agent complexes found in low-level radioactive decontamination waste. NUREG/CR-6124, U.S. Nuclear Regularity Commission, Washington. http://dx.doi.org/10.2172/219284 PMid:8772355

Shihab RM, Fahad AA, Tawfeek HA, Al-Hassani AA (2001). Movement of radioisotopes Cs and Co in calcareous soil as affected by organic matter and moisture content. Sci. J. Iraqi Atom. Energy Comm. 3:1-9.

Shuman LM (1985). Fractionation method for soil microelements. Soil Sci. 140:11-22. http://dx.doi.org/10.1097/00010694-198507000-00003

Sipos P, Nemeth T, Kovacs Kis V, Mohai I (2008). Sorption of copper, zinc and lead on soil mineral phases. Chemosphere 73:461-469. http://dx.doi.org/10.1016/j.chemosphere.2008.06.046 PMid:18674797

Skagges TH, Leij FJ (2002). Solute transport: Theoretical background. In: Dane J and Topp C (eds.), Methods of Soil Analysis, Part 4, ASA, SSSA, Madison WI, USA.

Soderlund M, Lusa M, Lehto J, Hakanen M, Vaaramaa K, Lahdenpera AM (2011). Sorption of iodine, chlorine, technetium, and cesium in soil. Working Report 2011-04 Posiva Oy. Olkiluoto P. 130.

Solovitch-Vella N, Garnier JM (2006). Comparative kinetics desorption of 60Co, 85Sr, and 137Cs from a contaminated natural silica and columns: influence of varying physicochemical conditions and dissolved organic matter. Environ. Pollut. 141:98-106. http://dx.doi.org/10.1016/j.envpol.2005.08.012 PMid:16198464

Van Genuchten MTh, Wierenga PJ (1986). Solute dispersion coefficients and retardation factor. In: Klute A (ed.), Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, Agron. No. 9, 2nd edition, ASA, SSSA, Madison WI, USA, pp. 1025-1054.

Xiangke W, Wenmeng D, Jinzhaou D, Zuyi T (1999). Sorption and desorption of radiocesium on calcareous soil: Results from batch and column investigations. J. Radioanal. Nucl. Chem. 240:783-787. http://dx.doi.org/10.1007/BF02349852

academicJournals

Vol. 5(5), pp. 62-71, August, 2014
DOI 10.5897/JSSEM12.060
Articles Number:153C8AF47218
ISSN 1996-0816 ©2014
Copyright ©2014
Author(s) retain the copyright of this article
http://www.academicjournals.org/JSSEM

Journal of Soil Science and Environmental Management

Full Length Research Paper

Effects of three tree species on microclimate and soil amelioration in the central rift valley of Ethiopia

Agena Anjulo Tanga[1]*, Tilahun Fromssa Erenso[2] and Bekele Lemma[3]

[1]Department of Plant Science, College of Agricultural Sciences, Arba Minch University, P. O. Box: 21, Ethiopia.
[2]Ziway Soil Laboratory, Oromia Institute of Agricultural Research, Addis Ababa, Ethiopia.
[3]Wondo Genet College of Forestry and Natural Resources, Hawassa University, Ethiopia.

Received 12 July, 2012; Accepted 25 July, 2014

The effect of *Balanites aegyptiaca*, *Acacia tortilis* and *Acacia seyal* on soil fertility and microclimate was studied in the central rift valley of Ethiopia. Sampling was done in randomized complete blocks at 1/3 radius, 2/3 radius and at crown edge radius from the tree base and control was maintained at an open area. All soil and microclimatic parameters observed under the canopy distances were significantly different from the open control (P<0.05) except soil texture. Soil bulk density increased from the trees base to open field. Available Nitrogen under crown of *A. tortilis* in all crown radii was much higher than that of *B. aegyptiaca* and *A. seyal*; available Potassium was significantly higher under *B. aegyptiaca* and *A. tortilis* at their 1/3 and 2/3 crown radii. *B. aegyptiaca* at 1/3 crown radius had significantly higher level of available Phosphorus. Cation exchange capacity (CEC) was significantly higher under the 1/3 and 2/3 crown radii of all the involved trees. Soil moisture decreased whereas relative illumination, soil and below canopy temperatures showed increasing trend towards the crown periphery revealing the significant canopy cooling effect. Inclusion of higher number of these trees can reduce adverse climatic effects in the semi-arid valley and supplement organic source of nutrients.

Key words: *Acacia seyal, Acacia tortilis, Balanites aegyptiaca,* microclimate modification, soil amelioration.

INTRODUCTION

Low soil fertility is the most fundamental cause for low agricultural productivity, food insecurity, low income and poverty in Ethiopia (Abebe, 2006). Maintenance of soil quality is considered essential for ensuring sustainable land use. Hence, land resource management must aim at soil conservation (Parysow, 2001). Loss of soil quality is explained through increased bulk density, reduced inorganic matter content and availability of soil nutrients (Brenner, 1994). Agroforestry can be a viable option to alleviate the degradation and loss of soil fertility from the agricultural fields.

The central rift valley in Ethiopia is being noticed for a shift in the use of land from dense woodland with palatable pasture to a farm land with scattered trees for growing agricultural crops to feed the growing population. The system is described as agroforestry parkland where naturally regenerated and scattered individual trees occur in cultivated fields. The scattered trees provide ecological

---

[*]Corresponding author. E-mail: agenaanj@yahoo.com

Author(s) agree that this article remain permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

services such as soil fertility and microclimate amelioration (Tomlinson et al., 1995; Boffa, 1999; Bayala et al., 2002; Teklehaimanot, 2004).

