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Effects of Area Closure on Selected Soil Physico-Chemical Properties in Hidabu Abote istrict, !orth She"a #one, $romia

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Abstract: =his stud4 w-s conducted -t sire moresse -re- closure0 7id-bu -bote district0 %orth shew- >one0 *romi- . egion-l $t-te to e5-lu-te the e22ects o2 -re- closure on selected ph4sic-chemic-l properties o2 soils. #n this stud4 -re-closure sites were comp-red with -dj-cent open gr->ing l-nd in simil-r l-ndsc-pe positions 2or soil 2ertilit4 buildup. $oil s-mples were collected 2rom the e?periment-l 2ields using . -ndomi>ed / omplete 3loc@ 6esign (. / 3 6) with 2-ctori-l -rr-ngement to e5-lu-te selected soil ph4sico- chemic-l properties. 6-t- -n-l4ses were c-rried out using -n-l4sis o2 5-ri-nce -ppropri-te to gener-l line-r model (AB :). , tot-l o2 & undisturbed -nd & disturbed soil s-mples were collected 2rom both closed -nd open gr->ing l-nd -t 10 -nd 20 cm s-mpling depths -long e-ch slope position with three replic-tion. =he result o2 the stud4 indic-ted th-t the me-n 5-lue o2 most o2 soil ph4sic-l -nd chemic-l properties were higher -t re-closure th-n -dj-cent open gr->ing l-nd -nd -lso higher -t bottom slope position th-n middl-

-nd l-nd m-n-gement D11E. / on5ersion o2 n-tur-l l-ndsc-pes into culti5-ted -nd gr->ing s4stems c-use -n -brupt decline in soil org-nic m-tter -nd reduces the nutrient content o2 soil through reduced litter production0 incre-se erosion r-tes -nd decomposition o2 org-nic m-tter b4 o?id-tion D1&E. 8nm-n-ged li5estoc@ o5ergr->ing o2 gr-ss l-nd is one o2 the most import-nt 2-ctors th-t results in gr-ss l-nd degr-d-tion0 soil erosion -nd nutrient losses D55E.

$oil degr-d-tion is - term th-t encomp-sses processes in5ol5ing the degr-d-tion o2 soil ph4sic-l0 biologic-l -nd chemic-l ch-r-cteristics -nd/or conditions -nd soils -re - 5it-l n-tur-l resource th-t is not c-p-ble o2 being renewed on the hum-n time sc-le D&0E. #t is - li5ing -nd d4n-mic n-tur-l bod4 th-t pl-4s m-n4 @e4 roles in terrestri-l ecos4stems0 2or inst-nce0 -s sources o2 -5-il-ble nutrients to pl-nts0 m-inten-nces in h4drologic-l st-bilit4 -nd biologic-l di5ersit4. 6egr-d-tion o2 soil Cu-lit4 is m-ni2ested through w-ter -nd wind erosion0 org-nic m-tter -nd nutrient depletion0 soil comp-ction0 soil -cidit40 -nd decre-sed microbi-l -cti5it4 D9E. $ust-ining soil -nd en5ironment-l 2e-tures -re the most e22ecti5e methods 2or ensuring su22icient 2ood suppl4 to support li2e0 reduce soil degr-d-tion -nd impro5e soil he-lth D50E.

#n 1thiopi-0 onl4 25F o2 the l-nd reh-bilit-tion t-rgets in terms o2 re2orest-tion e22orts -nd soil conser5-tion schemes h-5e been -ccomplished -nd most o2 the ph4sic-l soil conser5-tion me-sures -nd communit4 2orest pl-nt-tions were destro4ed D!E. =o comb-t these se5ere resource degr-d-tion problems n-tion-l le5el en5ironment-l conser5-tion -nd reh-bilit-tion e22orts were st-rted b4 the Ao5ernment o2 1thiopi- (Ao1)0 since 19"0s0 h-s supported rur-l l-nd reh-bilit-tion through w-tershed de5elopment -ppro-ch; -nd m-n-gement h-s mo5ed 2rom - 2ocus on ph4sic-l $G/ to the integr-tion o2 soci-l0 economic0 -nd en5ironment-l de5elopment D&9E.

#n this reg-rd0 the pr-ctice o2 est-blishing -re- closures h-s emerged -s - promising pr-ctice in di22erent p-rts o2 1thiopi-0 n-mel4 in =igr-4 D!0E0 -nd Gelo -nd $hew- D51E.

, re- closures -re -re-s selected 2or n-tur-l regener-tion o2 the n-ti5e 2lor- -s - me-ns o2 l-nd recl-m-tion through protection o2 the -re-s 2rom hum-n -nd -nim-l inter2erence D5E -nd #t reduce nutrient loss 2rom - site b4 controlling runo22 (5eget-tion -cting -s - ph4sic-l b-rrier to soil erosion)0 this e5entu-ll4 impro5es the c-p-bilit4 o2 the l-nd to support di5erse pl-nt species0 including e?otic pl-nt-tions D&"E. $ince the objecti5e o2 most -re- closures is 2or site reh-bilit-tion0 the4 were usu-ll4 est-blished in steep0 eroded -nd degr-ded -re-s used 2or gr->ing -nd crop production in the p-st D50 19E.

, ccording to the reports 2rom c-se studies conducted on closure in the centr-l -nd northern highl-nds o2 1thiopi-; -re- closure h-d twice the pl-nt species richness -nd di5ersit4 5-lue comp-red with commun-l gr->ing l-nds -2ter 22 4e-rs o2 closure est-blishment D52E -nd -n incre-se in soil org-nic m-tter o2 1.1F -nd tot-l % o2 0.1F -2ter 10 4e-rs o2 closure est-blishment D&50 & E. , lso0 - consider-ble decre-se in soil loss w-s reported -2ter the est-blishment o2 -re- closure on commun-l gr->ing l-nds D150 220 2!E reported th-t the soil ph4sic-l properties (soil te?ture0 soil moisture content0 soil bul@ densit4 -nd w-ter holding c-p-cit4) -re shows signi2ic-nt ch-nges under closure th-n opened l-nd (control) ones. , re- / losures -lso reduce nutrient loss 2rom - site b4 controlling runo22 (5eget-tion -cting -s - ph4sic-l b-rrier to soil erosion) D52E.

