The Evaluation of Soil Erosion C Factor

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Abstract

According to USLE model, soil erosion depends on a number of factors including type of crop (C factor). Tillage is the only agricultural practice with an evident impact on soil erosion. This has led us to estimate the above mentioned factor by the characteristics of tillage. These characteristics are amount of tillage, mode of tillage and sward absence. They were respectively estimated by normalizing the rates of agricultural mechanization companies, by the coefficients of the environmental hazard of tillage tools and by the ratio between the time that elapses from the first tillage and the emergence of the crop and the total time for which the crop remains on the soil. Referring to conventional cropping, an appropriate algorithm has allowed us to calculate the C factor for a number of crops for which it is already known from literature. The obtained values confirm the correctness of the estimation model.

Keywords: Soil erosion, C factor, tillage

1. *Introduction*

The term erosion indicates the phenomena of rock fragmentation and transport of the products of the fragmentation; its principal agents are gravity, ice, water and wind (Alden, 2014). It is, therefore, a natural phenomenon that over geological time is essential for the formation of agricultural land but which, if too accelerated, causes removal of the top soil layer, resulting in its degradation and consequent severe economic damage (Joint Research Centre, 2015). The main causes of soil erosion are inappropriate agricultural practices, deforestation, overgrazing and building activities (Van der Knijff et al., 2000). Regarding economic damage, it is estimated that only its "on-site" effects cause losses that on a regional level can reach 10% of the total production and that on a global level can reach 10 million hectares of arable land per year (FAO, 1996). The severe economic damage caused by soil erosion and its complexity have stimulated its modelling, so that in a study about soil erosion in Veneto Region (Italy) thirty different models to estimate soil erosion are listed (Arpav, 2008). Nevertheless, one of the most used models for its study is still the USLE model (Universal Soil Loss Equation) defined in 1960 by Wischmeier and Smith for the Soil Conservation Service of the United States. The equation is the following:

$$E = R\,K\,LS\,C\,P$$

Where:

E = amount of eroded soil (t/ha/year);
R = rainfall erosivity factor;
K = soil erodibility factor;
LS = length (L) and slope (S) factors;
C = plant cover factor;
P = cultural practice and/or anti-erosion factors.

USLE is an empirical model. The values assumed by the factors that compose it, thus, are experimentally determined. For the C factor, specifically, defined as the ratio between the erosion on bare soil and the one in presence of a given crop, it was found that it can assume the following values (FAO, 1996): 1 on bare soil, 1/1000 with forest, 1/100 with lawn and between 1 to 9/10 with root or tuber crops. More exactly, Table 1 shows some C factor values from different sources (Fugazza, 2011; Drzewiecki et al., 2013; Panagos et al., 2015).

In literature, moreover, there are also some studies that suggest different ways of estimating C factor. Kouk et al. (2013), for example, to investigate C factor values, determines it for a certain crop multiplying together the type of crop and the method of tillage corresponding to the considered crop; then, by a buffer zone calculator built on the river, measures the values of TSS (Total Suspended Soil) at the mouth.

According to several authors, however, (Panagos et al., 2015) the C factor of arable land can be calculated multiplying the C factor of crops (C crop) for the importance of the management practices (C management) which, in turn, depends on the tillage (C tillage), from plant residues left on the ground (C residues) and on the cover exerted by the same crops (C cover); all these sub C factors, of course, must be experimentally determined. Given the above, the aim of this contribution is to propose a methodology to estimate soil erosion C factor using the characteristics of tillage. The new knowledge brought by this contribution, therefore, consists in tying soil erosion C factor to tillage, in the identification and quantification of tillage characteristics that are relevant for this purpose and in the developing of a simple and effective algorithm to calculate soil erosion C factor processing these characteristics.

2. Materials and methods

The idea of estimating soil erosion C factor by means of the characteristics of tillage comes from the consideration that tillage is the only agricultural practice with a clear impact on soil erosion and that the impact made by it depends on the tillage amount, on the tillage mode and on the length of time in which the soil remains without grass. The estimation methodology that is proposed, therefore, involves the quantifying of the three factors mentioned above and their processing by means of an appropriate algorithm.