Parkland agfroforestry is an important land use system that has a positive influence on maintaining soil fertility, mainly due to the tree component (Kamara and Haque, 1992; Mulongey and Merck, 1993). The effect of the tree component on soil can be seen by comparing soil properties under individual tree canopies with surrounding tree-less areas. According to Tilahun (2007), *Faidherbia albida* has shown a 50 to 100% increase in organic matter and nitrogen under the canopy. In semi-arid climates, it is common to find higher soil organic matter and nutrient content under tree canopies than in adjacent open land and cropland (Rao et al., 1998). The presence of trees on farmland adds nutrients to the soil through biological nitrogen fixation and efficient nutrient cycling (Tadesse et al., 2002). This is an inexpensive and environmentally safe organic N source that has the potential of meeting nitrogen demand, the most important and scarce agricultural nutrient element (Nair, 1984).

Trees influence microclimate and soil property through organic matter accumulation and canopy produced shade which reduces evaporation from the soil surface and modifies air temperature extremes (Hugues and Philippe, 1998). Tree roots hold soil in place and tree crown reduces the intensive force of rainfall and also acts as physical barrier in controlling runoff. The contribution of *Acacia tortilis* and *Balanites aegyptiaca* to soil fertility improvement in Afar region of Ethiopia was documented by Abule et al. (2005). The tree species (*A. tortilis, B.aegyptiaca* and *Acacia seyal*) taken up for this study, are generally considered valuable species for soil improvement and conservation (Nyberg and Högberg, 1995; Raddad and Luukkanen, 2007). Thus, the present study was initiated with the objective to assess and compare the farm trees potential in site and soil amelioration in the semi-arid environment.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Arsi Negelle district, which is located in West Arsi zone of Oromia, a regional state of Ethiopia. The district is 210 km south of Addis Ababa at 38° 30´ to 38° 40´ E and 7°25´ to 7° 40´N. It is a part of the Ethiopian central rift valley, covering an area of 1400 km^2 (Efrem et al., 2009). The topography of the area is flat to undulating. According to local climatic classification, the altitude ranges from 1610-1680m.a.s.l is categorized as dry Weyna Dega/savannah (Azene et al., 2007). The annual rainfall of the site is between 500 and 835 mm, characterized by high intensity and short duration showers occurring mainly from June to August, sometimes extending up to September. The area is known for its high temperature with little variation between dry and rainy season. The mean monthly maximum temperature is 28°C and minimum temperature is 13.8°C.

The soil is dark brown to dark greyish brown Vitric Andosol and The surface soil, as Murphy (1968) explained, is generally loose (low bulk density, friable-coarse sandy loam). Soil pH ranges from 7.3 to 8.5 (alkaline) while organic matter varies between 2.93 and 3.10%. The soil is deficient in phosphorus (< 12.4 kg ha^{-1}), and to a lesser extent, also in nitrogen (< 272 kg ha^{-1}) as indicated by FAI (1977). The vegetation of the area is classified mainly as *Acacia-Balanities* vegetation type (Nazereth, 1998) with some thorny shrubs of *A. tortilis* and *A. seyal.* Crop production is primarily rain fed and livestock rearing is the mainstay of livelihood of the local population. The major crops grown are maize, wheat, *teff* and barley under parkland agrisilviculture system.

Experimental details

Three tree species namely *B. aegyptiaca* (L.) Del., *A. tortilis* (Forsk.) and *A. seyal* (Del.) were taken.

Distances from tree base were: at 1/3 of tree crown radius; 2/3 of tree crown radius; crown edge; and open control away from canopy/tree root influence. Soil physico-chemical properties and some microclimatic changes under tree crown were then studied at 0 at 20 cm soil depth at three distances from tree base and one open control common for all the three tree species. The experiment was conducted in randomized complete blocks with three replications.

Tree selection and soil sampling

Tree selection

Nine scattered trees, three from each species were randomly selected in the blocked area based on their relative similarities in diameter at breast height (DBH) and total height. There were dissimilarity in crown diameter and crown area measured (Tables 1 and 2) for the tree species involved, hence, variables were studied at 1/3, 2/3 and crown edge of the individual trees so as to enable comparison between species.

Soil sampling

Three concentric circles were drawn under each tree crown at 1/3 crown radius, 2/3 crown radius and edge of the crown. Additionally, samples were also taken from the blocks in the open control area away from tree effect. Aiming for a representative soil samples, four sub-composites from each direction under nine trees and four distances including the open control area were collected. Hence, thirty six samples which consisted of 144 sub-composites were analysed for soil fertility.

Data collection

Data on physico-chemical properties of soil

The distribution of different particle size fractions for soil texture evaluation was determined by the modified Bouyoucos method using a hydrometer after destruction of organic matter with 30% of H_2O_2 and using 5% sodium hexametaphosphate (Calgon) as a dispersing agent (Day, 1965; Gee and Bauder, 1989). Soil bulk density (g/cm^3) was determined using the non-destructive core-volume method by dividing the weight of oven dried soil in the core (g) to the volume of the dry soil (cm^3). Soil pH was determined in water at a soil-water suspension ratio of 1:2.5 after stirring for 2 h; a reading was made using combined electrode method (Jackson, 1973). Similarly, electrical conductivity was measured from the same soil-water suspension prepared for pH determination, using a conductivity meter at 25°C (Jackson, 1973).

Table 1. Mean height, DBH, and crown area distribution of the selected *Balanites aegyptiaca, Acacia tortilis* and *Acacia seyal* tree species.

Tree species	Height (m)	Std. error	DBH (cm)	Std. error	Crown area (m^2)	Std. error
B. aegyptiaca	8.33	0.33	37.44	0.46	90.05	11.54
A. tortilis	12	0.58	39.23	0.30	236.55	17.79
A. seyal	8.35	0.43	30.89	0.55	126.65	13.61

Table 2. Mean distance in meter of crown radii of the studied tree species.