6ue to o5ergr->ing0 the n-tur-l 5eget-tion in the northern highl-nds o2 1thiopi- h-s 5irtu-ll4 dis-ppe-red0 le-5ing degr-ded commun-l gr->ing l-nds with irregul-rl4 sp-ced trees -nd shrubs -nd 5-st -re-s o2 b-re l-nds de5oid o2 5eget-tion D E.

: ost o2 the commun-l l-nds in %orth $hew- ; one o2 *romi- . egion0 p-rticul-rl4 7id-bu , bote 6istrict -re degr-ded -nd unproducti5e due to the deterior-tion o2 the ph4sic-l0 chemic-l0 -nd biologic-l properties o2 the soil0 m-inl4 due to -cceler-ted r-te o2 soil erosion -nd poor m-n-gement pr-ctices D!&E. , lthough the restor-tion ecolog4 -nd bu22ering e22ect o2 closed -re-s h-5e been well studied D20 1!E0 there -re rel-ti5el4 2ew studies in the countr40 which would pro5ide - me-sure o2 the e22ect o2 -re- closure -s one str-teg4 to help pre5ent decline o2 soil 2ertilit4 -nd impro5ing soil Cu-lit4.

+urthermore0 there -re no enough Cu-ntit-ti5e studies th-t -n-l4>e the imp-ct o2 -re- closure on soil ph4sic-l -nd chemic-l properties in the countr40 p-rticul-rl4 in this stud4 -re-.

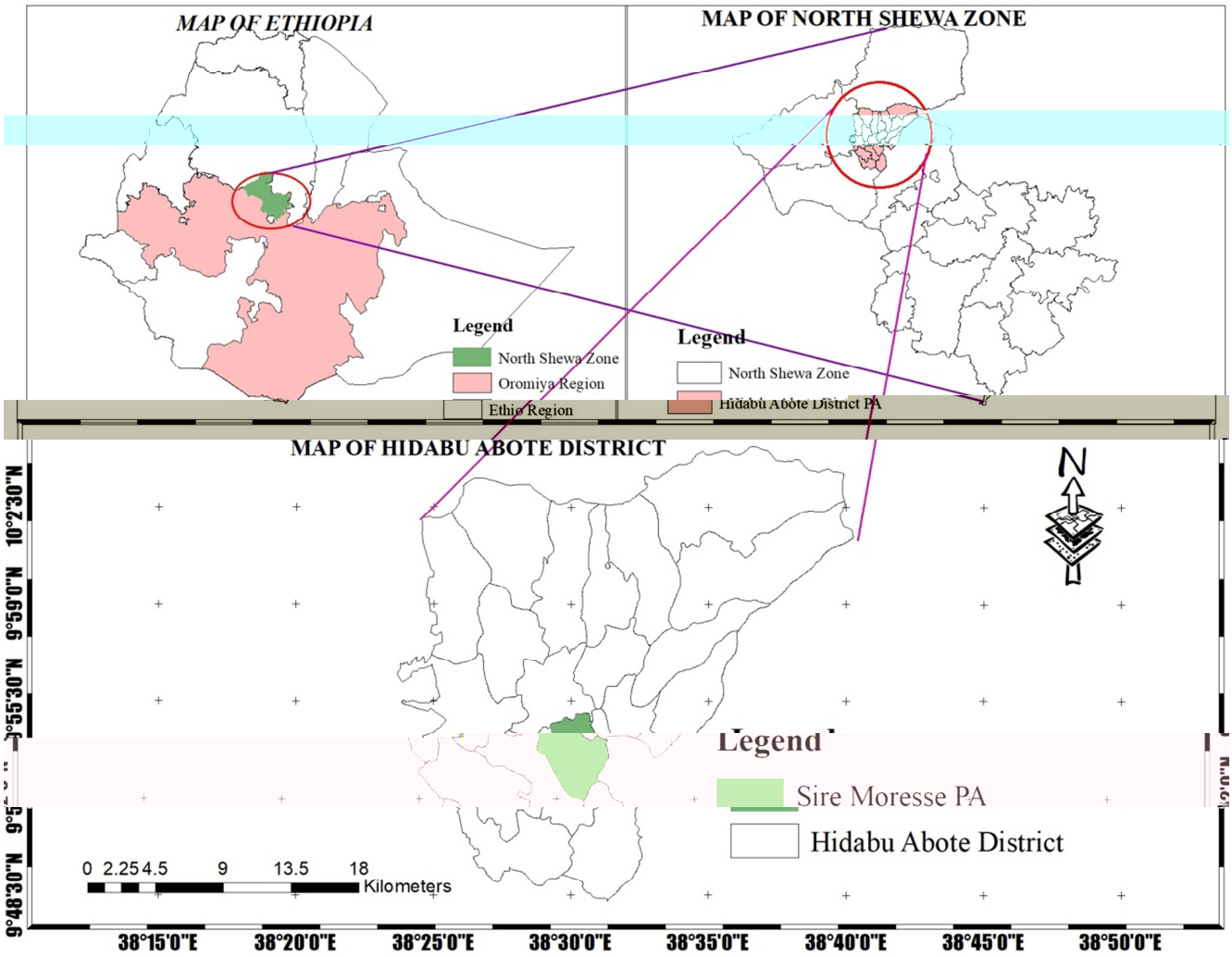
=here2ore0 this stud4 w-s initi-ted in the light o2 -ssess the possible e22ects o2 -re- closure comp-red to -dj-cent open gr->ing l-nd on selected soil ph4sic-l -nd chemic-l properties in the stud4 -re-.