2.1 Amount of tillage

Tillage is the breaking-up of soil surface. To quantify this factor, therefore, both the depth of tillage and the degree of fragmentation in which the soil is brought must be taken into account. Although these two parameters (depth and degree of fragmentation) can be measured, their combination into a single element is not a simple thing to do, also because, all other things considered equal, the degree of fragmentation which is obtained varies greatly depending on the moisture content of the soil and of its texture. This difficulty can be overcome by considering that the factor we want to quantify (tillage amount) is the result of mechanical stress applied to the soil to perform the tillage and that it is "measured" by the rates of agricultural mechanization companies. Therefore, an estimate of the tillage amount can be obtained by normalization of the considered rates[1]. In this regard, Table 2 shows the rates of UNIMA[2] 2011 and the related amount of tillage (AT). As can be seen, the normalization of rates has been made by means of the higher one. As will be seen shortly, also, it is important to note that rates are unable to discriminate between the modes of tillage. Tillage 13 and 14, for example, or 20 and 21, despite being very different in terms of execution mode, have very close or even the same rates. This is, obviously, because the magnitude of the rates of agricultural mechanization companies depends primarily on the machine purchase cost and on the time of its use per unit of area. Not varying these two factors, in fact, the mode in which tillage is performed is indifferent to the contractor.

2.2 Mode of tillage

In normal conditions, undisturbed soil is structured. The physical, chemical and biological processes that take place in it that is, involving the aggregation of the particles that compose it into lumps. Inside and between the lumps, the presence of water (micro-porosity) and air (macro-porosity) is respectively ensured. Thus, for soils consisting mainly of fine particles, its structure is essential for fertility (Bonciarelli, 1981). Tillage is a factor of evident ruin of the structure of the soil because it involves the break-up of lumps which can result in an excessive loss of macro-porosity and excessive oxidation. The loss of macro-porosity also reduces the ability of soil to lose water by percolation. The excessive oxidation, however, involves the rapid mineralization of organic substance, the main adhesive of lumps, therefore demolition of the structure with consequent soil compaction and further inability to lose water by percolation. All phenomena highly linked to the degradation and erosion of soil. It is also clear, moreover, that, all other things considered equal, the degree of break-up of the soil structure operated by tillage is related to the mode in which the tillage is realized.

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[1] To be correct, we should consider just the parts of the rates related to the machine purchase and management costs. At this level of the study, however, we think such a high degree of precision is not necessary.

[2] UNIMA = Italian National Union of Agricultural Mechanization Companies

This fact, in addition to being intuitive, is universally recognized, so that the very foundations of conservative agriculture (or blue farming) are based on the concepts considered here. Despite this, regarding the environmental hazard of agricultural tools, intending thereby their ability to effectively destroy the soil structure, not much information is available.

Nyakatawa et al. (2001) estimated that, respect to conventional tillage, the no-tillage reduces soil erosion by water by 75%. Pande et al. (2013) state that "Under the conventional (erosive) practices, it would take 59 years and 87 years to realize a reduction in yield to the tune of 50 per cent and 75 per cent, respectively. But if a conservation practice is adopted, this period is extended to 150 years and more than 200 years, respectively". Finally, about the C tillage factor seen above, Stone and Hilborn (2011) propose to use different values of it, depending on the tillage practice used. The values proposed are: 1 for conventional tillage, 0.35 for conservation tillage and 0.25 for no-tillage. Despite the scarcity of knowledge on the subject, the use of tillage mode in the evaluation of C factor requires its quantification. This quantification, therefore, is made on the basis of the main characteristics of tillage and on the basis of the main characteristics of tools. Tillage is traditionally classified into the following types (Bonciarelli, 1981):

- Tipping: determines the overturning of the topsoil inverting the layers of soil (ploughs and spades);
- Ripping: determines the break-up of soil without overturning and/or mixing it (rippers, grubbers);
- Mixing: determines the mixing of the soil layers (disk ploughs, disk and rotating harrows).

Tools, however, are distinguished into the following types:

- Unpowered, if they are simply pulled by the tractor. The motion to contingent mobile parts is due to the friction with the soil;
- Powered, if motion to the mobile parts is due to the power take off from the tractor.