Tree species	Crown radius	Mean distance in meter	Std. error
B. aegyptica	1/3 crown radius	3.07	0.19
A. tortilis		5.01	0.20
A. seyal		3.65	0.19
B. aegyptica	2/3 crown radius	4.35	0.27
A. tortilis		7.08	0.28
A. seyal		5.17	0.27
B. aegyptica	Crown edge	5.33	0.33
A. tortilis		8.67	0.35
A. seyal		6.33	0.33

Available nitrogen was assessed by Alkaline Potassium Permanganate method by using the Kjeldhal distillation unit where the digest was distilled in the presence of sodium hydroxide and distillate trapped in 0.02N H_2SO_4. The ammonia liberated was titrated with 0.02 N NaOH to assess the available nitrogen content of the samples (Subbiah and Asija, 1956).

Available phosphorus was determined by the Olsen method in which samples were extracted with sodium bicarbonate solution at pH 8.5 and the P content in the extracted samples was determined calorimetrically after they developed the blue colour with ammonium molybdate in the presence of ascorbic acid as a reducing agent (Olsen et al., 1954).

Available potassium was measured by the Neutral Ammonium Acetate extraction method (Merwin and Peech, 1951). The extracted sample was estimated by flame-photometer. Soil organic carbon was determined by Rapid Titration method in which the organic matter was oxidised by potassium dichromate in the presence of concentrated H_2SO_4.The excess potassium dichromate was back titrated with ferrous ammonium sulphate using diphenylamine indicator (Walkley and Black, 1934).

The cation exchange capacity (CEC) of the samples was estimated by 1 M Ammonium Acetate extraction method as outlined by Reeuwijk (2002).

Modification of microclimatic conditions

Sampling and all the measurements in the microclimate of the area were carried out in the midday of the study period. Soil moisture was determined gravimetrically where the samples of fresh soil were weighed and oven-dried at 105°C for 24 h. The percentage of water present in the soil was calculated as the weight difference between field soil and oven dried soil, divided by the weight of the oven dried soil, multiplied by 100. Soil temperature was measured using a Mercury Soil Thermometer whereas below canopy temperature by using Digital Infrared Thermometer (Model AG–42). The relative illumination for the respective distances under canopy was calculated in relation to open field by using Lux meter. The data was collected for three months during the main rainy season, that is, in the months of May, June and July; reason being foliage regrowth and full crown cover is achieved during this time.

Data analysis

The data collected from laboratory analysis on soil physico-chemical properties and field observation on microclimatic changes was subjected to two way analysis of variance (ANOVA). The significant differences between means were determined by LSD at 5% probability level.

The values for microclimatic study were the averages of the daily observations at midday of the particular month.

RESULTS AND DISCUSSION

Evaluation of the tree species potential in soil amelioration

Soil texture

The difference in the treatment effects of the trees on the mean values of soil particle fractions of sand, silt and clay at different distances from the trees base at 0 to 20 cm soil layer was not significant (Table 3). As a result, the particle size distribution of the soils at the measured soil layer of all treatments was categorized under sandy loam textural class indicating no significant effect of the tree

Table 3. Particle size distribution as affected by tree species and distance from tree bole.

Species	Crown radius	Soil particle distribution			Textural class
		Sand%	Silt%	Clay%	
	1/3 crown radius	63.00	22.33	14.66	Sandy loam
B. aegyptiaca	2/3 crown radius	61.00	24.66	14.33	Sandy loam
	Crown edge	63.00	24.33	12.66	Sandy loam
	1/3 crown radius	66.33	21.00	12.66	Sandy loam
A. tortilis	2/3 crown radius	66.33	21.00	12.66	Sandy loam
	Crown edge	65.66	21.00	12.66	Sandy loam
	1/3 crown radius	60.33	23.00	16.66	Sandy loam
A. seyal	2/3 crown radius	59.66	25.00	15.33	Sandy loam
	Crown edge	59.00	24.33	16.66	Sandy loam
	Open control	63.33	22.33	13.66	Sandy loam
LSD 0.05		7.29 (NS)	6.21 (NS)	5.19 (NS)	

species involved in soil texture. The finding is in agreement with Akpo et al. (2005) who reported no significant influence of tree species on soil texture modification. Soil texture is mainly dependent on parent materials of the soil. It affects soil quality; influences the nutrient supplying ability of soil solids, soil moisture and air relations, and root development (Spur and Barnes, 1980).

Soil pH

Analysis of soil pH revealed that it was not significantly affected by the different treatment combinations of tree species and the distances from tree base (Table 4). It was observed to be slightly above neutral in all the treatments; however, in semi-arid climates such as the area under study, pH at this range is expected and normal. For the growth of the most predominant crop of the area under study which is maize, the pH value is slightly higher; yet, would not be deleterious and need gypsum application. Agbede (2008) and Hailemariam et al. (2010) reported lower pH values under *B. aegyptiaca* at Goblel and Korbebite sites from northern Ethiopia. Higher organic matter and clay content coupled with sufficient soil moisture may have led to the lower pH values.

Electrical conductivity

The maximum and significantly higher mean value of electrical conductivity was recorded under *B. eagyptica* at 1/3 and 2/3 crown radii whereas the mean values of electrical conductivity recorded under the other tree crown radii were much lower and statistically at par with the open control and one another (Table 4). The higher values at the inner and middle crown radii of *B. aegyptiaca* may be caused due to the relatively higher leaf biomass and fruit drop which upon decomposition release soluble nutrients to the soil. Hailemariam et al. (2010) also reported higher EC value under canopy than the open field of *B. aegyptiaca* at Limat site in northern Ethiopia.

