Proposal of soil indicators for spatial analysis of carbon stocks evolution

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ABSTRACT

As erosion, exacerbated by the extension of vine growing on hillslopes in Mediterranean environment, takes part in the spatial reorganization of topsoil and his carbon stocks, we assume that aggregate stability indexes could be useful for studying the carbon stocks spatial reorganization in this environment. By comparing four widely used methods for the characterization of aggregate stability in three French Mediterranean study sites, we first found that 2 indexes resulting from the method of Le Bissonnais (1996) - log(MWDLB), the Mean Weight Diameter in its logarithmic form, and MA200LB, the rate of macro aggregates > 200 µm - were the best adjusted with several runoff and soil losses variables obtained from rainfall simulations. Secondly, we established relationships between these indexes and some soil properties that are relatively easy to spatialize. Results show a very significant correlation between these aggregate stability indexes and the organic carbon rate (CSOM), which appears as a good indicator for the spatialization of these 2 indexes.

OBJECTIVES

The final objective of this study was to define good indicators for the forecasting of the spatial evolution of carbon stocks caused by soil erosion.

☞ As *a first goal*, we compared four laboratory methods that produce aggregate stability indexes and partly reproduce the effect of intense rains in the Mediterranean climate, in order to select the index which is best correlated with runoff and erosion data from simulated rainfalls.

☞ As *a second goal*, we analyzed the relationships between the selected index and several soil properties that are relatively easy to spatialize, in order to find a pedotransfer function which could be usable for the mapping of this index.

MATERIALS AND METHODS

Study sites

Three representative study sites (cf table 1) were selected in the southern region of France, with 3 land use situatios : garrigue, fallow and vineyard. The climate of these sites is Mediterranean. The soils are brown calcareous (calcaric regosols and brown calcic cambisols) with a silty clay texture.

Study sites	Localisation	Annual rainfall	Land use	Clay	Silt	Sands	Coarse elements	Organic matter	$CaCO_3$	pH
Corconne Village	43°51 N 3°56 E	1100 mm Storms > 60 $mm.h^{-1}$	Garrigue	327	510	163	226	52	556	7.7
			Fallow	353	494	153	88	49	523	7.7
			Vineyard	405	392	203	97	9	552	7.9
Pradel	44°35 N 3°56 E	1000mm Storms > 50 $mm.h^{-1}$	Vineyard	341	413	246	132	27	342	7.7
Roujan	43°30 N 3°18 E	650mm Storms > 30 $mm.h^{-1}$	Vineyard	180	414	406	33	15	309	7.8

Table 1. Characteristics of the three study sites (Soil data expressed in $g.Kg^{-1}$) .

Field measurements

Picture 1. Rainfall simulations in a vineyard

For the first goal of this study, 14 simulated rains were carried out in fallow (weeded for this experimentation) and weeded vineyard at Corconne and Pradel sites. Under vineyard, the rains were carried out in the inter-rows. The Orstom-type rainfall simulator produced rains intensity of 60 $mm.h^{-1}$ with a metering and mobile jet, on $1m^2$ plots. The following variables were obtained from hydrograms and turbidigrams analysis :

- RBR = rainfall before runoff initiation
- KRU30 = runoff ratio during 30 mn.
- KRI30 = instantaneous runoff ratio at 30 mn.
- KRIPAL = instantaneous runoff ratio at equilibrium runoff rate
- TURBIPAL = running water turbidity at equilibrium runoff rate
- TURBI30 = turbidity at 30 mn.
- ERO30 = soil losses during the first 30 mn of simulated rainfalls

Soil sample analysis

For the first goal of this study, we took 38 soil samples from the topsoil layer (0-5 cm) in fallow and vineyard of Corconne and Pradel sites. These samples were the subject of aggregate stability analysis, according to 4 methods of which the common treatment is a slaking effect, by bursting of dry samples during their fast immersion in de-ionised water (cf table 2).

Aggregates sizes upper than 0.2 mm were separated by Sieving. Aggregates sizes lower than 0.2 mm were analyzed by laser diffraction (cf. picture 2).

Picture 2. Laser sizer

	Yoder (1936)	Hénin (1958)	Kemper & Rosenau (1986)	Le Bissonnais (1996)
Treatment	Slacking effect	Slacking effect	Slacking effect	Slacking effect
Sieving duration in water	10 mn	1 mn	6 mn	No sieving in water
% of aggregates > 200µm	$MA200_{YOD}$	$MA200_{HEN}$	$MA200_{KEM}$	$MA200_{LB}$
Mean Weight Diameter	MWD_{YOD}	/	/	MWD_{LB}

Table 2. Main characteristics of the 4 methods of aggregate stability measurement.