2. Materials and Methods

=he stud4 -re- is situ-ted in *romi- . egion-l $t-te o2 1thiopi- -t %orth $hew- ; one0 7id-bu , bote district. Aeogr-phic-ll40 it lies between 9H!"I&0II% -nd 10H!J!0JJ% l-titude -nd &"H2!I0II1 -nd &"H!0I12II 1 longitude (2igure 1). #t is -t -bout 1!2 @m in north o2 , ddis , b-b-0 the c-pit-l o2 1thiopi- -nd &0 @m 2rom +itche town0 the ; on-l c-pit-l.

, 5er-ge -nnu-l temper-ture 5-ries 2rom 1& to 2&H/0 while the -nnu-l r-in2-ll 5-ries between 1500 -nd 1'00 mm. =he -ltitude o2 the stud4 -re- r-nges 2rom 11 0 to 2!00 m -bo5e se- le5el -nd the district di5ided into three tr-dition-l m-jor -gro-clim-tic >ones K*baddaa*J -gro-clim-tic >one (high l-nd); K*badda Daree*J -gro-clim-tic >one (intermedi-te ele5-tion); K*Gammojjii*J -gro-clim-tic >one (low l-nd) D!&E. =he -re- is ch-r-cteri>ed b4 undul-ting0 rugged -nd hill4 topogr-ph4. : i?ed -griculture is the m-jor economic -cti5it4 -nd =e220 3-rle40 7-ricot 3e-n0 Ghe-t0 $orghum -nd : -i>e -re the m-jor crops grown in the district D!&E. , ccording to the d-t- obt-ined 2rom the 6istrict , gricultur-l *22ice D!&E0 the m-jor l-nd use t4pes in the district include Ar->ing l-nd sh-red -bout '.5F while communit40 st-te -nd n-tur-l 2orests -nd

bush l-nd ".1F0 12.5F degr-ded l-nd -nd =he rem-ining '1.9F w-s ,gricultur-l l-nd -nd others. =he m-jor 5eget-tion t4pes o2 the stud4 -re- -re ch-r-cteri>ed b4 -c-ci-woodl-nd which includes species such -s ,. -b4ssinic-0 ,. -lbid-0 ,. se4-l0 ,. tortilis0 etc.)0 : oreo5er0 other tree species li@e 3-l-nites -eg4pti-c-0 /ombretum molle0 /roton m-crost-ch4us0 6odon-e- -ngusti2oli-0 1r4thrin- -b4ssinic-0 *Cordia africana,* -nd *Eucalyptus* species -re grown.



Map of the Study area.

=he e?periments were l-id down in .-ndomi>ed /omplete 3loc@ 6esign (./36) with 2-ctori-l -rr-ngement. =he e?periment-l plots cont-ining e-ch l-nd use t4pes (-re-closure -nd open gr->ing l-nd -s control) were replic-ted three times in the selected l-nd use t4pes which were s4stem-tic-ll4 loc-ted -cross the slope position. ,ltogether (& replic-tion ? & slope position ? 2 B-nd use t4pe ? 2 s-mpling depthsN& s-mpling plots) were est-blished.

$oil s-mples were collected 2rom both l-nd use t4pe (-re-closure -nd open gr->ing l-nd) -t three slope position n-mel4 upper0 middle -nd bottom slope position with three replic-tion. ,t e-ch s-mpling loc-tions0 /omposite soil s-mples were collected 2rom 10 cm -nd 20 cm depths 2rom 2our corners -nd center o2 - plot o2 10mO10m si>e using -n P)Q s-mpling design D&1E unless soil depth w-s limited either b4 stoniness or bedroc@. =he disturbed s-mples were collected using -uger where-s soil core s-mpler w-s used to collect the undisturbed s-mples. Aener-ll40 tot-l o2 & undisturbed -nd & disturbed soil s-mples were collected 2rom e-ch s-mpling loc-tion -nd depths.

8ndisturbed soil s-mples were used 2or determin-tion o2 bul@ densit40 soil moisture content0 tot-l porosit40 -ir-2illed porosit4 -nd s-tur-ted h4dr-ulic conducti5it4. (rior the me-surement0 e?cess soil w-s c-re2ull4 remo5ed b4 sp-tul-in 2ield to remo5e e?cess soil -nd stored in 2ridge -t 2H/. =he disturbed soil s-mples were used 2or the -n-l4sis o2 soil te?ture -nd soil chemic-l properties. /omposite soil s-mples were t-gged0 mi?ed well0 -ir dried0 ground0 sie5ed with 2 mm sie5e -nd 2urther sie5ed to p-ss through 0.5 mm si>e sie5e 2or the -n-l4sis o2 tot-l nitrogen content o2 the soil -nd the s-mples were -n-l4>ed 2ollowing st-nd-rd procedures -t %-tion-l $oil =esting B-bor-tor40 ,ddis ,b-b-0 1thiopi-. =he cores s-mplers were co5ered with n4lon cloth 2rom the

bottom0 -nd s-tur-ted step-wise with c-pill-r4 w-ter 2rom bene-th. =hen0 the s-mples were used 2or me-surement o2 s-tur-ted h4dr-ulic conducti5it4 (Rs-t) using const-nt he-d method -s described in D2"E. =he me-surements o2 -5er-ge 5-lue o2 w-ter disch-rge (S) (unit: $mm^{&} hr^{-1}$) collected -2ter it re-ched ste-d4 st-te0 soil length (B) DmmE0 cross-section-l -re- o2 the soil s-mple (,) Dunit: mm^2E0 -nd h4dr-ulic he-d (7) DmmE0 were used to determine the Rs-t (mm hr^{-1}) using 6-rc4Js eCu-tion0 which is gi5en b4:

$$K_{sat} = \frac{QL}{AtH}$$

$oil 3ul@ 6ensit4 w-s determined b4 using the core method b4 2ollowed procedure -s described in D!2E0 which in5ol5ed weighing o5en dried s-mple (-t 105H / 2or 2! hours) -nd di5ided the 5-lue to the 5olume o2 core. $oil moisture content w-s determined gr-5imetric-ll4 -nd con5erted to 5olumetric b-sis b4 multipl4ing it with bul@ densit4 o2 soil b4 using core s-mple method. =ot-l porosit4 (=()0 w-s determined 2rom bul@ densit4 -nd p-rticle densit4 -nd , ir 2illed porosit4 w-s c-lcul-ted 2rom tot-l porosit4 -nd 5olumetric w-ter content. =he determin-tion o2 soil p-rticle si>e proportions were c-rried out b4 h4drometer method suggested b4 D! E. $oil re-ction (soil p7) w-s determined b4 - 1:2.5 soil: w-ter r-tio using - p7 meter -s described b4 D5!E. 1lectric-l conducti5it4 w-s determined in w-ter suspension with soil to w-ter r-tio 1:2.5 b4 / onducti5it4 meter D!5E. =he soil org-nic c-rbon ($* /) concentr-tion w-s determined b4 using G-l@le4 -nd 3l-c@ r-pid titr-tion method -s described in D! E. $oil org-nic m-tter ($* :) w-s determined b4 multipl4ing percent org-nic c-rbon b4 1.'2! D2 E. =ot-l nitrogen (=%) w-s determined b4 the modi2ied Rjeld-hl methods -s modi2ied b4 D! E. =he -5-il-ble phosphorus (,5. () content w-s determined using *lsen e?tr-ction method -s described b4 D5!E. $-mples were digested -nd titr-ted -g-inst 0.01% 7 / l -nd ,5-il-ble pot-ssium (,5.R) w-s -n-l4>ed using 2l-me photometer D12E. =he c-tion e?ch-nge c-p-cit4 (/ 1 /) w-s determined b4 using -mmonium -cet-te method D! E.

$t-tistic-l -n-l4sis w-s per2ormed to test the imp-ct o2 -re- closure on selected soil ph4sic-l -nd chemic-l properties using -n-l4sis o2 5-ri-nce (, %* <,) -ppropri-te to gener-l line-r model (AB :). B$6 (Be-st $igni2ic-nt 6i22erence) test -t (T 0.05 w-s used 2or me-n sep-r-tion utili>ing . $o2tw-re progr-m. . egression -n-l4sis w-s used to rel-te soil ph4sic-l properties.

3. Results and Discussion

=he results shows th-t there w-s - slight 5-ri-tion in soil te?ture me-n 5-lue -t both s-mpling depths between tre-tments -cross -ll slope position but st-tistic-ll4 there w-s insigni2ic-nt di22erence -t pU0.05 between tre-tments (=-ble 1). #n contr-st0 there w-s signi2ic-nt di22erence -t pU0.05 -cross slope position -t 10 cm s-mpling depth. #t is belie5ed th-t m-n-gement pr-ctices gener-ll4 do not -lter the te?tur-l cl-ss o2 - soil on - 2ield sc-le within short period o2 time. 3ut m-n-gement pr-ctices h-5e indirect roles in doing so. (edologic processes such -s erosion0 deposition0 illu5i-tion -nd we-thering which -re sh-ped b4 m-n-gement pr-ctices c-n -lter the te?ture o2 soils D"E. 8nder conditions o2 low 5eget-tion co5er0 -s in the open gr->ing l-nd c-se0 cl-4 2r-ctions -re li@el4 to be lost through processes o2 selecti5e erosion -nd migr-tion down the soil pro2ile which ultim-tel4 incre-se the proportion o2 s-nd -nd silt contents in sur2-ce soils. , ccording to D!'E0 soil erosion -nd selecti5e remo5-l o2 soil p-rticles do -22ect the p-rticle si>es.

Effects of Area closure on soil texture.

Soil depth (cm)	Soil parameter	Treatments		Slope position difference			Treatments * Slope position difference
		Closed	Open	Bottom	Middle	Upper	
	=e?ture						
10	$-nd (F)	&5.5 -	&9.11-	2 -	!0. '-	!5.&&b	%$
	$ilt (F)	29.5 -	&0.5 -	&0-	2'-	&1. '-	%$
	/l-4 (F)	& ."9-	29.&&-	!!-	&2.&&-	2&b	%$
	=e?ture						
20	$-nd (F)	&!."9-	!2.!!-	&1-	&&. '-	!9.&&-	%$
	$ilt (F)	25.5 -	&1.11-	2". '-	29.&&-	2'-	%$
	/l-4 (F)	&9.5 -	2 .!!-	!0.&&-	&5-	2&. '-	%$

: e-ns with s-me letter in e-ch row -re not st-tistic-ll4 signi2ic-nt -t (U0.050 %$Nnot signi2ic-nt. /omp-risons 2or tre-tments -nd slope position di22erence were done sep-r-tel4. =re-tment9 slope position di22erence re2ers to the inter-ction between tre-tment -nd slope position di22erence.

*ther (h4sic-l properties o2 soils0 collected 2rom two tre-tments -t three slope position -long with the inter-ction e22ect o2 tre-tments -nd slope position di22erence0 -re shown in =-ble 2.

Effects of Area closure on selected soil physical properties.

Soil depth (cm)	Soil parameter	Treatments		slope position difference			Treatments * Slope position difference
		Closed	Open	Bottom	Middle	Upper	
10	3 6 (g/cm&)	1.22&-	1.&'5b	1.25'-	1.&1"b	1.&22c	%$
	Vw (cm&/cm&)	0.!0-	0.&!1b	0.!1-	0.&9!-	0.&1b	%$
	, +((cm&/cm&)	0.1&9b	0.1!1-	0.11'-	0.11-	0.19b	%$
	Rs-t (mm/hr)	5". 1"-	!'. 25-	5!.9&-	5&.1&-	51.&1-	%$
20	3 6 (g/cm&)	1.22!-	1.&'9-	1.291-	1.2''b	1.&&'c	%$
	Vw (cm&/cm&)	0.!12-	0.&&'b	0.!0-	0.&95b	0.&2-	%$
	, +((cm&/cm&)	0.12 -	0.1!&-	0.11-	0.12&-	0.1'2-	%$
	Rs-t (mm/hr)	55.9!'-	!".1'!b	55.1&c	5!.'1b	! .&!-	%$

: e-ns with s-me letter in e-ch row -re not st-tistic-ll4 signi2ic-nt -t (U0.050 %$Nnot signi2ic-nt. / omp-risons 2or tre-tments -nd slope position di22erence were done sep-r-tel4. =re-tment9 slope position di22erence re2ers to the inter-ction between tre-tment -nd slope position di22erence.