Organic carbon in soil

Soil organic carbon under *A. tortilis* at 1/3 crown radius was recorded the highest; it was also statistically at par with and significantly high under tree crown of other treatments as compared to the open control area. However, *B. aegyptiaca* at the crown edge had lower value of organic carbon due to the narrower crown radius and its sparse crown edge cover which possibly yield less leaf litter at that distance (Table 4). Rao et al. (1998) argues that it is common to find higher soil organic matter and nutrient content under tree canopies than in adjacent open land and cropland in semi-arid climates. For soil under cultivation, mineralization is favoured over humification (Brinson *et* al., 1980; Toky et al., 1989). The major avenues for addition of organic matter to the soil where trees are growing, is through litter that is, leaves, twigs, branches, fruits, and so on (Quideau and Bockheim, 1996).

Available Nitrogen

Available nitrogen was significantly influenced by the combined treatments of tree species and distances where the maximum value was recorded under *A. tortilis* at 1/3 crown radius which however, was statistically at par with its mean value at 2/3 crown radius and crown

Table 4. Bulk density, pH, electrical conductivity and organic carbon as influenced by tree species and distance from tree bole.

Species	Crown radius	Bd gcm^{-3}	pH	EC (dS/m)	%OC
A. aegyptiaca	1/3 crown radius	0.94^{a}	7.68^{a}	0.13^{a}	2.49^{a}
	2/3 crown radius	1.02^{b}	7.31^{a}	0.13^{a}	1.62^{a}
	Crown edge	1.10^{b}	7.58^{a}	0.11^{b}	1.35^{b}
A. tortilis	1/3 crown radius	0.87^{a}	7.63^{a}	0.10^{b}	2.83^{a}
	2/3 crown radius	0.95^{a}	7.66^{a}	0.08^{b}	2.24^{a}
	Crown edge	1.02^{b}	7.6^{a}	0.08^{b}	2.17^{a}
A. seyal	1/3 crown radius	0.97^{a}	7.69^{a}	0.12^{b}	2.73^{a}
	2/3 crown radius	1.10^{b}	7.74^{a}	0.11^{b}	2.14^{a}
	Crown edge	1.11^{b}	7.73^{a}	0.10^{b}	2.16^{a}
	Open control	1.24^{b}	7.66^{a}	0.09^{b}	1.32^{b}
LSD $_{0.05}$		0.23	0.47(NS)	0.03	0.55

Different superscript alphabets within a column at a particular treatment represent significant difference from the control at $P < 0.05$

Table 5. Available Macronutrients and CEC as influenced by tree species and distance from tree bole.

Species	Crown radius	Soil variables			
		Av. N (kg/ha)	Av. P (kg/ha)	*Av. K (kg/ha)*	CEC (cmol Kg^{-1})
B. aegyptiaca	1/3 crown radius	159.93^{a}	14.34^{a}	211.61^{a}	34.31^{a}
	2/3 crown radius	139.02^{b}	12.63^{b}	188.26^{a}	32.69^{a}
	Crown edge	129.62^{b}	10.29^{b}	171.5^{b}	31.69^{b}
A. tortilis	1/3 crown radius	185.02^{a}	12.86^{b}	216.96^{a}	37.55^{a}
	2/3 crown radius	169.34^{a}	12.63^{b}	198.62^{a}	33.29^{a}
	Crown edge	164.11^{a}	11.41^{b}	189.09^{a}	29.75^{b}
A. seyal	1/3 crown radius	157.84^{a}	13.11^{b}	$153.96^{b,bc}$	34.65^{a}
	2/3 crown radius	139.02^{b}	11.33^{b}	$145.26^{b,bc}$	32.69^{a}
	Crown edge	137.02^{b}	11.22^{b}	136.99^{c}	28.56^{b}
	Open control	111.15^{b}	9.06^{b}	106.38^{d}	23.83^{c}
LSD $_{0.05}$		33.35	4.32	29.21	5.03

Different superscript alphabets within a column at a particular treatment represent significant difference from the control at $P < 0.05$

edge, *B. aegyptiaca* and *A. seyal* at their 1/3 crown radius (Table 5). The lowest value of available nitrogen was recorded at the open control which was preceded but statistically alike to the values under *B. aegyptiaca* and *A. seyal* at their 2/3 crown radius and crown edge. Despite the higher contribution of the tree species in available nitrogen content, the observed values in both the soil layers were categorized as “low fertility class” as per the ratings of FAI (1977). Total nitrogen and the mineral nitrogen flux had progressive decrease from the trunk to the canopy margin under the tree of *Acacia Senegal, B. aegyptiaca and Adansonia digitata* in semi-arid zones of northern Senegal (Young, 1989). Higher soil nitrogen content under tree canopies than away from tree influence was reported for all distances and soil depths under *F. albida*, *B. aegyptaica* and *Cordia africana* (Kamara and Haque, 1992; Akpo et al., 2005; Abebe Yadessa et al., 2009).

Available Phosphorus

Significantly higher amount of available phosphorus was recorded under *B. aegyptiaca* at 1/3 crown radius, which was followed by statistically different values under *A. seyal* and *A. tortilis* at their 1/3 crown radius. On the other hand, minimum value of available phosphorus was recorded at the open control away from tree influence which however, was statistically same to the values in the rest of the trees distance treatments (Table 5). Higher level of available phosphorus at the closest distance to the tree base can be ascribed to organic phosphorus input from leaf litter deposition and release at mineralization, higher microbial population stimulated by organic matter input which supported phosphorus solubilisation from fixation. However, the observed values near the tree base for available phosphorus put the soil under category of “medium fertility class” (FAI, 1977). The soil in the open control away from tree influence is deficient in available P content is in agreement with the findings of Fikru (1998). Soil phosphorus concentration decreased as the distance increased from the bole to the outside of the canopy (Kamara and Haque, 1992).

