EFFECTS OF WEED CONTROL ON PHYSICAL AND MICROPEDOLOGICAL PROPERTIES OF A BRAZILIAN ULTISOL(1)

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SUMMARY

In the tropical soil environment, raindrop impact is capable of disrupting natural soil aggregation and porosity, thus influencing the amount of infiltrated water and its redistribution. Under such conditions, a vegetation cover of weeds cannot be viewed simply as a crop competitor. This research project was designed to examine, under field conditions, the changes of soil properties, namely soil water content, structure and sealing, resulting from different types of weed management, with the aim of contributing to the establishment of more sustainable agricultural practices. Four weed management types - hoe-weeded, bare soil (combined application of pre-emergence herbicide Arsenal-250® (Imazapir) 2.0 L ha^{-1} and the systemic herbicide Gliz® (Glifosate) 5.0 L ha^{-1}), cut and cut + herbicide (systemic herbicide Gliz® (Glifosate) 5.0 L ha^{-1}) - were studied on an intensively cropped Kanhapludult in Minas Gerais State, Brazil. In high rainfall periods, the insulating effect of cut and cut + herbicide resulted in higher soil water, as compared to bare soil and hoe-weeded. On the other hand, in dry periods, the bare soil and hoe-weeded covers presented higher soil water content than the cut and cut + herbicide. Based on macro and micropedological observations, a sealing effect up to 15 mm below the surface was observed in bare soil and hoe-weeded covers and was particularly well-sorted and stratified in the latter. It is postulated that microerosional and microdepositional processes are involved in hoe-weeded sealing. These processes result from the breakdown of microaggregates, repacking the soil matrix. In the bare soil, the sealing was associated with physical alterations in the top layer, related to raindrop impact. Cut and cut + herbicide covers showed greater development of algae, bryophytes and worm activity in the soil surface. Based on the results obtained, the use of motorized cutters associated with herbicides appears to be a suitable alternative to hoeing and hand-weeding, reducing soil physical degradation and losses of water and soil in this particular environment.

Index terms: Land use, sealing, micropedology, ultisol, soil water content, weed control.

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RESUMO: *EFEITO DO CONTROLE DE INVASORAS EM PROPRIEDADES FÍSICAS E MICROPEDOLÓGICAS DE UM PODZÓLICO VERMELHO-AMARELO*

Nos trópicos, o impacto das gotas de chuva é capaz de destruir agregados e a porosidade natural do solo, influenciando o montante de água infiltrada e sua redistribuição. Em tais condições, a cobertura vegetal produzida pelas plantas invasoras não pode ser vista, simplesmente, como competidora com a cultura de interesse. Este projeto de pesquisa foi concebido para examinar, em condições de campo, a influência de diferentes tipos de manejo de invasoras sobre a umidade, estrutura e selamento do solo, visando contribuir para o desenvolvimento de técnicas compatíveis com uma agricultura sustentada. Quatro tipos de manejo de invasoras (coberturas): capina, sem vegetação (aplicação combinada do herbicida de pré-emergência Arsenal-250® (Imazapir) 2,0 L ha^{-1} e do herbicida sistêmico Gliz® (Glifosato) 5,0 L ha^{-1}), roçado e roçado + herbicida (herbicida sistêmico Gliz® (Glifosato) 5,0 L ha^{-1}), foram estudadas em um Podzólico Vermelho-Amarelo fase terraço em Minas Gerais. Nos períodos de elevada precipitação, as coberturas roçado e roçado + herbicida apresentaram maiores valores de umidade de solo quando comparados com capina e sem vegetação. Por outro lado, nos períodos secos, capina e sem vegetação apresentaram maiores valores de umidade de solo em relação as demais. Um selamento de aproximadamente 15 mm a partir da superfície do solo foi observado nas coberturas capina e sem vegetação, sendo particularmente bem estratificado na última. Postulou-se que processos microerosionais e microdeposicionais foram envolvidos no selamento observado na cobertura capina. Estes processos resultaram da quebra, e posterior rearranjo dos microagregados. Na cobertura sem vegetação, o selamento foi associado com alterações físicas na superfície do solo, devido ao impacto das gotas de chuva. As coberturas roçado e roçado + herbicida apresentaram grande desenvolvimento de algas, briófitas e atividade de minhocas na superfície. Baseado nos resultados obtidos, o uso de roçadeira motorizada com herbicida sistêmico, parece ser uma alternativa apropriada para o controle das invasoras, por reduzir a degradação física e as perdas de água e solo neste ambiente particular.

Termos de indexação: Uso do solo, selamento, micropedologia, Podzólico Vermelho-Amarelo, umidade do solo, controle de invasoras.

INTRODUCTION

In the tropics, soil degradation is a widespread phenomenon (Greenland, 1994) which only sometimes is reversible. Surface sealing development in some intensively tilled soils, the consequence of a number of soil management practices, such as the use of pre-emergence herbicides, harrowing, ploughing and weeding, is one of those processes which are reversible. Depending upon certain conditions, these practices can induce erosion and losses of soil, water and organic matter.

Recognition of the fact that erosivity of rain in the humid tropics is substantially greater than in the temperate, is recent (Greenland, 1979a). In much of Latin America, soil erosion is becoming more serious since small farmers are forced to cultivate land more frequently and more intensively (Greenland, 1979b). According to the "World map on the Status of Human-induced Soil Degradation" (Oldeman et al., 1990), there are many alarming figures on soil degradation, both chemical and physical, in the poorer countries of the tropics. However, there is little consideration in this map or elsewhere, of measures to control erosion and many soil improvements, resulting from the incorporation of sustainable practices of soil management in vast areas of the tropics, which aim to maintain levels of soil organic matter. The problem of soil erosion remains one of the most serious, threatening the future of mankind (Greenland, 1979a).