=he result o2 the stud4 showed th-t -dj-cent *pen gr->ing l-nd plots h-d st-tistic-ll4 signi2ic-nt higher me-n 5-lue o2 bul@ densit4 th-n -re- closure plots (=-ble 2)0 which c-n be -ttributed to tr-mpling e22ect 2rom the li5estoc@ popul-tion -nd direct imp-ct o2 r-indrops on the -re-. *5ergr->ing led to the degr-d-tion o2 5eget-tion0 soil comp-ction0 -nd wind -nd w-ter erosion. 6uring s-mpling0 soil crusting -nd se-ling in the open l-nds w-s obser5ed0 which w-s resulted 2rom l-c@ o2 5eget-tion co5er which in turn incre-se bul@ densit4. =he result o2 this stud4 -grees with the 2inding o2 D'E who reported th-t higher soil bul@ densit4 under open gr->ing l-nd th-n -re- closure.

: e-sured bul@ densit4 h-d showed st-tistic-ll4 signi2ic-nt di22erence -t (U0.05 le5els -mong slope position di22erence -t both s-mpling depths. =he me-n 5-lue o2 bul@ densit4 w-s highest 2or upper slope position0 lowest 2or bottom slope -nd with intermedi-te 5-lue -t middle slope position (=-ble 2). =his lowest bul@ densit4 -t the bottom slope position might be resulted 2rom the l-nd slope which resulted in decre-ses runo22 speed -nd thereb4 enh-nced sediment-tion -nd org-nic m-tter de5elopment. 3etter root -bund-nce0 5eget-tion st-nd0 5eget-tion production -nd pl-nt residues were obser5ed -t bottom slope position o2 the l-nd comp-red to its upper slope position. D5'E -lso pointed out th-t soil bul@ densit4 h-s - direct rel-tion with slope gr-dient which might be -ttributed to the corresponding decline in soil org-nic c-rbon content with the incre-se in slope gr-dient/steepness.

<olumetric moisture content o2 the soil -t s-mpling showed - st-tistic-ll4 signi2ic-nt di22erence between tre-ted -nd untre-ted l-nd -nd -lso -mong slope position -t both depths. =he l-rger numeric-l 5-lues o2 5olumetric moisture content were -ssoci-ted with high org-nic m-tter content o2 -re- closure th-n 5-lues obser5ed in -dj-cent open gr->ing l-nd soils. $imil-r 2indings were reported pre5iousl4. +or inst-nce0 D2'E indic-ted higher soil moisture content through impro5ements in soil structure in -re- under -re- closure th-n open gr->ing l-nds. #t is -lso -n est-blished 2-ct th-t the incre-sing org-nic m-tter incre-ses the w-ter holding c-p-cit4 o2 soils D"E. =he men 5-lues o2 5olumetric moisture content o2 soil were highest -t the bottom slope position with intermedi-te 5-lue -t the middle -nd lowest -t the upper slope position 2or both s-mpling depths (=-ble 2).

, ir 2illed porosit4 w-s higher in open gr->ing th-n -re- closure l-nd -t both s-mpling depths (=-ble 2). =his might be due to more pore sp-ce o2 soil w-s 2illed b4 w-ter in the soil o2 -re- closure. =he me-n o2 -ir 2illed porosit4 w-s highest -t upper0 intermedi-te -t the middle -nd lowest -t bottom slope position -t both s-mpling depths (=-ble 2). =his lower -ir 2illed porosit4 -t bottom slope position o2 the l-nd e?pl-ined th-t high moisture content o2 deposited soil -t the bottom o2 slope position. #n gener-l the obser5ed -ir 2illed porosit4 o2 this soil w-s higher th-n the 5-lue -ssumed -s critic-l 5-lue 2or pl-nt growth b4 D1"E0 which is 10F.

=he me-n 5-lue o2 s-tur-ted h4dr-ulic conducti5it4 in the closed -re- w-s higher th-n open gr->ing l-nd -t both s-mpling depths (=-ble 2). =his might be due to high porosit4 -nd org-nic m-tter content -t tre-ted l-nd -nd -lso open gr->ing l-nd soil might be comp-cted b4 li5estoc@. D&2E h-5e shown th-t the decre-se in soil porosit4 in the comp-cted -re-s0 2ollowing li5estoc@ tr-mpling o2 soil0 w-s strongl4 correl-ted with -n incre-se o2 soil penetr-tion resist-nce -nd - decre-se in h4dr-ulic conducti5it4. $oil comp-ction ch-nges the -bilit4 o2 soil s-tur-ted 74dr-ulic conducti5it4 -nd incre-ses penetr-tion resist-nce D!"E. =his stud4 -lso con2irmed with the stud4 o2 D&E who reported th-t s-tur-ted h4dr-ulic conducti5it4 is rel-ted to soil structure. =he h4dr-ulic conducti5it4 is ob5iousl4 higher in -ggreg-ted soil th-n tightl4 p-c@ed soil -s in the c-se o2 open gr->ing l-nd0 which is e?posed to -nim-l tr-mpling. 74dr-ulic conducti5it4 is -lso depends on the si>e o2 conducting pores th-n tot-l porosit4 o2 the soil.