Available Potassium

The analysis indicated that the mean value of available potassium content was significantly higher under *A. tortilis* at 1/3 crown radius, which was followed by statistically same values under *B. aegyptiaca* at 1/3 and 2/3 0crown radii; and *A. tortilis* at all crown distances (Table 5). Lowest available potassium content was recorded at the open control which was preceded by the value under *A. seyal* at the crown edge (Table 5). The observed values under the trees’ crown radii for available potassium are in the medium range (FAI, 1977). In soil amelioration study, high total nitrogen and potassium concentration was observed under canopy of *Parkia biglobosa* (Jacq.) Benth. in West Africa (Tomlinson et al., 1995). The reason behind the high concentration of available potassium under canopy than the open area might be high organic matter accumulation, decomposition and release in the soil (Brady and Weil, 2002).

Cation exchange capacity

The treatment combinations involving tree species and distances from tree base have significantly influenced the mean values of cation exchange capacity of the soil. Cation exchange capacity (CEC) was maximum (37.55 cmol kg^{-1}) under *A. tortilis* at 1/3 crown radius which however, was statistically similar to the mean values at its 2/3 crown radius; *B. aegyptiaca* and *A. seyal* at 1/2 and 2/3 crown radii. The minimum value of 23.83 cmol kg^{-1} cation exchange capacity was recorded at the open control which was preceded, but statistically similar to the values under *A. tortilis* and *A. seyal* at their crown edge (Table 5). Soil with CEC values above 25 cmol kg^{-1} is commonly taken as having a good nutrient holding capacity. The results depict the trees’ influence with added organic matter to attain higher CEC values at their inner crown radii. Similar findings by Taddese et al. (2002) state the concentration of CEC under canopy of *Millettia ferruginea* to be higher than the open field in south Ethiopia. In the middle awash rift valley of Ethiopia, concentration of CEC under canopy of *Prosopis juliflora* was higher as compared to the open area with no clear difference in soil layers (Ameha, 2006).

Tree species relative effect on microclimate during the main cropping season

Soil moisture

Soil moisture is one of the factors that hinder crop success in the semi-arid rift valley. The valley has history of several crop failures due to erratic rains. Under canopy of the studied tree species it appeared to be significantly higher than the open control. The highest soil moisture recorded in the month of May was 11.3% under *B aegyptiaca* at the 1/3 crown radius which increased to 12.87% in June (Figure 1). Then due to the denser canopy cover, *A. tortilis* took over the maximum in July which was recorded 18.99%. The differences in soil moisture from the maximum at 1/3 crown radius of the tree species over the open control were 4.13, 4.55 and 7.87% in May, June and July respectively. The soil moisture, from the beginning of the first month of cropping season to the second and third month increased under each tree species. The reasons for this change were increased rainfall, decreased evapotranspiration and increased relative humidity in the valley. Similarly, Kessler (1992) reported that improved availability of water under tree canopies was due to decrease in actual evapotranspiration as well as better water infiltration. On the other hand, Akpo et al. (2005) observed that soil moisture under shade was not significantly different under *A. tortilis* and *B. aegyptiaca*, suggesting that there was no species effect on soil moisture content.

Soil temperature

The tree species had cooling effect with their aboveground influence on the soil under crown cover. The lowest temperature recorded was 30°C under *B. aegyptiaca* at 1/3 crown radius in the month of May. Later on it decreased under 1/3 canopy radius of *A. tortilis* to 28 and 25°C in the month of June and July respectively. About 6.11, 4.44 and 6.0°C reduction in soil temperature was achieved (Figure 2) over the maximum at the open control in May, June and July respectively. In a similar microclimate modification study, Lin (2007) observed that the amount of shade cover is directly related to the

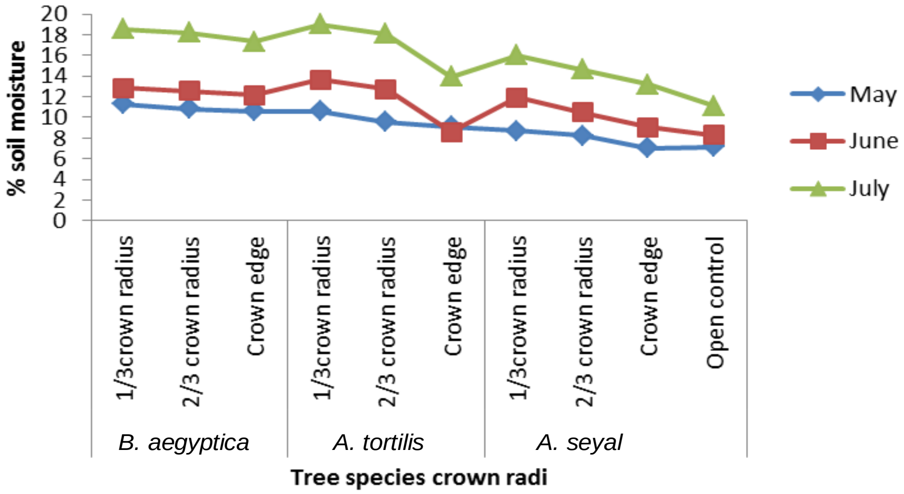

Figure 1. Soil moisture as influenced by tree species and distance away from tree base.