In the tropics, little is known about the effects of various weed control strategies on soil structure, water dynamics and other physical properties (Table 1), like microstructural reorganization (Hall, 1990; Kooistra et al., 1990). For tree crops, where the use of ground vegetation to protect the surface has long been a common practice, herbicides are increasingly applied to soils prone to erosion, thus replacing traditional hand-weeding, hoeing and cultivation. No-tillage techniques have been widely adopted in large-scale farming systems. Recently, however, small farmers are also using no-tillage techniques.

In the highlands of the Viçosa plateau (Zona da Mata region - Minas Gerais State), traditional farming systems are widespread, based on small-scale farmers, who rely on hand cultivation and simple ploughs to prepare their lands (Monteiro & Resende, 1988). These traditional farmers produce subsistence crops of bean, rice and corn, as well as perennials. The crops are grown mainly on clayey terrace soils, covering approximately one third of available land (Ker & Schaefer, 1995). In this area, one important development is the adoption of herbicides by some small farmers. Under cultivation, these clayey Ultisols are prone to sealing/crust formation, although this is usually reversible due to the seasonal fallow period (Faria, 1996).

There is a consensus in the literature that soil cover can influence losses of soil water and arable soil (Table 1). However, there is need for a better understanding of the role of crop history, weed management strategies and vegetation cover on soil protection (Lal et al., 1980). The main problem is that keeping a stable mulch on soil surface in the tropics, while recommended, is not always a feasible practice (Lal et al., 1980). Because soil physical properties, other than bulk density and soil texture, are difficult, time consuming, and expensive to measure, their importance often receives insufficient attention (Cassel & Lal, 1992).

This research project was designed to examine changes on soil properties at the field level, namely, soil water content, structure and sealing resulting from differing types of weed management, with the aim of contributing to the establishment of more sustainable agricultural practices in these traditional systems of non-intensive farming.

MATERIAL AND METHODS

The soil is a Ultisol (Kanhapludult) developed from Tertiary/Quaternary alluvial sediments, from the Viçosa Plateau (located at 20°45'49"S; 42°52'09"W) with an average slope of 0,08 m m^{-1}, under wet-and-dry tropical climate. The area had not been cultivated in the previous two years, prior to which it had been under corn. The experimental area was covered by a short, herbaceous vegetation, the dominant weed species being *Cyperus rotundus* (tiririca), *Bidens pilosa L.* (picão-preto), *Blainvillea rhomboidea* (picão-grande) and *Brachiaria plantaginea* (capim marmelada). At the end of the dry season, the soil surface layer was uniformly inverted to a depth of 5 cm using a disk plough, and left for the natural regeneration of weeds. Since then, no crops were grown on the area.

Treatments began 60 days after ploughing. Four types of weed control with four replicates were applied to plots of 3 x 10 m in a random block experimental design.

Table 1. Experimental results of the effects of no-tillage and associated practices of management, reported in the literature

Variable	Increase	Reduction
Macroporosity and total porosity at the soil surface.	Lal et al., 1980; Parker et al., 1992; De Vleeschauwer et al., 1980; Tollner et al., 1984.	Carpenedo & Mielniczuk, 1990; Hulugalle, 1994.
Size and ammount of water-stable aggregates.	Lal et al., 1980; Mahboubi et al., 1993; De Vleeschauwer et al., 1980; Carpenedo & Mielniczuk, 1990.	Parker et al., 1992.
Bulk density.	Mahboubi et al., 1993; Tollner et al., 1984; Hulugalle, 1994.	Lal et al., 1980; De Vleeschauwer et al., 1980; Alvarenga et al., 1986.
Saturated hydraulic conductivity.	Lal et al., 1980; Mahboubi et al., 1993.	
Infiltration rate.	Dick et al., 1989; Tollner et al., 1984; Hulugalle, 1994.	
Water-storage capacity.	De Vleeschauwer et al., 1980.	Tollner et al., 1984.
Faunal effects on soil structure.	Lal et al., 1980; Parker et al., 1992; De Vleeschauwer et al., 1980.	
Soil and water losses.		De Vleeschauwer et al., 1980; Lal et al., 1980; Seta et al., 1993; Parker et al., 1992.

1) Hoe-weeded: the weeds were controlled solely by hand, using the traditional hoe, and were cut when they were 15 to 20 cm high, spreading residues uniformly on the soil surface, offering a limited protection against raindrop impact.

2) Bare soil: the plots were kept entirely free of vegetation by combined application of pre-emergence herbicide Arsenal-250® (Imazapir) 2.0 L ha^{-1} and the systemic herbicide Gliz® (Glifosate) 5.0 L ha^{-1}.

3) Cut: the vegetation was kept short to heights of between 2 to 3 cm by a rotation motor-cutter. The cut residues were uniformly spread on the surface, offering a considerable protection.

4) Cut + herbicide: The same as above (3) in the first 120 days, followed by the use of systematic herbicide Gliz® (Glifosate) 5.0 L ha^{-1}. The aim was to allow the accumulation of protective vegetation on the surface and, following the herbicide application, the maintenance of this as a mulch.

Forty soil samples were randomly collected on the experimental area at 10, 20 and 30 cm depth for physical (Table 2) and chemical (Table 3) determinations, according to Klute (1986) and Sparks (1996), respectively. Bulk density was determined by the core method (Klute, 1986) at 10, 20 and 30 cm. The field capacity was estimated by the column method described by Fernandes & Sykes (1968).

Soil water content was determined every 15 days for 180 days from 10/26/1994 to 03/26/1995, by sampling about 50 g of wet soil from experimental plots at 10, 20 and 30 cm depths, using a soil auger. Values for soil water content were calculated as the mean of two replicates for each plot.

Two undisturbed soil blocks from the upper 10 cm were collected in all plots, for micropedological studies, using Kubiena Boxes, following the recommendations of Fitzpatrick (1993). Samples were dried at 35°C for 4 days, and saturated with acetone to remove the remaining moisture. The samples were then impregnated with Polylite T-208 resin mixed with styrene, catalyst and Ultra-Violet dye (UVITEX-OB, Ciba Geigy). After curing, the impregnated blocks were cut in successive slices, 1 cm thick, for micropedological observations. Black & white photographs of polished blocks were taken in a dark room, using a U.V. lamp (Altemuller & van Vliet-Lanoe, 1990).