Considering the above, for the quantification of tillage mode, the environmental hazard (EH) coefficient is proposed and its values are shown in Table 3. As can be seen, the values were obtained by normalizing, with respect to their average value, of the products that are obtained by multiplying the weights assigned to the different types of tillage by those assigned to the type of tool. Considering the information available from literature not enough to build an equilibrate weighting system, the weights we have used are natural numbers (those in brackets) that align and place at regular interval the above examined characteristics of tillage and tools, in ascending order according to their environmental hazard. No tillage, of course, has zero weight. Given the importance of the tillage mode in the context of soil erosion, the normalization of the above products was carried out on the basis of their average value (instead of the maximum one) so that the coefficients of environmental hazard will not have values that are clearly underestimated compared to the other factors in the model (amount of tillage and absence of the sward)[3]. The use of the average value of the products as the normalization factor also allows us to limit the variability of the coefficients of environmental hazard. The variability of the unpowered tools, more exactly, is limited within a range of one unit, with minimum and maximum values respectively equal to zero and one. This, moreover, makes an easier comparison between both types of tools for each type of tillage.

2.3 Sward absence

The consequence of tillage is not only the break-up of the soil surface but also the destruction of the sward that, under no-tillage, retains the soil and protects it from weathering. Absence of sward, therefore, facilitates the erosive action of these agents so that, all other things considered equal, they will be much more effective the longer the time in which the soil remains without the protection considered here[4]. In view of the above, the aspects of crops that appear relevant to the estimation of the sward absence contribution to soil erosion are essentially two: the time between the first tillage and the moment in which the crop covers the soil again (t) and the duration of the crop, namely the time between the first tillage and the harvest (T). An objective measurement of the degree of coverage of the soil by a crop is given by the LAI[5].

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[3] We could have to obtain the same result weighting the factors considered in the evaluation model. At this stage of the study, however, the selection of the weights can be only subjective. So, we think that the adopted solution is more easy and clearer.

[4] Rainfall is the most important soil erosion factor and it is varying during the year. So, to be correct, the sward absence months should be weighted by the respective rainfall quantity. We think, however, that, at this level of the study, such a high degree of precision is not necessary.

[5] Leaf Area Index. It is given by the leaf area insisting upon a soil unit area.

The first parameter mentioned above (t), therefore, should be calculated with reference to the moment in which, for the considered crop, the examined index assumes a particular value. Unfortunately, it is not very easy to find information regarding this index related to the specific crops and to the specific moments of their life. So, if we rule out the possibility of the use of the named index, the best proxy of it seems to be inferred from the phase in which the crop emerges of the land[6] because, given the unequal development between plants belonging to different families, the use of more advanced phonological stages seems inappropriate. Table 4 shows the t values calculated for some crops on the basis of the above explained criterion (Baldoni and Giardini, 2000). Regarding the duration of the crop (T), moreover, we think we have to consider the effective time for which the crop remains on the land. So, we ought to consider 12 months for annual crops, multiples of 12 months for perennial crops and periods shorter than a year for the succeeding crops. As stated above, we propose as estimator of the sward absence the ratio t/T. Note that its maximum value is 1 only for fallow.

2.4 The processing algorithm

It is not always very easy to decide if two or more factors that cooperate in forming an event have additive or multiplicative effect. In medical and environmental fields, for example, the current approach is to consider pathological agents with multiplicative effect (Stella, 2011). With reference to the phenomenon considered here, between the amount and the mode of tillage there is a clear multiplicative effect. This type of effect, in fact, is the only one able to cancel out the amount of tillage carried out with a tool without environmental hazard (grass shredding, for instance). The existence of an additive effect among the types of tillage carried out for a crop, moreover, is assumed. Finally, for the sward absence, being a factor that exerts its action over time, we have to assume once again the existence of a multiplicative effect. To sum up, the algorithm that seems more appropriate to process the factors discussed above and, therefore, to estimate the soil erosion C factor is the following:

$$C = \left[\sum_{i=1}^{n} (ATi\ EHi)\right] t/T$$

Where:

C = soil erosion C factor

AT_i = amount of the i-th tillage carried out for the crop

EH_i = environmental hazard of the tool used for carrying out the i-th tillage

t = time (month) between first tillage and the emergence of the crop

T = duration of the crop (month).

As already mentioned, the value of t must be adapted to the different circumstances.

In the case of tree plantation, for example, the value of t can be calculated considering the time between the first tillage and the period in which spontaneous grass emerges. As can be seen, moreover, the value of C factor is zero (no contribution of the crop to the soil erosion) only in conditions of no tillage.

3. *Results and discussion*

The C factor evaluation procedure by the algorithm seen above is shown in table 5. The table, more exactly, lists the above mentioned crops and illustrates the set of tillage carried out for each crop. The set of tillage is provided by traditional farming techniques (Baldoni and Giardini, 1982). For each tillage, moreover, the table shows the tillage amount and the environmental hazard coefficient of the tool used to till. The weight of each tillage (single tillage weight) is obtained multiplying these two variables (tillage amount and environmental hazard). The total tillage weight, furthermore, is obtained by summing the single weights within the crop. The value of sward absence, moreover, is obtained by the ratio of “t” and “T”[7] values of each crop. The value of the C factor, finally, is obtained multiplying the total weight of the tillage by the sward absence value.