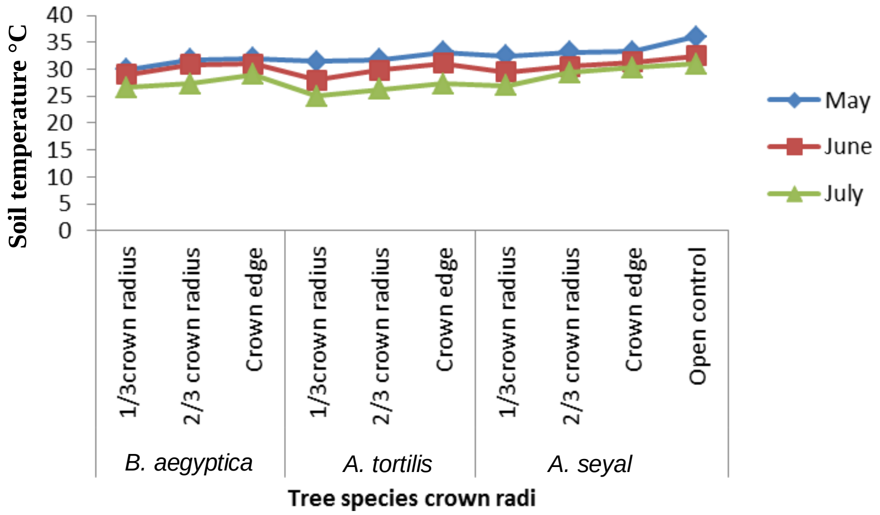

Figure 2. Soil temperature in °C as influenced by tree species and distance from tree base.

mitigation of variability in microclimate for the crop of interest. The use of agroforestry systems is an economically feasible way to protect crop plants from extremes in microclimate and should be considered a potential adaptive strategy for farmers in areas that will suffer from extremes in climate.

Below-canopy temperature

In the month of May erratic rains stimulated the regrowth of new flush leaves on the trees thereby influencing the below canopy temperature of the trees. *B. aegyptiaca* do not shed all the leaves in the dry season and moreover it develops edible fruits of pecan nut size during the dry season. Therefore, *A. tortilis* and *B. aegyptiaca* had significantly lower below canopy temperature in the studied months over the open control. Accordingly, mean temperature reductions over the open control during May, June and July were 6.3, 6.7 and 7.3°C at 2/3 crown radius of *A. tortilis*, 1/3 crown radius of *B. aegyptiaca* and 1/3 crown radius of *A. tortilis* respectively (Figure 3). However, below canopy temperatures at crown edge of *B. aegyptiaca*, at 2/3 crown radius and crown edge of *A. seyal* were statistically same to the open control. Narrower were the below canopy temperature differences at middle and peripheral distances of *A. seyal* to that of the open control. From the data, it is evident that *A. tortilis* is superior in reducing below canopy temperature at its nearest and middle canopy distances as compared

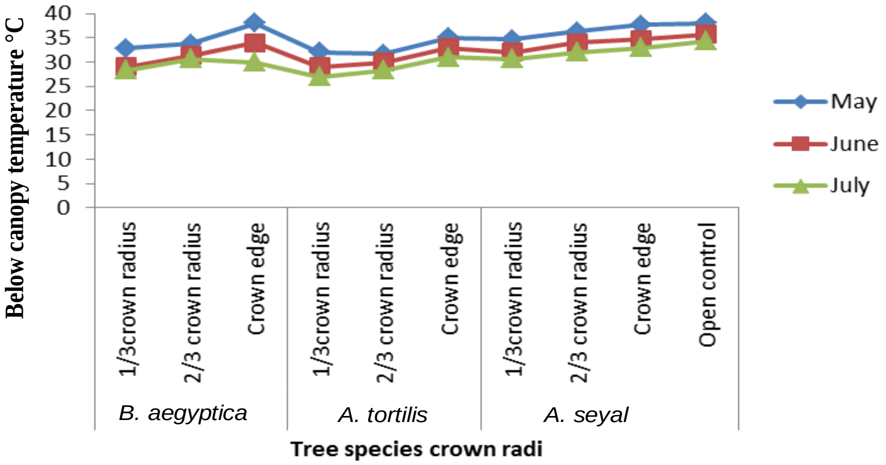

Figure 3. Below canopy temperature in °C as influenced by tree species and distance from tree base.

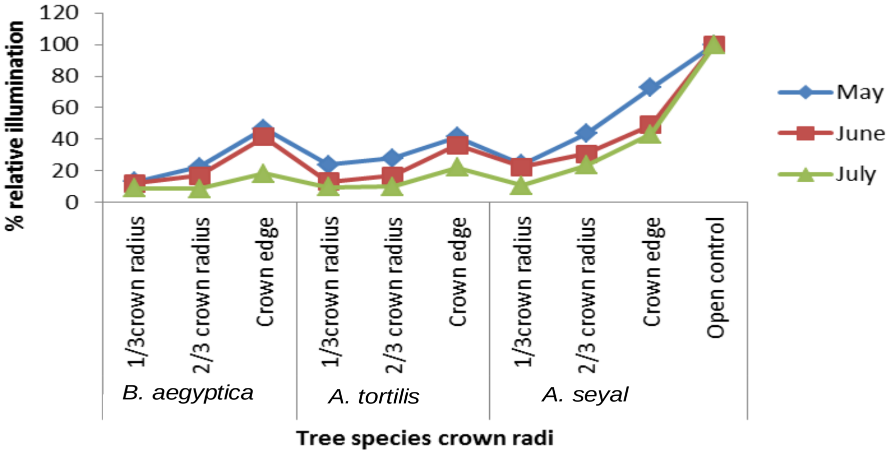

Figure 4. Percent relative illumination as influenced by tree species and distance from tree base.

to the other tree species. Akpo et al. (2005) recorded mean difference of 5°C between the shaded, that is, 1 m away from the tree trunk and in the open, that is, 16m away from trunk areas in the midday. The authors interestingly noted that early in the morning temperature under the shade was higher than in the open by about 1.5°C. The results indicated that trees reduce below canopy temperature fluctuations by decreasing the maxima and increasing the minima.