For the second goal of this study, we took 68 soil samples of the 0-5 cm topsoil layer, from the whole study sites and the whole land use situations. We analysed 3 potential factors of the aggregate stability in calcareous soils : the organic carbon rate, the texture and the content of $CaCO_3$. Aggregate stability were measured according to the method selected at the exit of the first part of this study.

Data analysis

An overall assessment of the intensity between each aggregate stability index and the whole of the variables of simulated rainfall was obtained by a synthetic coefficient of correlation (rsyn), defined as a the root square of the mean of the squares of the Pearson's correlation coefficients of the best non linear regressions betwwen each aggregate stability indexes and each variable of simulated rainfall.

RESULTS AND DISCUSSION

1. Aggregate stability indexes efficiency

The land use situations with the highest aggregate stabilities (fallow and secondarily mechanically weeded vineyard) have also the highest rainfall before runoff initiation (RBR), the lowest runoff coefficients(KRU30, KRI30, KRIPAL) and the lowest soil losses (ERO30) (cf table 3). The values of aggregate stability indexes, however, can be relatively different from one method of obtention to another method.

			Corconne Village: Grassy Fallow	Corconne Village: Young weeded Vineyard	Corconne Village: weeded Vineyard	Pradel: Chemically weeded Vineyard	Pradel: Mechanically weeded Vineyard
Simulated Rainfall variables	Runoff	RBR mm	42	9	9	10	21
		KRU30 %	0	38	26	27	4
		KRI30 %	0	74	77	64	7
		KRIPAL %	0	82	88	86	36
	Soil losses	TURBI30 $g.l^{-1}$	/	6	4	4	4
		TURBIPAL $g.l^{-1}$	/	7	2	3	5
		ERO30 $g.m^{-2}$	0	76	29	40	3
Soil Aggregate Stability Indexes	Le Bissonnais	$MA200_{LB}$ %	91	37	33	42	55
		MWD_{LB} µm	3730	136	132	156	245
	Yoder	$MA200_{YOD}$ %	93	35	33	24	37
		MWD_{YOD} µm	3940	135	135	53	85
	Henin	$MA200_{HEN}$ %	73	32	28	35	30
	Kemper & Rosenau	$MA200_{KEM}$ %	83	24	21	37	31

Table 3. Averages of the simulated rainfall variables and corresponding aggregate stability values.

Figure 1 shows that the indexes resulting from the method of Le Bissonnais (MA200 and MWD in its logarithmic form) are the best adjusted with the runoff and soil losses variables :

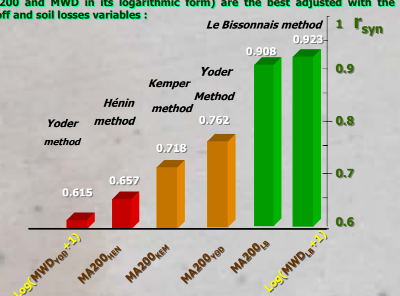


Figure 1. Synthesis of statistical relationships between aggregate stability indexes and rainfall simulation variables

2. MWD_{LB} spatialization

2a. obtention of a pedotransfer function for MWD_{LB} evaluation

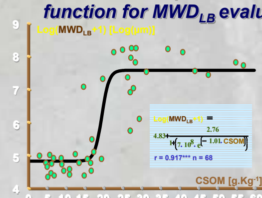


Figure 2 . Relationship between CSOM and MWD_{LB}.

1. A strong relationship were found between log(MWD_{LB}) and the organic carbon rate CSOM (cf figure 2). The function shows a threshold between 20 and 25 g/kg of CSOM. The relationships between log(MWD_{LB}) and texture was weaker (r < 0.42) and limited to the low organic carbon rates. No significant relation was found between MWDLB and CaCO3 content

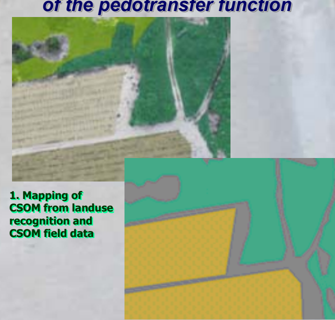
2b. High resolution aerial imaging

Picture 3. Aerial image from IRD Pixy drone ®.
(The car on the top right side of the picture gives approximately the scale).

2. Remote sensing using the Pixy drone ® allowed to obtain a high resolution aerial image, from which the land use areas can be easily identified

MWD_{LB} mapping

2c. Image analysis and application of the pedotransfer function



1. Mapping of CSOM from landuse recognition and CSOM field data

2. Mapping of MWD from pedotransfer function (cf figure 2) and CSOM Map

Conclusion :

In Mediterranean region, the MWD_{LB} aggregate stability index, as soil indicator, could be integrated in a model of spatial evolution of carbon stocks which would take into account the erosion risks.

SELECTED REFERENCES

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