As can be seen, the obtained C factor values, in term of their magnitude, divide the crops into two groups: renewal crops (Corn, Sorghum, Cotton, Soybean, Potatoes and Sugar beet) and not renewal cereal (Rice, Wheat and Barley). Inside each group, in fact, the C factor values are very close to each other.

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[6] The degree of coverage of the soil by a crop during the emergence phase depends, of course, on its sowing density. So, choosing this phenological phase, we underestimate the soil protection capacity of the crops characterised by high sowing density (cereals, for example) or, on the contrary, we overestimate the soil protection capacity of the crops characterised by low sowing density (vegetables, for example).

[7] T was evaluated 36 months in the case of Alfalfa and 12 months for all the other crops.

This is, obviously, due to the fact that, inside each group, the crops are very similar for both the tillage weight and the sward absence. The only exception to this is given by the Soybean which, in fact, is a renewal crop less demanding in term of tillage. In the end, Alfalfa, being a pluriannual forage crop, needs a very small tillage and has very good soil coverage, so its C factor value is very small. The difference between the C factor values in renewal crops and the ones in the crops of the second group, in any case, is well evident. In Table 6, at last, the estimated values of C factor and the ones already shown in Table 1 are compared. Note that from the Morgan series we have considered just the crops labelled like “high productivity”.

This is because the aim of the table is to compare this data set with the one estimated for Italian agriculture, and we assume that Italian agriculture is “high productivity”. From the Drzewiecki and Panagos series, instead, we have considered just the C factors referred to single crops[8]. From the Drzewiecki series, moreover, we have considered the C factors of winter wheat and barley because in Italy they are more common of the spring ones. The estimated value of Alfalfa, finally, is been compared with the one of the green fallow (Drzewiecki series) because these two crops are very similar. As can be seen, the estimated values are always very close to those measured. The correlation coefficients between the estimated data and the measured ones, stressed in the last line of the table, in fact, are always very high, especially for the Morgan series. The lower correlation coefficient (Drzewiecki series), which in any case represents a good result, can result from the low number of data contained in the series and from the fact that they exhibit very little variability. Overall, the obtained results are surely better than the expected ones, and this can only mean that the estimation model we are proposing works very well.

4. Concluding remarks

The aim of the paper is to propose an estimate methodology of the soil erosion C factor using the characteristics of tillage. In order to formalize this thesis, the identification and the quantification of the factors related to tillage and potentially impacting on soil erosion were necessary. These factors were identified in tillage amount, tillage mode and in sward absence. Tillage amount was quantified by normalizing the rates of tillage in use by agricultural mechanization companies. Tillage mode, defined by the combination between types of tillage and types of tools, was quantified by the environmental hazard coefficients. The contribution to the soil erosion of sward absence, finally, was estimated by the ratio between the time in the middle of the first tillage and the crop emergence and the crop duration. In the definition of the processing algorithm of the considered factors, a multiplicative effect between tillage amount and tillage mode was supposed.

Then, an additive effect was hypothesized between all the tillage carried out for the same crop. Finally, a further multiplicative effect was supposed between the sum of the tillage and the sward absence index. A test for the proposed methodology was carried out by calculating the C factor of some crops which was already known in literature; this, obviously, referring to traditional production techniques. The results obtained were better than the expected ones. The statistical analysis, in fact, showed that between the sets of data (estimated and measured) there is a correlation coefficient included between 0.823 and 0.965. It must be noted, in the end, that the effectiveness of the proposed methodology could also be better than that demonstrated. The differences between the compared sets of data, in fact, could, at least partly, be justified by any differences in the techniques used for the crops production. This means, in other words, that the crops for which the C factor is known, could be cultivated with different techniques from the ones for which the C factor was estimated. As previously mentioned, moreover, we must consider that the proposed methodology could be improved at least in the following parts:

- deducting from the rates the costs not related to the machine used;
- calculation the sward absence with reference to the stages of development of the crops;
- Weighting up the months of sward absence with the rain precipitations in the given period.