Percent relative illumination

The tree canopies during the month of May had transmitted much of the light received from the sun. When the deciduous trees regrow new leaves stimulated by the first rains, the canopy started to cover reducing the light transmission ratio in the following months. Relative illumination followed decreasing trend from May through June to July. In all the studied months, light transmission was the lowest through the crown of *B. aegyptiaca* at the 1/3 crown radius followed by *A. tortilis*. Percent relative illumination received at 1/3 crown radius under *B. aegyptiaca* was reduced by 86% in May, 87.9% in June and 91.44% in July over the open area. However, much higher intensity of relative illumination was received at the middle and peripheral distances of the trees species under study (Figure 4). Trees and shrubs may reduce solar radiation under canopies by 45 to 60% in the Sahelian zone and 85 to 95% in the Sudan savannah. The transmission of direct solar radiation through tree canopies at midday differed a little across species, that is, *A. tortilis* 21.3%, *B. aegyptiaca* 16.8% and *Ziziphus Mauritania* 20.1% (Akpo et al., 2005).

Conclusion

From the findings of the study of the effect of the trees on soil and microclimate, it can be concluded that (i) the tree species studied had no effect on soil texture; (ii) there is an improvement in the physical properties of the soil and also an increase in the content of plant available nutrients in the soil below tree canopies. *A. tortilis* contribute much higher level of available N than that of *B. aegyptiaca* and *A. seyal* in all crown radii; however, it was found to be in lower range to satisfy growth of associated crops and requires inorganic amendments. Available K was significantly higher under *B. aegyptiaca* and *A. tortilis*. *B. aegyptiaca* at 1/3 crown radius had significantly higher and superior level of available phosphorus. Similarly, CEC was significantly higher under the 1/3 and 2/3 crown radii of all the involved trees than in the open field. (iii) There is favourable effect on the microclimate as shown by a reduction in relative illumination, soil and below canopy temperatures as well as higher level of soil moisture below tree canopies; (iv) The semi-arid rift valley demands higher tree density than it currently has, to have broader area canopy cover to avert crop failure and ensure crop success, reduce livestock heat stress and improve food security in the region.

Conflict of Interest

The authors have not declared any conflict of interests.

REFERENCES

Abebe N (2006). Soil fertility status under indigenous tree canopies on farmland in selected areas of Eastern and Western Hararghe zone. M.Sc. Thesis, Haramya University, Ethiopia.

Abebe Y, Fisseha I, Olsson M (2009). Scattered trees as modifiers of agricultural landscapes: the role of Waddeessa (*Cordia africana* Lam.) trees in Bako area, Oromia, Ethiopia. Afr. J. Ecol. 47:78-83. http://dx.doi.org/10.1111/j.1365-2028.2008.01053.x

Abule E, Smit GN, Snyman HA (2005). The influence of woody plants and livestock grazing on grass species composition, yield and soil nutrients in the Middle Awash valley of Ethiopia. J. Arid Environ. 60:343-358. http://dx.doi.org/10.1016/j.jaridenv.2004.04.006.

Agbede OO (2008). Soil husbandry: Life for national food security and economic empowerment. An inaugural delivered on March 19th, 2008 at Nasarawa State University, Keffi, Nigeria.

Akpo LE, Goudiaby VA, Grouzis M, Houerou HN (2005). Tree shade effects on soil and environmental factors in a Savanna of Senegal. West Afr. J. Appl. Ecol. 7:41-52.

Ameha T (2006). Impact of Prosopis juliflora (SW.DC.): Invasion of plant biodiversity and soil properties in the middle Awash, rift valley, Ethiopia. M.Sc. Thesis, Hawassa University, Ethiopia.

Azene B, Ensermu K, Sebsibe D, Maundu P, Tegnas B (2007). Useful trees and shrubs in Ethiopia. Identification and management for 17 agro climatic zones. World Agroforestry Centre, Eastern Africa Region, Nairobi, Kenya.

Bayala J, Teklehaimanot Z, Ouedraogo SJ (2002). Millet production under pruned tree crowns in a parkland system in Burkina Faso. Agroforest. Syst. 54:203–214. http://dx.doi.org/10.1023/A:1016058906682

Boffa JM (1999). Agroforestry parklands in sub-Saharan Africa. FAO Conservation Guide. Rome. 34:230.

Brady NC, Weil RR (2002). The nature and properties of soils, 13th Ed. Prentice-Hall Inc., New Jersey, USA. P. 960.

Brenner T (1994). Accelerated soil erosion in watersheds of Yunnan province, China. J. Soil. Water Conserv. 1(49):67-68.

Brinson M, Bradshaw HD, Holmes RN, Elkins JB (1980). Litter fall, stem flow and through fall nutrient fluxes in an alluvial swamp forest. Ecology 61:827-835. http://dx.doi.org/10.2307/1936753

Day PR (1965). Hydrometre method of particle size analysis. In: methods of soil analysis (Black CA ed.) American Society of Agronomy, Madison, Wisconsin.

Efrem G, Sandewall M, Soderberg U, Campbell BM (2009). Land-use and land-cover dynamics in the central rift valley of Ethiopia. Environ. Manage. 44:683-694. http://dx.doi.org/10.1007/s00267-009-9355-zPMid:19688359

FAI (1977). Hand book of fertilizer usage. Fertilizer Association of India, New Delhi, India.

Tilahun G (2007). Soil fertility status as influenced by different land uses in Maybar areas of South Wollo zone, North Ethiopia. MSc. Thesis. Haramaya University, Ethiopia.