Table 2. Physical characteristics of soil at 10, 20 and 30 cm depth

Characteristic	Unit	Depth, cm		
		10	20	30
Bulk density	$t\ m^{-3}$	1.305	1.342	1.249
Field capacity	$m^3\ m^{-3}$	0.370	0.398	0.401
Particle-size analysis				
Coarse sand	$g\ kg^{-1}$	230	230	150
Fine sand	$g\ kg^{-1}$	150	140	120
Silt	$g\ kg^{-1}$	80	80	90
Clay	$g\ kg^{-1}$	540	550	640
Water-dispersed clay	$g\ kg^{-1}$	360	360	90
Porosity	$m^3\ m^{-3}$	0.510	0.500	0.540

The biological effects of sealing were evaluated by qualitative characterization of algae (Cyanobacter, Chrysophyte and Clorophyte) bryophytes and weeds as observed in the field.

Statistical analyses were performed using the SAS program. ANOVA analysis of the experimental data was carried out using a split-split-plot scheme. Type of cover was allocated at plot level, depth at split-plot level and time at split-split-plot level. The regression analysis applied (soil water content = f (time)$|_{\text{cover, depth}}$) was based on the harmonic analysis of Fourier transformations (Churchill, 1963).

RESULTS AND DISCUSSION

Soil water content

The water contents, for each depth, are shown in figure 1a, b and c. The ANOVA is shown in table 4. Coefficients of regression analysis (r^2) were above 0.98 in all cases.

Table 3. Chemical characteristics of soil at 10, 20 and 30 cm depth

Depth	Organic C	pH H_2O	P	K	Al	Ca	Mg	H + Al	S	T
cm	mg dm^{-3}		— mg dm^{-3} —		cmol$_c$ dm^{-3}					
10	22.6	5.5	14.3	134	0.1	2.4	0.5	5.4	3.24	8.64
20	21.6	5.5	7.2	58	0.0	2.6	0.6	4.7	3.35	8.05
30	22.3	5.7	1.1	50	0.0	1.9	0.6	3.4	2.63	6.03

Figure 1a shows the soil water behavior at 10 cm depth. When compared with the hoe-weeded and bare soil, the cut and cut + herbicide covers showed a trend of higher values of soil water content, especially at the peaks of rainfall (periods 2 to 4, 7 to 8 and 10 to 11). In this first group, the hoe-weeded cover presented higher water contents. It was also possible to observe that soil water contents for the hoe-weeded and bare soil tend to be progressively lower than the cut and cut + herbicide, during the peaks of maximum rainfall.

Since net radiation is the primary climatic factor controlling evapotranspiration (Jensen et al., 1990) when water is not limiting, it is postulated that these values are associated with differences between the amount of solar radiation intercepted by the vegetation (alive or dead) and the exposed soil surface. Any lower temperature of the topsoil may result in reduced water losses (Hillel, 1971). Water removal by transpiration in the cut and cut + herbicide covers, which may be increased by the presence of weeds (Jensen et al., 1990), would not