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[8] In our opinion, some crops can have the same C factor just if they need the same tillage and if they cause the same sward absence. A different think is, of course, the case in which the contribution to soil erosion of some crops is expressed by a single C factor as a result of the weighting, for the respective areas, of the considered crops.

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Table 1. C Factor values from different sources

Morgan (Fugazza)			Drzewiecki et al.		Panagos et al.	
	Min	Max				
Wheat	0.10	0.40	Winter wheat	0.15	Common wheat and spelt	0.20
			Spring wheat	0.18	Durum wheat	0.20
			Rye	0.15	Rye	0.20
			Winter barley	0.15	Barley	0.21
			Spring barley	0.18		
			Oats	0.18		
			Winter wheat-rye	0.15		
			Spring wheat-rye	0.18		
			Winter mixed cereal	0.15		
			Spring mixed cereal	0.18		
Maize (high productivity)	0.50	0.90	Maize	0.22	Grain maize - corn	0.38
Maize (low productivity)	0.02	0.10				
Rice	0.10	0.20			Rice	0.15
Sorghum (high productivity)	0.50	0.90				
Sorghum (low productivity)	0.02	0.10				
Millet (high productivity)	0.50	0.90				
Millet (low productivity)	0.02	0.10				
			Buckwheat, millet and other cereals	0.18		
					Dried pulses and protein crops	0.32
Potatoes (contour ploughing)	0.10		Potatoes	0.22	Potatoes	0.34
Potatoes (up and down ploughing)	0.50					

			Sugar beet	0.22	Sugar beet	0.34
					Oil seeds	0.28
			Winter rape	0.15	Rape and turpin rape	0.30
			Spring rape	0.18		
					Sunflower seed	0.32
					Linseed	0.25
Soya	0.20	0.50			Soya	0.28
Cotton	0.40	0.70			Cotton	0.50
					Tobacco	0.49
			Other industrial crops	0.18		
			Vegetables	0.22		
Meadow	0.01	0.025				
			Fodder bulb plants	0.22		
			Other fodder crops	0.18		
			Green fallow	0.01	Fallow land	0.50
			Black fallow	1.00		

Source: our processing of data from different sources

Table 2. Tillage: rates and tillage amount

N.	Tillage (or tool)	Slope	Type of soil (or other variable)	Tillage depth (cm)	Rates (€/ha)	Amount of tillage (AT)
1	Rolling	plain			32	0.03
2	Pasture/spiked-tooth harrowing	plain			44	0.05
3	Pasture/spiked-tooth harrowing	hill			45	0.05
4	Inter row hoeing (grass crops)				54	0.06
5	Spring-tooth harrowing	plain			55	0.06
6	Spring-tooth harrowing	hill			56	0.06
7	Inter row hoeing (tree plantation)				62	0.07
8	Grass shredding				68	0.07
9	Plough mouldboard	plain			82	0.09
10	Plough mouldboard	hill			82	0.09
11	Disk		2nd tillage		97	0.10
12	Rotary harrowing	plain			103	0.11
13	Combined harrowing		2nd tillage		103	0.11
14	Hoeing	plain	1st tillage		121	0.13
15	Disk		1st tillage		122	0.13
16	Combined harrowing		1st tillage		145	0.16
17	Rotary harrowing	hill			150	0.16
18	Spade				150	0.16
19	Ploughing	plain	loam	25-30	153	0.17
20	Ploughing	plain	loam	35-40	179	0.19
21	Spade	hill	2nd tillage		180	0.19
22	Ploughing	plain	loam	45	223	0.24
23	Ploughing	plain	loam	50	245	0.26
24	Ploughing	plain	clay	40-45	260	0.28
25	Ploughing	hill	both ways	45	273	0.30
26	Ploughing	plain	clay	50	299	0.32
27	Ploughing	hill	both ways	50	317	0.34
28	Ploughing	plain	clay	60	355	0.38
29	Deep ploughing	plain		80-90	693	0.75
30	Deep ploughing	plain		90-100	843	0.91
31	Deep ploughing	plain		more then 100	925	1.00

Source: Our processing on Unima data

Table 3: Coefficients of environmental hazard (EH) of tillage tools

Type of tillage	Type of tool	
	Unpowered (1)	Powered (2)
No tillage (0)	0.00	0.00
Rippers (1)	0.33	0.67
Tippers (2)	0.67	1.33
Remixing (3)	1.00	2.00

