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SOIL PHYSICAL CHARACTERISTICS OF HILLSLOPE PASTURES UNDER REPEATED ANIMAL AND MACHINERY TRAFFIC

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A b s t r a c t. The results are reported of the measurements of animal and machinery traffic effects on sloping pastures subjected to rotational grazing, or to haymaking plus grazing.

The trampling produced serious soil compaction and changed sward composition, already in the second year of trial in the newly estabilished pastures. In the perennial pastures a soil pan was formed at 7-10 cm depth. Not all the measurement methods commonly used made it possible to follow the evolution of compaction correlated to the botanical changes. Only penetration resistance, when measured in autumn, and water infiltration were sensitive to changes in soil compaction.

K e y w o r d s: soil physical characteristics, animal and machinery traffic, sloping pastures, soil compaction

INTRODUCTION

For soil conservation in sloping areas, forage crops are established for use based on livestock grazing. However, the operating conditions differ from traditional pastures as recourse has to be made to year-long rotational grazing of the animals on fenced plots.

Several studies on the aspects of the animal-plant relationship have revealed that the intensity and the frequency of defoliation are the main causes of the sward decay, but also treading, even moderate, damages the soil surface. The most important impact of animal and machinery traffic on pasture lands is compacting, induced by trampling, which changes the hydrological conditions and causes runoff in intensely grazed soil.

It is possible to limit damages to the flora by changing the grazing pressure. It is harder to control the adverse effects of traffic on the soil as the animals have to return several times to the same plot even when the bearing capacity conditions are unfavourable. In the immediate term, the grass loses appetency due to dirtying; in the long term the floristic composition changes together with the destruction of the structure in the surface part of the soil [1].

Hoofprinting considerably affects the soil: a cow imparts a dynamic pressure of 0.5-0.7 MPa and, at the end of the grazing season, each point of the plot has been trodden on 6 to 10 times [2].

To our knowledge, technical literature contains few and often discordant data on the treading of sloping pastures.

Increased penetration resistance has been found, correlated to the increase of animal traffic, with maximum rates at 3.5 cm [6] or at 7 cm depth [8].

Some researchers have ascertained degradation of the sward but little alteration of the characteristics of the soil. Edmond reports that the measurements carried out (bulk density, porosity) were not affected much by trampling [3]. Mc Intyre, cited by Tanner and Mamaril [9], found water infiltration very sensitive to changes in soil compaction but it was arduous to measure and difficult to interpret. Aeration porosity, bulk density and total porosity were found to have lower resolution capability than air permeability and cone penetrability [9].

The presence of herbage cover all over the year, the repetition of animal treading, and in the case of sloping pastures, the variability of the slope and thickness of the soil, make the soil compaction surveying methods used in flat croplands less sensitive and difficult to apply. The measurement of space and time variability of the physical and hydrological characteristics of the soil subjected to rotational grazing is particularly complicated.

As part of a research on partially free-range cattle breeding techniques on hill lands, a methodological work for the study of the traffic effect on the soil was carried out.

The major objective of the study was to define measurement methods to quantify soil compaction damages on sloping pastures, relating them to the changes in composition of the sward, in order to determine the critical grazing intensities above which irreversible changes take place in soil physical characteristics. Another aim was to find a bearing capacity threshold for each plot - i.e., the minimum soil resistance rate below which the hoof sinks - so enabling the cattle manager to decide when to let the animals into the pasture.

EXPERIMENTAL PROCEDURES

The tests were carried out over three years, on a hillside area with a climate characterized by equinoctial rain distribution, winter with periods of snow and summer dry period.

Four fenced paddocks, sloping between 15 % and 50 % were used, two of them had been sown the previous autumn with polyphytic mixture (recent pasture, RP), the others were perennial pastures (PPG) that had been subjected for 10 years to rotational cattle grazing. The soils, varying in thickness with the slope, are mainly of sandy-loam texture.

Inside each paddock, untrodden control areas (C) were established with permanent exclosures. On half of the surface of the recent pastures a herd of adult cattle was rotated four times during the season (RPG), on the other half, first cut of hay, was made in late May, and three grazing rotations were carried out (H+G). The traffic of the machinery was recorded as number of passes, size and mass of the tractors and working machines.

For mowing and baling (with conventional baler) a 52 kW four-wheel tractor was employed, for turning and tedding the hay a 33 kW tractor was used.

The floristic composition of the sward and the bare areas were monitored periodically and production was sampled. Soil measurements were carried out with the methods and devices already experimented in woodland grazing tests [5].

At the beginning of the tests, some chemical characteristics and the soil texture were determined; each year, at the start and end of the season, the bulk density, porosity, hydrological characteristics, water infiltration and penetration resistance were assessed. The first year the penetration resistance and soil water content measurements were repeated several times, in order to obtain the force-humidity regression line in the layers: 0-6 cm, 7-14 cm, 15-21 cm depth. Further soil samples were taken after appreciable rain to follow the changes of moisture content. On some undisturbed saturated samples (200 cm^3), the water release curve, weight versus time, was determined according to a method developed at our Institute. Lastly, on ten spade slices of soil from each paddock, the roots-epigeous dry matter production ratio and the root density along the layer, 0-25 cm depth were measured.