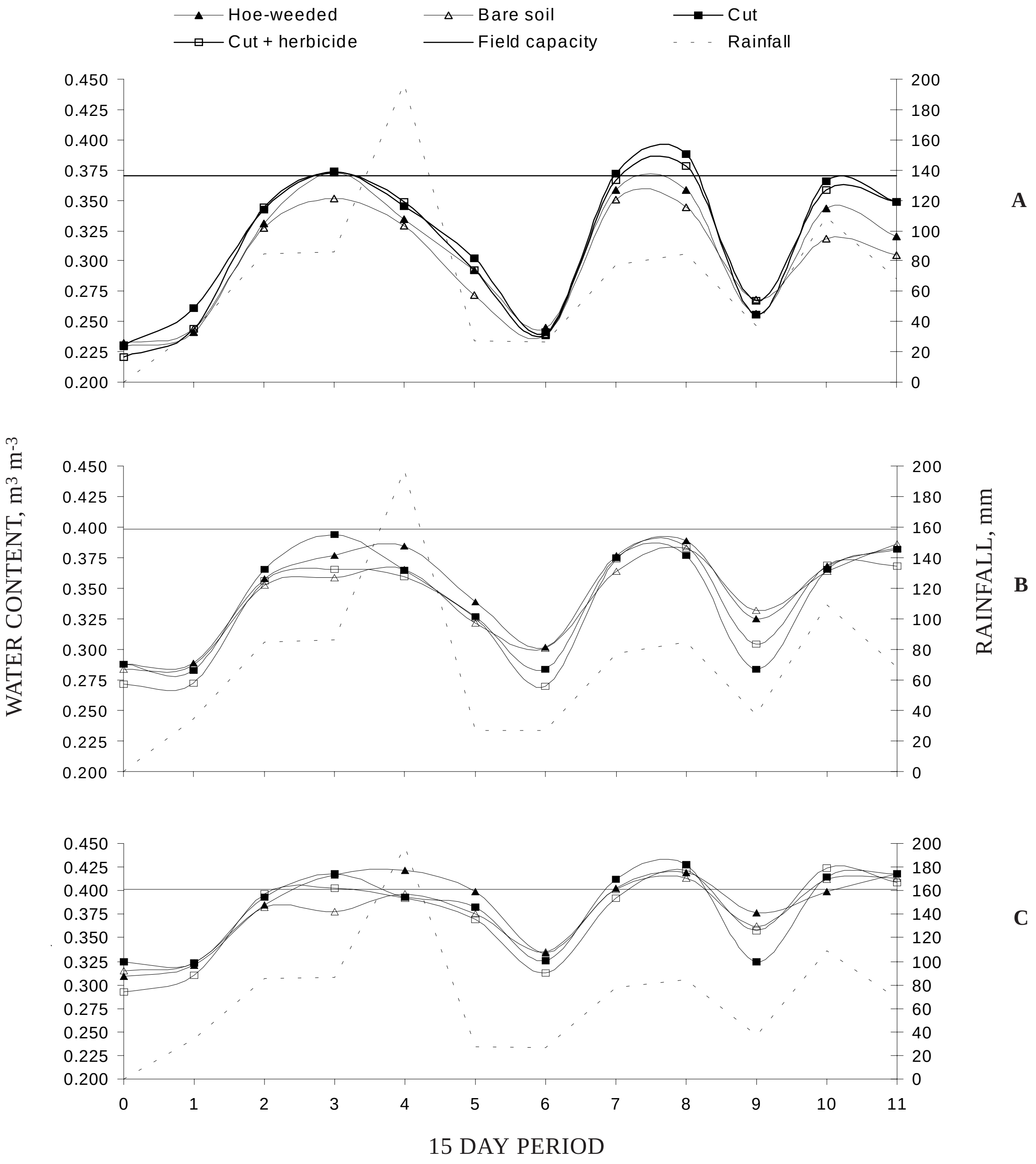


Figure 1. Water content at A: 10, B: 20 and C: 30 cm depth. Dotted line indicates rainfall data accumulated fortnightly.

Table 4. Analysis of variance of soil water content values

Source	Soil water contents	
	D.F.	M.S.
Blocks	3	1,880.89^{ns}
Cover	3	2,178.42^{ns}
Error A	9	1,260.57
Depth	2	223,177.00**
Cover x Depth	6	2,103.78^{ns}
Error B	24	1,116.02
Time/hoe-weeded/depth 10 cm	11	
Regression	10	11,753.16**
Residual	1	643.76^{ns}
Time/hoe-weeded/depth 20 cm	11	
Regression	8	8,138.83**
Residual	3	103.19^{ns}
Time/hoe-weeded/depth 30 cm	11	
Regression	9	7,940.29**
Residual	2	252.92^{ns}
Time/bare soil/depth 10 cm	11	
Regression	10	8,986.70**
Residual	1	769.32^{ns}
Time/bare soil/depth 20 cm	11	
Regression	10	5,643.82**
Residual	1	82.29^{ns}
Time/bare soil/depth 30 cm	11	
Regression	10	5,556.64**
Residual	1	14.21^{ns}
Time/cut/depth 10 cm	11	
Regression	10	14,561.10**
Residual	1	2,075.90^{ns}
Time/cut/depth 20 cm	11	
Regression	10	8,666.26**
Residual	1	19.33^{ns}
Time/cut/depth 30 cm	11	
Regression	10	8,005.38**
Residual	1	27.62^{ns}
Time/cut + herbicide/depth 10 cm	11	
Regression	10	15,086.98**
Residual	1	81.26^{ns}
Time/cut + herbicide/depth 20 cm	11	
Regression	10	8,585.79**
Residual	1	27.62^{ns}
Time/cut + herbicide/depth 30 cm	11	
Regression	10	9,079.18**
Residual	1	709.03^{ns}
Error C	396	230.69
C.V.		4.43

** Significant at 1%. ^{ns} non significant.

preferentially occur at a depth of 10 cm. Alternatively, the frequent use of motorized cutting created a surface mulch, which enhanced infiltration (Lal et al., 1980; De Vleeschauwer et al., 1980; Tollner et al., 1984; Parker et al., 1992) and internal drainage, and thus allowed more water to migrate downward into the deeper parts of the profile, where it is retained over longer periods and is less likely to be lost by evaporation (Hillel, 1971). Furthermore, the wind action enhancing the evaporation would be decreased by the presence of the cut weed microclimate, as pointed out by Aasae & Siddoway (1980).

At the 20 and 30 cm depths (Figure 1b, c) there was no clear distinction during the peaks of rainfall (periods 2 to 4, 7 to 8 and 10 to 11) between the different types of weed control. Between periods 2 and 3, is was observed that the soil water content in the bare soil was not increasing at the same rate as the other treatments, the gap being even greater with depth. The seal formation and the consequent mechanical impedance and losses of water by runoff have possibly contributed to reduce the amount of water infiltrated and its further downwards redistribution.

After the rainfall peaks, the hoe-weeded and bare soil covers showed lower water loss with time. This may be attributed to higher water consumption, via transpiration (Jensen et al., 1990), in the cut and cut + herbicide covers, induced by higher temperatures during these periods. In the periods 6 and 9, the cut and cut + herbicide covers showed lower soil water content values. Water removal by transpiration of weeds may be the responsible factor. This is in agreement with the inversion observed between periods 6 and 9. It is possible to note that in the period 6, at 20 and 30 cm depth, the cut showed higher soil water content than cut + herbicide; and in period 9 the inverse was found, just after the application of herbicide in the cut + herbicide cover, promoting lower rates of transpiration (Figure 1b, c).

In the hoe-weeded and bare soil treatments, though not measured, it was observed in the field that some water was lost by runoff, a process that is furthered by the formation of the surface sealing, which in turn may reduce the rates of water infiltration and redistribution. This also applies to the case of lower soil water contents after rainfall peaks, at all depths, for the bare soil.

The experimental results indicate that in tropical conditions, where rainfall is highly erosive (Greenland, 1979a), weed management practices can significantly alter soil surface porosity (Faria, 1996) and the amount of infiltrated water (Dick et al., 1989; Tollner et al., 1984; Hulugalle, 1994). Thus weed management cannot be analyzed solely from the viewpoint of a competitive process for water and light between weed and crop. In tropical conditions, where high rainfall prevails, less evapotranspiration favoured by constant cuts (cut), mulch (herbicide), or both (cut + herbicide), can lead to increasing water availability to the crops.