=he soil s-tur-ted h4dr-ulic conducti5it4 (Rs-t) did not show signi2ic-nt 5-ri-tion -t pU0.05 in the stud4 -re- -mong slope position di22erence. =he me-n 5-lue o2 s-tur-ted h4dr-ulic conducti5it4 w-s highest -t bottom p-rt o2 the slope position -t both s-mpling depths (=-ble 2). =his might be due to higher org-nic m-tter content -t bottom slope position -s - result w-ter erosion which remo5es 2ertile soil 2rom the upper p-rt o2 slope position. #n this stud4 there w-s no signi2ic-nt inter-ction e22ect between tre-tments -nd slope position 2or -ll ph4sic-l soil p-r-meters -t both s-mpling depths (=-ble 2).

#n gener-l0 in contr-st with the r-pid onset o2 d-m-ge0 n-tur-l reco5er4 o2 soil structure -nd post d-m-ge regener-tion is - slow process th-t m-4 t-@e 4e-rs to dec-des D1'E. =hough this est-blished 2-ct0 -re- closure0 in the stud4 -re-0 en-bled the soil to undergone 2-st reco5er4 2rom perturb-tion through n-tur-l process. D1 E h-s discussed -

number o2 Kn-tur-lJ processes0 which pl-4 import-nt roles in restor-tion o2 soil structure such -s: swelling-shrin@-ge beh-5ior o2 soil go5erned b4 wetting -nd dr4ing0 root proli2er-tion0 -nd e-rthworm perturb-tion. #n this stud4 -re-0 n-tur-l regener-tion process w-s m-inl4 domin-ted b4 root proli2er-tion -nd e-rthworm -cti5ities. D10E obser5ed th-t e-rthworms -re import-nt -gents 2or n-tur-l restor-tion o2 degr-ded soils.

. esults o2 chemic-l properties o2 soil under both m-n-gement s4stems -re shown in =-ble &.

Effects of Area closure on selected soil chemical properties.

Soil depth (cm)	Soil parameter	Treatments		Slope position difference			Treatments * Slope position difference
		Closed	Open	Bottom	Middle	Upper	
	(7	.25-	.0&&-	5.9"-	.2"-	.1 '-	%$
	1/ (ds/m)	0.1 9-	0.091b	0.205b	0.12-	0.0'-	%$
	=% (F)	0.210-	0.1'2b	0.2 -	0.1"&b	0.12'-	%$
10	*/ (F)	2.5'&-	2.1 &b	&.22-	2.& -	1.5&-	%$
	,5.((ppm)	.25-	!. "b	'.'9-	.0!b	2.5'b	%$
	,5.R (mg/@g)	20-	11. '-	&0."&-	12.5-	!.1'-	%$
	/1/ (/mol/@g)	2'.&5-	2'.2-	&2.2"-	2'.&2-	22.21-	%$
	(7	.25 -	.0 'b	5.9&-	.&-	.25-	%$
	1/ (ds/m)	0.1&"-	0.0'&-	0.1"-	0.0"b	0.0 b	%$
	=% (F)	0.1"2-	0.1'b	0.2!-	0.1 -	0.1&-	%$
20	*/ (F)	1."00-	1.' -	2.&2-	1.'&-	1.2"-	%$
	,5.((ppm)	'.!52-	'.29b	12.9&-	."5-	2.&&-	%$
	,5.R (mg/@g)	2".&&-	2'.22-	!5.00-	2'.50-	10."&b	%$
	/1/ (/mol/@g)	2 .9!-	2&.& -	&1."&-	2!.'2-	1".90-	%$

: e-ns with s-me letter in e-ch row -re not st-tistic-ll4 signi2ic-nt -t (U0.050 %$Nnot signi2ic-nt. /omp-risons 2or tre-tments -nd slope position di22erence were done sep-r-tel4. =re-tment9 slope position di22erence re2ers to the inter-ction between tre-tments -nd slope position di22erence.

$oil o2 the -re- showed no signi2ic-nt 5-ri-tion p7 me-n 5-lue between -re- closure -nd open gr->ing l-nd use t4pe. $imil-rl40 the result showed th-t there w-s no signi2ic-nt di22erence in me-n p7 5-lues between the soils o2 the open gr->ing l-nd -nd the -re- closure l-nd -t pU0.05 signi2ic-nt le5el -t 10 cm s-mpling depths but signi2ic-ntl4 di22erence -t 20 cm depths (=-ble &).

=he rel-ti5el4 lower p7 5-lues on the open gr->ing l-nds could be -ssoci-ted with loss o2 b-sic c-tions through erosion -nd le-ching -s well -s low ground co5er in the open gr->ing plots th-n the -re- closure ones. ,ccording to the cl-ssi2ic-tion r-nges suggested b4 D2 E p7 5-lues recorded in the soil studied in -re- closure -nd -dj-cent open gr->ing l-nd were c-tegori>ed under the slightl4 -cidic re-ction.

=he me-n 5-lues o2 electric-l conducti5it4 were st-tistic-ll4 signi2ic-nt di22erence -t pU0.05 between open gr->ing l-nd -nd the -re- closures -t 10 cm s-mpling depth -nd there w-s no signi2ic-nt di22erence -t 20 cm s-mpling depths (=-ble &).

=ot-l nitrogen (=%) contents were st-tistic-ll4 signi2ic-nt di22erence -t pU0.05 between -re- closure -nd open gr->ing l-nd -t both s-mpling depths. =he -re- closure l-nd h-d higher =ot-l nitrogen -s comp-red to open gr->ing l-nd 2or both s-mpling depths (=-ble &). =he higher tot-l nitrogen content in the -re- closure is might be the result o2 higher soil org-nic m-tter content -nd the presence o2 leguminous pl-nts which h-5e the c-p-cit4 to 2i? nitrogen 2rom the -tmosphere through the rootsJ nodules. =his 2inding is in -greement with the 2inding b4 D1E0 who reported th-t there w-s signi2ic-nt di22erence on =ot-l nitrogen between the open gr->ing l-nd -nd -re- closure. D&!E 1?pl-ined th-t tot-l nitrogen is higher in -re- closure l-nd use t4pe th-n open gr->ing l-nd use t4pe. Ghere-s0 soils under open gr->ing l-nd h-5e lower tot-l nitrogen due to continuous o5ergr->ing th-t results in the remo5-l o2 gr-sses -nd org-nic m-tter 2rom the soil.