RESULTS AND DISCUSSION

The long-term grazed plots showed clear effects of cattle treading, with the formation of floristic communities better adapted to frequent clipping and with the presence of species indicating compaction where the sod was trodden most.

Moreover, there were considerable bare areas in the sward, often up to 30 % of the total basal bare-ground cover, but the bare spaces filled during the recovery growth with other herbs having lower forage value; the same behaviour was reported by Edmond [3].

In the vertical section of the soil, at a depth of 7-10 cm a compact 'floor', 5-7 cm thick, has formed, with the characteristic colour of asphyxiated soil.

Already at the beginning of the second year, and particularly at the second growth, the newly established pasture showed changes in botanical composition confirming, in accordance with Edmond, that most of the effects occur after the first treading, however, no clear signs of changes in bulk density were found (Table 1).

If carried out in spring, with the moisture content at field capacity, the measurements of the bulk density, porosity and hydrological properties - field capacity (FC), saturation capacity (SC), percolating water (PC) - did not differ significantly in the renovated pastures and in the old ones. Moreover, they did not make it possible to measure the compacted 'floor' that has formed (Table 2).

This confirms that trampling has a substantial impact on the physical properties of the soil, but it is unclear which level of change of them will affect forage productivity [4].

The changes in the botanical composition are the result of multiple actions of the animal such as defoliation, burying of the grass, and with regard to trampling, it would probably be necessary, as other researchers suggest [7], to give more study to the horizontal component of the dynamic force imparted by the hoof to the soil. The penetration resistance measurements carried out at the start of the grazing season (Fig. 1A), with high soil moisture content, did not differ significantly in the grazed plots and in the untrodden control areas. The above measurement made in autumn, with water content at approx. 2/3 of the FC, though the

Table 1. Botanical composition (%DM) and soil bulk density in relation to utililzation techniques of recent and perennial pastures, determined at summer regrowth, in the second year of trial

Treatment	Grasses (%)	Legumes (%)	Others (%)	Weeds (%)	Bare earth (%)	Bulk density ($g\ cm^{-3}$)
New pasture						
Control	52a	18b	16bc	14b	9c	1.22b
Hay+grazing	49b	19b	17b	15b	18b	1.26ab
Grazing	46b	21ab	15c	18a	16b	1.30a
Old pasture						
Grazing	35c	24a	22a	19a	21a	1.25ab

a,b-Means in the same column followed by different letters differ at 0.05 level.

Table 2. Some soil and physical properties determined at the end of the second year of trial, from recent and perennial pastures, in relation to utilization techniques

Parameter		New pasture						Old pasture	
		Control		Hay+Grazing		Grazing		Grazing	
		*A	B	A	B	A	B	A	B
Organic matter	($g\ kg^{-1}$)	60.2b	47.3	58.2b	45.6	63.2b	42.2	75.1a	46.3
C/N ratio		9.3a	8.7	8.9b	8.5	9.1a	8.6	9.9a	8.8
Bulk density	($g\ cm^{-3}$)	1.28b	1.32	1.39a	1.334	1.29b	1.34	1.25b	1.36
Saturat. capacitiy	(%, v/v)	50.0a	46.2	47.7b	48.2	50.1a	46.3	54.7a	45.2
Field capacity	(%, v/v)	40.7b	39.3a	41.3b	38.4a	42.8ab	37.4a	44.1a	35.6b

*A: 0-7 cm depth; B: 8-15 cm depth; a,b-Means in the same row, relating to the same depth, with different letters, differ at 0.005 level.

spatial differences were considerable, revealed (Fig. 1B) clear differences between the pastures compared, showing a 'bearing capacity threshold'. In fact, using the penetration force-soil water content regression line determined in each plot in the test, and the multiple correlation force-humidity-depth, it was possible to obtain comparable graphs of penetration resistance.

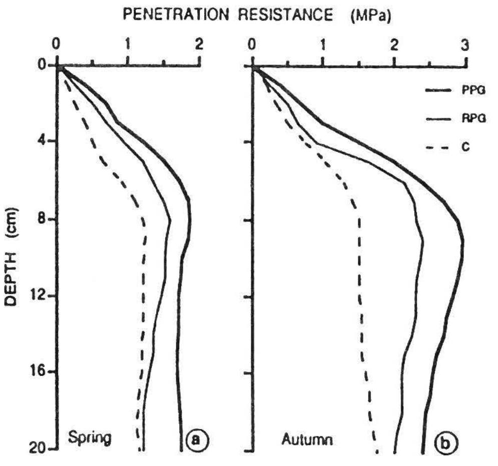

Fig. 1. Penetration resistance with soil depth measured in the second year of trial in recent pastures under rotational grazing regime (RPG), in the control plots (C), and in perennial pastures (PPG) over a period of ten years.