Structural changes and seal formation: Macroscopic observations

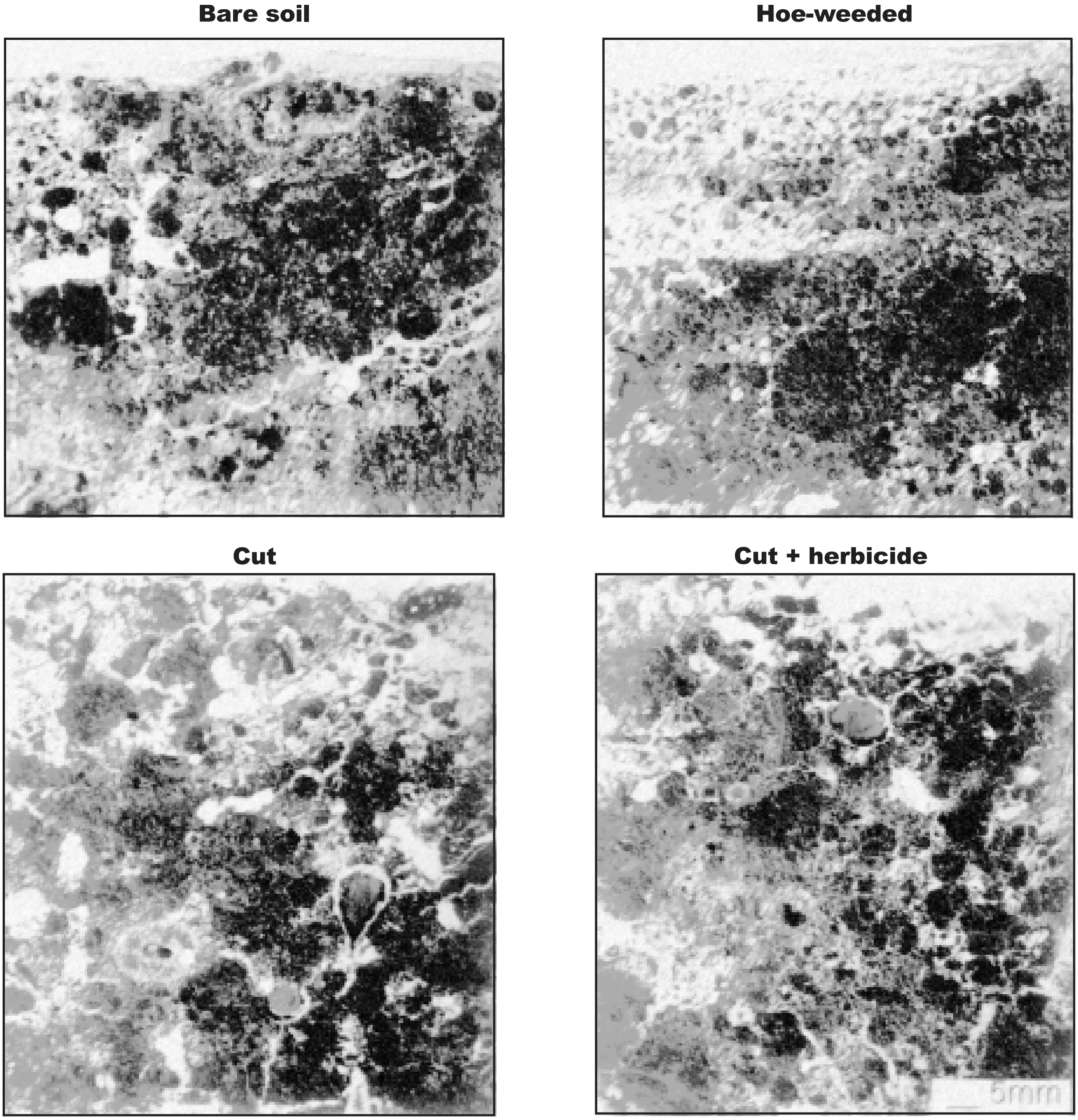
A rapid and dynamic seal formation was observed in the field for the bare soil after the first rains. Although less pronounced, the same phenomenon was noticed in the hoe-weeded cover. A dynamic process of constant formation/degradation and redeposition of seal was observed in both covers, resulting in a reduction of volume, of soil material at the lower end of experimental plots.

The bare soil surface displayed clear signs of sheet erosion, associated with the formation of micro-rills and micro-knolls on the surface. In the lower slope positions of the experimental plots, the surface was covered by a thin layer of fine sand, mainly quartz, whereas the fine particles had been washed away from the plots. Micropedestals resulting from raindrop impact were observed, similar to those reported by Slattery & Bryan (1992).

Similar features of physical degradation were also observed in the hoe-weeded plots, although to a lesser extent. This may be attributed to repetitive hoeing continuously breaking the surface seal, thereby facilitating water infiltration. In contrast, and still at macroscopic scale, the cut and cut + herbicide showed no evidence of significant erosion or redeposition, as well as a complete absence of observable micro-rills or channels.

Micropedological observations

Photographs of the polished block pictures using U.V. sensitive film revealed micropedological features, suggesting a clear relation between type of cover and structural reorganization (Figure 2).



Bare soil

Hoe-weeded

Cut

Cut + herbicide

Figure 2. Photographs (1:1 scale) of polished blocks using U.V. sensitive film, for the differing types of covers.

In qualitative terms, there were large contrasts between the group cut and cut + herbicide and the group hoe-weeded and bare soil. In the former, where the stubble and trash cover were retained on the topsoil, the A horizon maintained a high biological activity. This became evident by the presence of abundant channels and pores related to faunal activity, the associated crumb structure formation, and the increasing number of medium to macropores associated with root penetration. There was no evidence of sealing in the upper part of the soil (Figure 3a), whereas a trend of smaller aggregates (crumbs) at the surface, promoted by the incorporation of organic debris, was observed.

The deleterious effects of mechanical dispersion and breaking down of microaggregates and the consequent formation of surface sealing was clearly demonstrated in the hoe-weeded (Figure 3b) and bare soil. These treatments displayed a characteristic platy structural pattern, with planar pores, roughly parallel to the surface, as originally described in crust/seal formation elsewhere (Evans & Buol, 1968; Falayi & Bouma, 1975; Fitzpatrick, 1993; Pagliai & De Nobili, 1993).