*rg-nic c-rbon w-s rel-ti5el4 signi2ic-nt di22erence -t pU0.05 between -re- closure -nd open gr->ing l-nd -t 10 cm s-mpling depths but not -t 20 cm s-mpling depths. =he me-n 5-lue o2 org-nic c-rbon w-s higher in -re- closure plots th-n th-t o2 open gr->ing plots -t both s-mpling depths (=-ble &). =his could be -ttributed to the presence o2 signi2ic-ntl4 higher org-nic m-tter -s - result o2 m-n-gement pr-ctices. =he results -grees with the 2indings o2 D!!E who obser5ed incre-sed org-nic c-rbon in the -re- closure l-nd use t4pe -s comp-red to the open gr->ing l-nd use t4pe. D21E $howed th-t the lower content o2 $oil *rg-nic /-rbon under open gr-ssl-nd m-4 be due to reduced org-nic m-tter input bec-use o2 uncontrolled gr->ing -nd browsing. D5&E mentioned th-t soil org-nic c-rbon 5-lues -re t4pic-ll4 low in the 1thiopi-n highl-nds -s - conseCuence o2 stubble gr->ing -nd the -bsence o2 2-llowing. , re- closure l-nd use t4pe h-s

content might be due to const-nt remo5-l o2 soluble phosphorous 2rom root >one b4 pl-nt roots -nd elu5i-tions -nd sur2-ce tr-nsport through erosion.

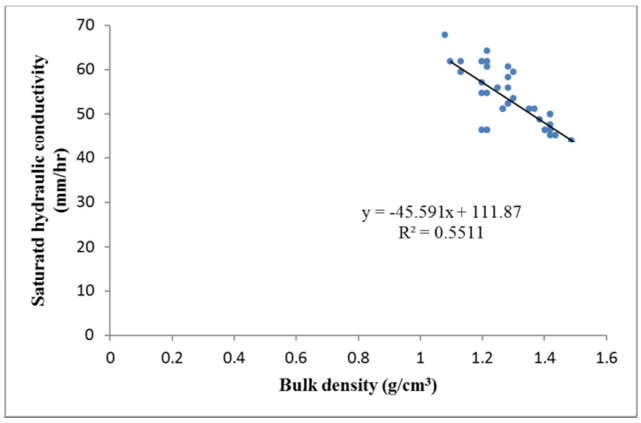
=he -5-il-ble (ot-ssium 5-lues were st-tistic-ll4 insigni2ic-ntl4 di22erent -t pU0.05 between -re- closures -nd open gr->ing l-nd use t4pe -t both s-mpling depths (=-ble &). =he me-n 5-lues o2 -5-il-ble pot-ssium 5-lues o2 -re-closure w-s higher th-n open gr->ing l-nd. =his is prob-bl4 due to the selecti5e remo5-l o2 this 5it-l m-cronutrient 2rom open gr->ing l-nd b4 -cceler-ted erosion. 3ec-use o2 its high mobilit4 in the soil0 pot-ssium is most susceptible to le-ching losses D&&E0 which might be the re-son 2or the decline o2 this 5it-l m-cronutrient in open gr->ing l-nd use t4pe. =here2ore0 prob-bl4 the higher soil le-ching r-tes in the gr->ing l-nd c-used lower pot-ssium content.

=he result o2 /-tion 1?ch-nge /-p-cit4 shows th-t there were st-tistic-ll4 insigni2ic-nt di22erence -t pU0.05 between the two tre-tments (open gr->ing -s control -nd the 1 4e-rs closed -re-) -t both s-mpling depths. =he me-n 5-lue o2 /-tion 1?ch-nge /-p-cit4 under closed -re- w-s higher th-n the -dj-cent open gr->ing l-nd -t both s-mpling depth (=-ble &). =his 2inding is in -gree with the stud4 b4 D5 E who reported th-t -s c-tion e?ch-nge c-p-cit4 (/1/) w-s signi2ic-ntl4 higher in closed -re-s th-n in -dj-cent open l-nds. =he higher /-tion 1?ch-nge /-p-cit4 in closed -re-s comp-red to th-t o2 -dj-cent open l-nd c-n be due to the presence o2 di22erence in org-nic m-tter -nd cl-4 content between the l-nd use t4pes. #t is -pp-rent th-t /1/ content positi5el4 correl-tes with org-nic m-tter content -nd soil org-nic c-rbon D"E.

#n gener-l the result o2 p70 */0 ,5(0 ,5R -nd /1/ shows th-t there were st-tistic-ll4 insigni2ic-nt di22erence -t pU0.05 -mong slope position di22erence in 10 cm s-mpling depth where -s the result o2 1/ -nd =% shows th-t there were signi2ic-nt di22erence -mong slope position di22erence -t 10 cm s-mpling depth -nd -lso =he result o2 1/ -nd ,5R shows th-t there were signi2ic-nt di22erence -mong slope position di22erence in 20 cm s-mpling depths but the result o2 p70 =%0 */0 ,5(-nd /1/ shows there were st-tistic-ll4 insigni2ic-nt di22erence -t pU0.05 -mong slope position di22erence in 20 cm s-mpling depths (=-ble &). #n -ll c-ses0 the me-n 5-lues were highest -t bottom slope position di22erence e?cept 2or p7 -t both s-mpling depths (=-ble &). =his might be due to the w-shing -w-4 o2 the 2ertile soil 2rom the upper p-rt o2 the l-nd settling -t bottom p-rt o2 the l-nd. ,s the l-nd slope decre-ses runo22 speed -lso decre-ses0 sediments -nd org-nic m-tter then st-rt to -ccumul-te.