Gee GW, Bauder JW (1986). Particle size analysis. In: methods of soil analysis. Part 1, (2nd ed). (Klute A ed.). Agron. Monogr. 9, ASA and SSSA Madison, WI. pp. 383-411.

Hailemariam K, Kindeya G, Charles Y (2010). Balanites aegyptiaca, a potential tree for parkland agrofrorestry systems with sorghum in Northern Ethiopia. J. Soil Sci. Environ. Manage. 1(6):107-114.

Hugues D, Philippe DL (1998). Trees and multi-storey agriculture in Africa, Brussels, Belgium.

Jackson ML (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi. P. 498.

Kamara CS, Haque I (1992). Faidherbia albida and its effects on Ethiopian highland vertisoils. Agroforest. Syst. 18:17-29. http://dx.doi.org/10.1007/BF00114814

Kessler JJ (1992). The influence of Karite (*Vitellaria paradox*) and Nere (Parkia biglobosa) trees on sorghum production in Burkina Faso. Agroforest. Syst. 17:97-134.http://dx.doi.org/10.1007/BF00053116

Lin BB (2007). Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agricul. Forest Meteorol. 144:85–94. http://dx.doi.org/10.1016/j.agrformet.2006.12.009

Merwin HD, Peech M (1951). Exchangeability of soil potassium in sand, silt and clay fraction as influenced by the nature of complementary exchangeable cations. Soil Sci. Soc. Am. Proc. 15:125-128. http://dx.doi.org/10.2136/sssaj1951.036159950015000C0026x

Mulongey K, Merck R (1993). Soil organic matter dynamics and sustainability of tropical agriculture. John Wiley and Sons, Inc., New York, P. 392.

Murphy HF (1968). A report on the fertility status and other data on soils of Ethiopia. Experimental Bulletin Haile Sellassie I university, Dire Dawa. 44:294-297.

Nair PKR (1984). Soil productivity aspects of agroforestry. International Centre for Research in Agroforestry, Nairobi, Kenya. P. 85.

Nazereth F (1998). Study of farmers species preference and evaluation of some fuel wood qualities. A case study in Abijata Shalla national park in Arsi-Negelle district, Ethiopia. M.Sc. Thesis, SLU, Sweden.

Nyberg G, Högberg P (1995). Effects of young agroforestry trees on soils in on-farm situations in Western Kenya. Agroforest. Syst. 32:45–52. http://dx.doi.org/10.1007/BF00713847

Olsen SR, Cole CV, Watanabe FS, Dean LA (1954). Estimation of available phosphorus in soil by extraction with $NaHCO_3$; U.S. Department of agriculture circular, U.S. Government Printing Office, Washington, D.C. P. 939.

Parysow ET (2001). Assessing uncertainty of erodibility factors in national cooperative soil surveys: A case study at Fort Hood, Texas. J. Soil. Water Conserv. 56(3):207-208.

Quideau SA, Bockheim JG (1996). Vegetation and cropping effects on pedogenic processes in a sandy prairie soil. Soil Sci. Soc. Am, 60:536-545. http://dx.doi.org/10.2136/sssaj1996.03615995006000020028x

Raddad EY, Luukkanen O (2007). The influence of different Acacia Senegal agroforestry systems on soil water and crop yields in clay soils of the Blue Nile region. Agric. Water Manage. 87:61-72. http://dx.doi.org/10.1016/j.agwat.2006.06.001.

Rao MR, Nair PKR, Ong CK (1998). Biophysical interactions in tropical agroforestry. Agroforest. Syst. 38:3–50. http://dx.doi.org/10.1023/A:1005971525590

Reeuwijk LPV (2002). Procedures for soil analysis. 6th edition. Technical paper/international soil reference and information centre, Wageningen, The Netherlands.

Spur SH, Barnes BV (1980). Forest ecology (3rd ed). John Wiley and Sons. P. 679.

Subbiah BV, Asija GL (1956). Rapid procedure for the estimation of available nitrogen in soil. Current Sci. 25:259-260.

Tadesse H, Lemma N, Olsson M (2002). *Millettia ferruginea* from southern Ethiopia: Impacts on soil fertility and growth of maize. Agroforest. Syst. 48:9-24.

Teklehaimanot Z (2004). Exploiting the potential of indigenous agroforestry trees: *Parkia biglobosa* and *Vitellaria paradoxa* in sub-Saharan Africa. Agroforest. Syst. 61:207-220. http://dx.doi.org/10.1023/B:AGFO.0000029000.22293.d1

Toky OP, Kumar P, Khosla PK 1(989). Structure and function of traditional agroforestry systems in the Western Himalayan.II. Nutrient Cycling Agroforest. Syst. 9:71-89.

Tomlinson H, Teklehaimanot Zewuge, Traore A, Olapade E (1995). Soil amelioration and root symbioses of *Parkia biglobosa* (Jacq.) Benth. in West Africa. Agroforest. Syst. 30:145 159. http://dx.doi.org/10.1007/BF00708918

Walkley AJ, Black IA (1934). Estimation of soil organic carbon by chromic acid titration method. Soil Sci. 37:29-38.http://dx.doi.org/10.1097/00010694-193401000-00003

Young A (1989). Agroforestry for soil conservation, CAB International, Netherlands.

Journal of Soil Science and Environmental Management

Related Journals Published by Academic Journals

- *Journal of Plant Breeding and Crop Science*
- *African Journal of Agricultural Research*
- *Journal of Horticulture and Forestry*
- *International Journal of Livestock Production*
- *International Journal of Fisheries and Aquaculture*
- *Journal of Cereals and Oilseeds*
- *Journal of Soil Science and Environmental Management*
- *Journal of Stored Products and Postharvest Research*

academicJournals