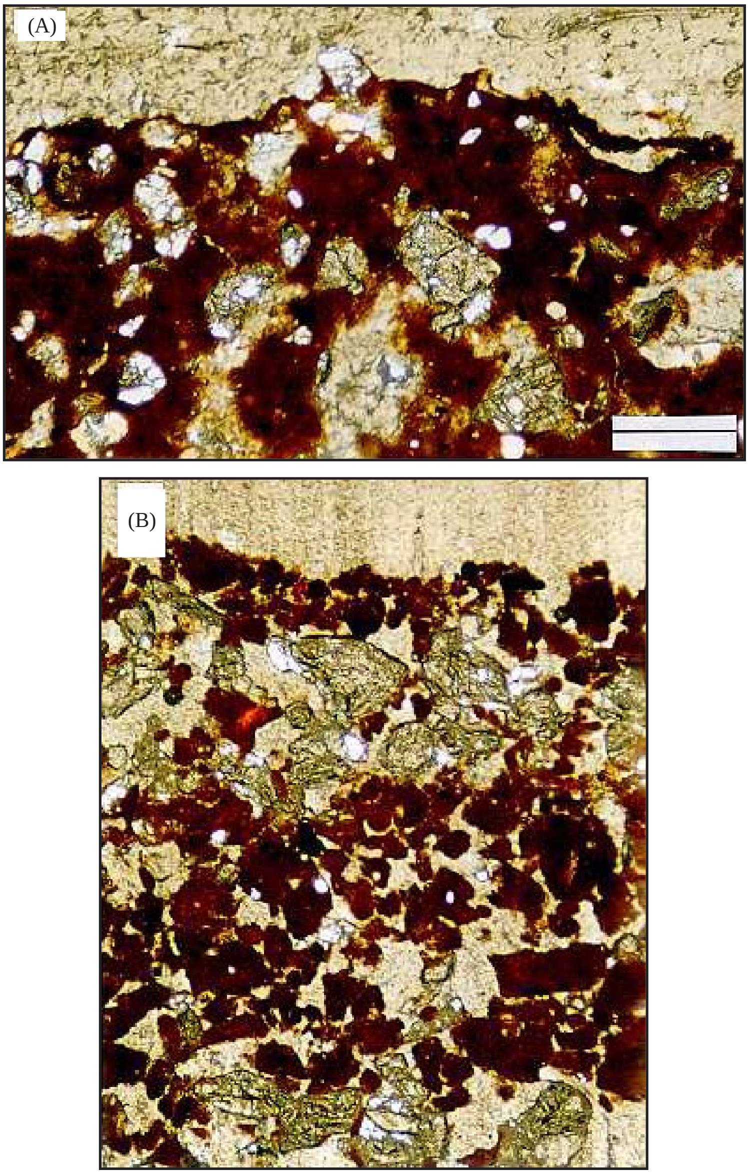


Figure 3. A: Micrograph of thin section of an aggregate at the top of the cut + herbicide cover, showing no traces of microerosion or physical disruption; and B: Micropedological effect of surface sealing of the hoe-weeded cover. Platy structural pattern with planar pores, formed by selective deposition of suspended particles. Note sorting and the presence of layers of quartz and broken aggregates (bar = 1 mm).

Surface crust formed by deposition of suspended particles carried by runoff were recognized by Evans & Buol (1968), and they involve micro-sedimentation process (Bishay & Stoops, 1975; Mücher & De Ploey, 1977). As Bresson & Valentin (1994) pointed out, sedimentology provided the basic concepts which were used to explain crust formation, whereas micromorphology provided a useful tool for determining the main diagnostic characters, such as microbedding, sorting and orientation.

In the present study, the hoe-weeded cover showed a gradual, decreasing degree of particle sorting in the sealed layer (Figure 2). This suggests that turbulent wash led to laminar stratification, because pure splash deposition does not show any lamination or particle sorting (Mücher et al., 1981). In this case, the densely packed sealing displayed small, disrupted aggregates, dispersed within the sealing groundmass, as described by Bresson & Boiffin (1990) and Bresson & Valentin (1994).

Thin section observation of the soil from hoe-weeded plots (Figure 3b) indicates that the sealing fabric was composed mainly by quartz grains, especially in the range of very fine sand to fine sand size, interspersed with fragments of microaggregates. The surface of the seal, however, showed no traces of dispersed clays, either in the form of clay skins (cutans) or cementing materials.

At the base of the sealing, a different pattern emerges, with quartz grains immersed in a fine, clayey matrix and aggregates of various sizes, displaying moderately developed grade of pedality. These aggregates were generally larger than those in the upper seal, and a vughy structure (Bullock et al., 1985) was observed.

Biological effects

Table 5 illustrates the main biotic factors that resulted from different types of weed management. Differences in terms of type and distribution of plant species were noticed during the experimental period. These species varied greatly with the type of cover and time. In the hoe-weeded cover, there was a dominance of *Cyperus rotundulus* ("tiririca"), followed by *Brachiaria plantaginea* ("capim marmelada"), while the remaining species were various types of dicotyledons. During the winter, a drastic reduction in the *Brachiaria* population was noticed, whereas the dicotyledons increased in number.

In the cut and cut + herbicide covers, similar types and frequency of weeds were observed during the 1 to 8 periods. However, following the first herbicide application in the cut + herbicide cover, there was a substantial invasion of *Raphanus raphanistrum* ("nabiça") and *Cyperus rotundulus* ("tiririca"). Overall, the major difference between the cut and hoe-weeded covers was the general development of bryophytes covering the soil surface, especially where the mulch was thinner. Associated with these bryophytes, some species of algae were also noticed, giving when dry, a lustrous and sliny surface (Table 5). This indicated a more favourable microenvironment for these species, as well as for worms, which helped to maintain the crumb structure in the surface soil, matching the concepts of Eldridge & Greene (1994), who suggested that biotic crusts may enhance water infiltration.