=he inter-ction o2 =re-tments -nd slope position di22erence e22ects on chemic-l properties in this stud4 shows there w-s insigni2ic-nt inter-ction between tre-tments -nd slope position di22erence 2or -ll chemic-l properties -t both s-mpling depths (=-ble &).

3ul@ densit4 is one o2 the common p-r-meters used to Cu-nti24 these ch-nges. =his is bec-use o2 the w-4 o2 me-surement o2 bul@ densit4. =he4 -lso used the ch-nges in bul@ densit4 to Cu-nti24 rel-tionships between bul@ densit4 -nd s-tur-ted h4dr-ulic conducti5it4. #n this stud40 strong -nd signi2ic-nt rel-tionship between bul@ densit4 -nd s-tur-ted h4dr-ulic conducti5it4 w-s obt-ined (2igure 2).



Relationship between Saturated hydraulic conductivity and Bulk density.

=he 2igure shows th-t there w-s signi2ic-nt correl-tion (Rs-tN-!5.59 3 6X111."0 pU0.050 .YN0.551) between s-tur-ted h4dr-ulic conducti5it4 -nd bul@ densit4 o2 soil. =he result shows th-t s-tur-ted h4dr-ulic conducti5it4 decre-ses with incre-sing bul@ densit4 -s - response o2 the sm-ller 5olume porosit4 -nd org-nic m-tter content o2 soil. .em-r@-bl40 the regression eCu-tion in this in5estig-tion w-s -lmost identic-l to the rel-tionship 2ound b4 D1"E 2or soils th-t were collected 2rom di22erent sites o2 -gricultur-l 2ields 2rom 10 to 20 depths.

4. Conclusion and Recommendations

=he results o2 this stud4 showed th-t -re- closures -re e22ecti5e in restoring the nutrient st-tus -nd Cu-lit4 o2 degr-ded soils. =he results o2 the soil -n-l4sis showed th-t most o2 the soil ph4sic-l -nd chemic-l properties h-d signi2ic-nt 5-ri-tions with respect to m-n-gement pr-ctices -nd slope position di22erence. =he stud4 -lso re5e-led th-t -re-closure 2-rm plots h-d higher me-n 5-lue o2 soil ph4sic-l -nd chemic-l properties other th-n bul@ densit4 -nd -ir 2illed porosit4. =his m-4 be due to the less biom-ss return to the open gr->ing l-nd bec-use m-jor p-rt o2 -bo5e ground biom-ss w-s remo5ed b4 li5estoc@ gr->ing which in turn neg-ti5el4 -22ect the -5-il-bilit4 o2 m-n4 soil nutrients. 3esides the tr-mpling -nd comp-ction e22ect on the soil due to open li5estoc@ gr->ing -nd soil erosion problem h-5e - role to pl-4 in ph4sic-l soil degr-d-tion o2 the open gr->ing l-nd use t4pe. =he result o2 most o2 ph4sic-l -nd chemic-l properties o2 soil shows th-t there were st-tistic-ll4 signi2ic-nt di22erences -mong slope position. #n -ll c-ses0 the me-n 5-lues were highest -t bottom slope position e?cept 2or 3ul@ densit40 ,ir 2illed porosit4 -nd p7 -t both s-mpling depths. =his might be due to the w-shing -w-4 o2 the 2ertile soil 2rom the upper p-rt o2 the l-nd settling -t bottom p-rt o2 the l-nd.

3-sed on the impro5ed soil conditions o2 -re- closure l-nd0 it is possible to conclude th-t the est-blishment o2 -re- closures

in the degr-ded l-nds is - 5i-ble option 2or soil Cu-lit4 impro5ement -nd biodi5ersit4 conser5-tion. =here2ore 2rom technic-l point o2 5iew0 open gr->ing -re-s in hill4 l-nds should be ch-nged to -re- closure be2ore soil ph4sic-l properties -nd soil nutrient contents -re depleted more -nd -lso the m-n-gement -cti5it4 c-rried out in -re- closure should be strengthened in the 2uture to incre-se soil 2ertilit4 impro5ement.

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D29E B-l0 . . 200!. / -rbon seCuestr-tion in dr4l-nd ecos4stems. 1n5ironment-l : -n-gement0 &&0 52"-5!!.

D&OE Biu)0 7erbert $L0 7-shemi , : 0 ; h-ng)0 6ing A (200) 122ects o2 -gricultur-l m-n-gement on soil org-nic m-tter -nd c-rbon tr-ns2orm-tion. $oil 1n5iron 5&: 5&1Z5!&.

D&1E : -rgesin0 . .0 $chinner0 +. : -nu-l o2 $oil , n-l4sis- : onitoring -nd , ssessing $oil 3ioremedi-tion. $pringer-<erl-g 3erlin 7eidelberg0 #nnsbruc@0 , ustri-0 2005. 6ep-rtment0 +in2inne0 p '5.

D&2E : -rsili0 , (199"). /h-nges o2 some ph4sic-l properties o2 -cl-4 soil 2ollowing the p-ss-ge o2 rubber -nd met-l tr-c@ed tr-ctors. $oil =ill. . es. !90 1"5Z199.

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D& E : e@uri- Golde0 201&. P/on5ersion o2 commun-l gr->ing l-nds into e?closures restored soil properties in the semi--rid lowl-nds o2 %orthern 1thiopi-0Q , rid B-nd . ese-rch -nd : -n-gement0 5ol.0 2'0 pp. 15&Z1 .

D&'E : e@uri- G0 B-ng-n $0 %oble , 0 Lohnston . (201!) $oil *rg-nic /-rbon -nd %utrient /ontents -re not in2luenced b4 1?closures est-blished in com- mun-l gr->ing l-nd in %ile b-sin0 %orthern 1thiopi-. #ntern-tion-l /on2er- ence on , d5-nces in , gricultur-l0 3iologic-l M 1n5ironment-l $ciences (, , 31$-201!) *ct 15-1 0201! 6ub-i (8 , 1).

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