Table 4: Sward absence: t values of some crops

Crop	Period of first tillage		Period of crop emergence		t values (month)
	Decade	Month	Decade	Month	
Corn	1	10	1	5	7.0
Sorghum	1	9	1	5	8.0
Cotton	1	9	1	5	8.0
Meadowland (Alfalfa)	1	12	1	4	4.0
Soybean	1	10	1	5	7.0
Rice	2	3	2	5	2.0
Wheat	3	9	1	11	1.3
Barley	2	9	1	11	1.6
Potatoes	1	10	1	5	7.0
Sugar beet	1	9	3	3	6.6

Source: our processing on data from different sources

Table 5. Evaluation procedure and C factor values

Crop	Tillage (or tool)	Tillage amount	Environmental hazard	Single tillage weight	Total tillage weight	Sward absence	C factor value
Corn	Ploughing (40-50 cm)	0.24	0.67	0.16	0.56	0.58	0.327
	Rotary harrowing	0.11	1.00	0.11			
	Rotary harrowing	0.11	1.00	0.11			
	Inter row hoeing	0.06	2.00	0.12			
	Plough mouldboard	0.09	0.67	0.06			
Sorghum	Ploughing (40-50 cm)	0.24	0.67	0.16	0.56	0.67	0.374
	Rotary harrowing	0.11	1.00	0.11			
	Rotary harrowing	0.11	1.00	0.11			
	Inter row hoeing	0.06	2.00	0.12			
	Plough mouldboard	0.09	0.67	0.06			
Cotton	Ploughing (40-50 cm)	0.24	0.67	0.16	0.50	0.67	0.334
	Rotary harrowing	0.11	1.00	0.11			
	Rotary harrowing	0.11	1.00	0.11			
	Inter row hoeing	0.06	2.00	0.12			
Meadowland (Alfalfa)	Ploughing (40 cm)	0.19	0.67	0.13	0.05	0.11	0.006
	Pasture harrowing	0.11	0.33	0.04			
	Rolling	0.03	0.00	0.00			
Soybean	Ploughing (40-50 cm)	0.24	0.67	0.16	0.39	0.58	0.228
	Rotary harrowing	0.11	1.00	0.11			
	Inter row hoeing	0.06	2.00	0.12			
Rice	Ploughing (20 cm)	0.17	0.67	0.11	0.33	0.17	0.056
	Rotary harrowing	0.11	1.00	0.11			
	Rotary harrowing	0.11	1.00	0.11			
Wheat	Ploughing (35-50 cm)	0.24	0.67	0.16	0.38	0.11	0.041
	Rotary harrowing	0.11	1.00	0.11			
	Rotary harrowing	0.11	1.00	0.11			
Barley	Ploughing (35-50 cm)	0.24	0.67	0.16	0.38	0.13	0.051
	Rotary harrowing	0.11	1.00	0.11			
	Rotary harrowing	0.11	1.00	0.11			
Potatoes	Ploughing (40-50 cm)	0.24	0.67	0.16	0.68	0.58	0.394
	Ploughing (30 cm)	0.17	0.67	0.11			
	Rotary harrowing	0.11	1.00	0.11			
	Rotary harrowing	0.11	1.00	0.11			
	Inter row hoeing	0.06	2.00	0.12			
	Plough mouldboard	0.09	0.67	0.06			
Sugar beet	Ploughing (60 cm)	0.38	0.67	0.25	0.60	0.55	0.333
	Rotary harrowing	0.11	1.00	0.11			
	Inter row hoeing	0.06	2.00	0.12			
	Inter row hoeing	0.06	2.00	0.12			

Source: our processing of data from different sources

Table 6. Estimated and measured C factor values and their correlation coefficients

Crops	Soil erosion C factors				
	Estimated values	Measured values			
		Morgan		Drzewiecki	Panagos
		Min	Max		
Alfalfa	0,006	0,010	0,025	0,010	-
Wheat	0,041	0,100	0,400	0,150	0,200
Barley	0,051	-	-	0,150	0,210
Rice	0,056	0,100	0,200	-	0,150
Soybean	0,228	0,200	0,500	-	0,280
Maize (corn)	0,327	0,500	0,900	0,220	0,380
Sugar beet	0,333	-	-	0,220	0,340
Cotton	0,334	0,400	0,700	-	0,500
Sorghum	0,347	0,500	0,900	-	
Potatoes	0,394	0,500	-	0,220	0,340
Correlation coefficients	**-**	**0,965**	**0,935**	**0,823**	**0,847**

Source: our processing of data from different sources