Table 5. Main biologic factors studied as related to differing types of weed management (covers). Names between brackets indicate the presence of very few individuals on the experimental plot

Type of cover	Cut	Cut + herbicide	Hoe-weeded	Bare soil
Sealing	Absent	Absent	Present, sorted	Present
Summer weeds	70% *Brachiaria plantaginea* 20% *Cyperus rotundulus* 10% Dicotyledons	70% *Brachiaria plantaginea* 20% *Cyperus rotundulus* 10% Dicotyledons	80% *Brachiaria plantaginea* 10% *Cyperus rotundulus* 10% Dicotyledons	Absent
Winter weeds	60% *Brachiaria plantaginea* 20% *Cyperus rotundulus* 20% Dicotyledons	2% *Brachiaria plantaginea* 18% *Cyperus rotundulus* 80% Dicotyledons	20% *Brachiaria plantaginea* 10% *Cyperus rotundulus* 70% Dicotyledons	Absent
Bryophytes	*Eubriales, Politrichales*	*Eubriales, Politrichales*	Not observed	(*Eubriales, Politrichales*)
Algae (Cyanobacter)	*Nostoc* sp. *Scytonema* sp. *Oscillatoria* sp. *Lyngbya* ap. *Gloeocapsa* sp.	*Nostoc* sp. *Scytonema* sp. *Oscillatoria* sp. *Lyngbya* ap. *Gloeocapsa* sp.	Not observed	(*Nostoc* sp.) (*Scytonema* sp.) (*Oscillatoria* sp.) (*Lyngbya* ap.) (*Gloeocapsa* sp.)
Algae (Chrysophyta)	*Bacillariophyceae* Diatomaceae	Bacillariophyceae Diatomaceae	Not observed	(Bacillariophyceae) (Diatomaceae)
Algae (Chlorophyta)	*Chloroccocum* sp. *Klebsormidium* sp.	*Chloroccocum* sp. *Klebsormidium* sp.	Not observed	(*Chloroccocum* sp.) (*Klebsormidium* sp.)
Worm activity	Abundant	Abundant	Traces	Absent

CONCLUSIONS

1. The type of weed management on a clayey Ultisol had significant influences on water availability. During rainfall peaks, cut and cut + herbicide covers showed higher soil water contents than hoe-weeded and bare soil covers. On the contrary, hoe-weeded and bare soil retained more water during dry periods.

2. The experimental results indicate that in tropical conditions where rainfall erosivity is high, weed management practices can significantly alter soil surface porosity and the amount of infiltrated water. Thus weed management cannot be analyzed solely from the viewpoint of a competitive process for water, with a given crop. For tropical conditions in which high rainfall prevails, evapotranspiration is less enhanced by constant cuts (cut), mulch (herbicide), or both (cut + herbicide), leading to increased water availability to crops.

3. Sealing formation, due to a greater exposure, was observed in the bare soil and hoe-weeded covers and was absent in the cut and cut + herbicide. Cut and cut + herbicide presented a well-formed crumb structural pattern and higher biological activity, as illustrated by the presence of abundant bryophytes and algae, and biopores and higher worm activity, in comparison with bare soil and hoe-weeded covers.

4. Micropedological observations indicated sealing development to a depth of 15 mm, essentially associated with physical alterations, aggregate disruption and subsequent rearrangement and repacking of individual particles and aggregates fragments. Dynamic microerosion and microdeposition processes were presumed to explain the microbedding and sorting in the seal, formed in the hoe-weeded plots. This feature was not observed in the bare soil.

5. Applying motorized cutting for weed control and systemic herbicide, instead of hoeing and hand-weeding, may be promising alternatives for reducing physical degradation and losses of water and soil, although further understanding about weed control is necessary in order to reduce competition for water, especially during periods of lower rainfall and higher temperatures.

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LITERATURE CITED

AASAE, J.K. & SIDDOWAY, F.H. Stubble height effects on season microclimate water balance, and plant development of no till winter wheat. Agric. Meteorol., 21:1-20, 1980.

ALTEMULLER, H.J. & van VLIET-LANOE, B. Soil thin section fluorescence microscopy. In: DOUGLAS, L.A., ed. Soil micromorphology: a basic and applied science. Amsterdam, 1990. p.565-580. (Developments in Soil Science, 19)

ALVARENGA, R.C.; FERNANDES, B.; SILVA, T.C.A. & RESENDE, M. Estabilidade de agregados de um latossolo roxo sob diferentes métodos de preparo do solo e de manejo da palhada de milho. R. Bras. Ci. Solo, 10:273-277, 1986.

BISHAY, B.G.& STOOPS, G. Micromorphology of irrigation crusts formed on a calcareous soil of the mechanized farm, north-west Egypt. Pedologie, 25:143, 1975.

BRESSON, L.M. & BOIFFIN, J. Morphological characterisation of soil crust development stages on an experimental field. Geoderma, 47:301-325, 1990.

BRESSON, L.M. & VALENTIN, C. Soil surface crust formation: contribution of micromorphology. 1994. In: RINGROSE-VOASE, A.J. & HUMPHREYS, G.S., eds. Soil micromorphology: studies in management and genesis. Amsterdam: 1994. p.737-762.

BULLOCK, P.; FEDEROFF, N.; JONGERIUS, A.; STOOPS, G.; TURSINA, T. & BABEL, U. Handbook for the soil thin section description. Wolverhampton, Waine Research Publications, 1985. 153p.

CARPENEDO, V. & MIELNICZUK, J. Estado de agregação e qualidade de agregados de Latossolos Roxos, submetidos a diferentes sistemas de manejo. R. Bras. Ci. Solo, 14:99-105, 1990.

CASSEL, D.K. & LAL, R. Soil physical preperties of the tropics: common beliefs and management restraints. In: LAL, R. & SANCHEZ, P.A. Myths and science of soils of the tropics. Madison, SSSA, 1992. p.61-89 (SSSA Speciel Publication 29).

CHURCHILL, R.V. Fourier series and boundary value problems. New York, McGraw-Hill, 1963. 248p.