These results confirm that the measurement of penetration resistance, widely used to determine soil compaction, is heavily affected by soil water content and that it is necessary to work within a restricted range of it, according to the type of soil and crop [5].

The trend over two years of the average penetration resistance in the depth examined (0-21 cm) showed that the largest differences were to be found at the end of the season, while they were low in spring. Apparently, as also Tanner and Mamaril reported [9], soil compaction induced by the animals during the grazing season is largely ameliorated over winter by the rain and the snow cover.

At the end of the second year of trial, the quantity of infiltrated water, measured using a double cylinder infiltrometer, was much lower in the old pasture (Fig. 2); intermediate quantities between this and the control were found in the paddock grazed for two years. The water release curves of the saturated soil versus time, determined on undisturbed samples, allowed to identify a first phase of drying down to about the FC, which seems quicker in the recently grazed paddock and an intermediate stage, down to values of about 45 % of the FC, slower than in the old pasture (Fig. 3).

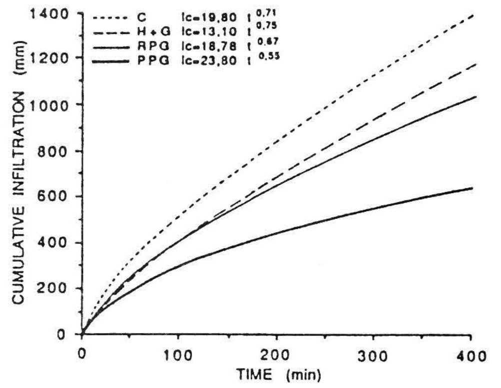

Fig. 2. Water cumulative infiltration in soils of recent pastures given two year grazing (RPG) or haymaking plus grazing (H+G), of the control plots (C), and of those from perennial pastures long-term grazed (PPG).

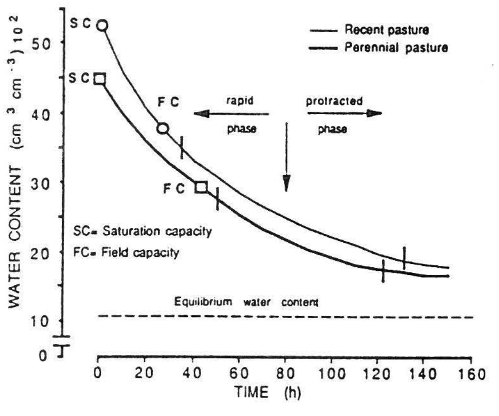

Fig. 3. Changes in water content versus time, of undisturbed soil samples from recent pasturs given two year grazing (RPG) and form perennial pastures long-term grazed (PPG).

If this trend is confirmed by further measurements with samples taken in different moments of the season, it might enable the definition of a water release behaviour model for differently trampled pastures that could be used operatively by the cattle manager to single out the critical periods, concerning the soil moisture, for maintaining the animals on the pastures.

The measurements of the roots distribution in the soil layer, 0-30 cm depth, revealed higher total root content (DMw/w) in the perennial pastures (PPG), having clear concentration in top 6 cm, and, deeper, few thick roots mainly of *Taraxacum officinale* and *Rumex spp.* (Fig. 4). Lower yield of DM roots was found in the soil of the recent pastures, but was observed, particularly in the control plots, more uniform density along the profile of the examined layer.

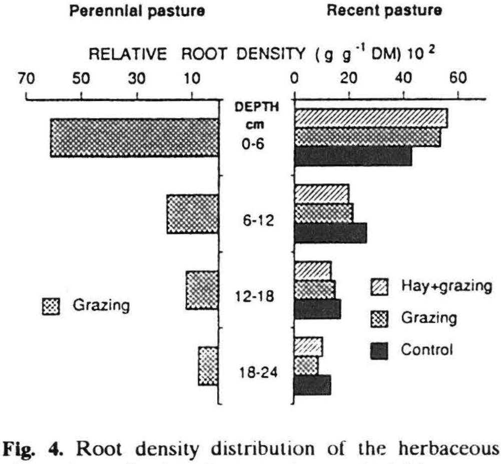

Fig. 4. Root density distribution of the herbaceous plants determined at the second year of trial in perennial pastures under rotational grazing and in recent pastures under different utilizations.

CONCLUSIONS

To conclude, it may be said that trampling highly affects the composition of the herbage cover of the pasture, but with traditional measurements it is difficult to follow the evolution of the physical characteristics of the soil right from the earliest stages of changes in the flora. It is therefore necessary to develop new methods more suited to the conditions of the pastures, especially if they are sloping, in order to locate the first changes caused by trampling on the ground before they become irreversible.

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