DE VLEESCHAUWER, D.; LAL, R. & MALAFA, R. Effects or amounts of surface mulch on physical and chemical properties of an alfisol from Nigeria. J. Sci. Food Agric., 31:730-738, 1980.

DICK, W.A., ROSEBERG, R.J. & McCOY, E.L., et al. Surface hydrologic response of soils to no-tillage. Soil Sci. Soc. Am. J., 53:1520-1526, 1989.

ELDRIDGE, D.J. & GREENE, R.S.B. Microbiotic soil crust: a review of their roles in soil and ecological processes in the rangelands of Australia. Austr. J. Soil Res., 32:389-415, 1994.

EVANS, D.D. & BUOL, S.W. Micromorfological study of soil crusts. Soil Sci. Soc. Am. Proc., 32:19-22, 1968.

FALAYI, O. & BOUMA, J. Relationships between the hydraulic conductance of surface crusts and soil management in a Typic Hapludalf. Soil Sci. Soc. Am. Proc.,39:957-963, 1975.

FARIA, J.C. Dinâmica da água, comportamento térmico e selamento de um Podzólico Vermelho-Amarelo em relação ao controle de plantas invasoras. Viçosa, UFV, 1996. 75p. (Tese de Mestrado)

FERNANDES, B. & SYKES, D.J. Capacidade de campo e a retenção de água em três solos de Minas Gerais. R. Ceres, 15, 1-39, 1968.

FITZPATRICK, E.A. Microscopy and micromorphology of soils. Chichester: John Wiley, 1993. 304p.

GREENLAND, D.J. Soil science and sustainable land management. In: SYERS, J.K. & RIMMER, D.L., eds. Soil science and sustainable management in the Tropics. Wallingford, CAB International, 1994. p1-16.

GREENLAND, D.J. The magnitude and importance of the problem. In: GREENLAND, D.J. & LAL, R., eds. Soil conservation & management in the humid tropics. Chichester, John Wiley & Sons, 1979a. p.3-7.

GREENLAND, D.J. Soil structure and erosion hazard. In: GREENLAND, D.J. & LAL, R., eds. Soil conservation & management in the humid tropics. Chichester, John Wiley & Sons, 1979b. p.17-24.

HALL, N.W. Micromorphology and complementary assessments of soil structure description and their relationships to the lenght of time under tillage and calcium carbonate contents. In: DOUGLAS, L.A., ed. Soil micromorphology: a basic and applied science. Amsterdam, Elsevier, 1990. p.41-52. (Developments in Soil Science, 19)

HILLEL, D. Soil and water, physical principles and process. New York, Academic Press, 1971. 288p.

HULUGALLE, N.R. Long-term effects of land clearing methods, tillage system and cropping system on surface properties of a tropical alfisol in S. W. Nigeria. Soil Use Manag., 10:25-30, 1994.

JENSEN, M.E; BURMAN, R.D. & ALLEN, R.G. Evapotranspiration and irrigation water requirements. New York, 1990. 332p. (ASCE Manual and Reports on Engineering Practice 70).

KER, J.C. & SCHAEFER, C.E.R. Roteiro da excursão pedológica Viçosa-Sete Lagoas. Viçosa, SBCS/UFV/CNPS-EMBRAPA, 1995. 47p.

KLUTE, A. Methods of soil analysis. Part I. Madison, Soil Science Society of America, 1986. 1188p.

KOOISTRA, M.J.; JUO, A.S.R. & SCHOODERBEEK, D. Soil degradation in cultivated Alfisols under different farming systems in western Nigeria. In: DOUGLAS, L.A., ed. Soil micromorphology: a basic and applied science. Amsterdam, Elsevier, 1990. p.61-70. (Developments in Soil Science, 19)

LAL, R., VLEESCHAUWER, D. & NGANJE, M.R. Changes in properties of a newly cleared tropical alfisol as affected by mulching. Soil Sci. Soc. Am. J., 44:827-833, 1980.

MAHBOUBI, A.A.; LAL, R. & FAUSSEY, N.R. Twenty-eight years of tillage effects on two soils in Ohio. Soil Sci. Soc. Am. J., 57:506-512, 1993.

MONTEIRO, J.A. & RESENDE, L.M.A. A pequena propriedade agrícola em Minas Gerais. Inf. Agropec. 14:10-18, 1988.

MÜCHER, H.J. & DE PLOEY, J. Experimental and micromorphological investigation of erosion and redeposition of loess by water. Earth Surf. Proc., 2:117-124, 1977.

MÜCHER, H.J.; DE PLOEY, J. & SAVAT, J. Response of loess material to simulated translocation by water: micromorphological observation. Earth Surf. Proc., 6:331-336, 1981.

OLDEMAN, L.R., HAKKELING, R.T. & SOMBROEK, W. World Map on the Status of Human-induced soil degradation. FAO, 1990.

PAGLIAI, M. & DE NOBILI, M. Relationships between soil porosity, root development and soil enzyme activity in cultivated soils. Geoderma, 56:243-256, 1993.

PARKER, I.J.; HAMILTON, G.J. & KOEN, T.B. Runoff, soil loss and physical property changes of light textured surface soil from long-term tillage treatments. Austr. J. Soil Res., 30:789-806, 1992.

SETA, A.K.; BLEVINS, R.L. ; FRYE, W.W. & BARFIELD, B.J. Reducing soil erosion and agricultural chemical losses with conservation tillage. J. Environ. Qual., 22:661-665, 1993.

SLATTERY, M.C. & BRYAN, R.B. Laboratory experiments on surface seal development and its effects on interrill erosion processes. J. Soil Sci., 43:517-529, 1992.

SPARKS D.L. Methods of soil analysis. Part 3. Madison, Soil Science Society of America, 1996. 1390p.

TOLLNER, E.W.; HARGROVE, W.L. & LANGDALE, G.W. Influence of conventional and no-till practices on soil physical properties in the southern Piedmont. J. Soil Water Conserv., 39:73-76, 1984.