THE EFFECT OF DIFFERENT CROPPING SYSTEMS ON EROSION AND FERTILITY OF ERODED SOILS FROM THE MOLDAVIAN PLATEAU

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Abstract

Investigations, set up in 1968, were carried out on a Cambic Chernozem with a slope of 16%. They have shown the influence of different crop rotations and fertilization on soil erosion and fertility. The determination of water runoff, soil, humus and nutritive element losses by erosion in different crops was done by means of loss control plots, which are isolated from the rest of the area by metallic walls and have basins and devices for division; we took water and soil samples from plots, for determining the partial turbidity and for analyses of chemical elements. The combined use of mean rates of mineral fertilizers ($N_{70}P_{70}$), together with 40 t/ha manure or 6 t/ha crop residues from wheat and maize crops, has resulted in improving soil physical and chemical characteristics and getting yield increases in wheat of 2073-2912 kg/ha, on weakly eroded lands, and 1908-2436 kg/ha on highly eroded lands, compared to the unfertilized control. On highly eroded lands, the mean wheat yields obtained during 1998-2009**,** were comprised between 1238 kg/ha at the unfertilized control and 3674 kg/ha at rates of 70 kg N + 70 kg P_2O_5 + 40 t/ha manure. From the results obtained on erosion in different crop rotations, we have found out that in 16% slope fields from the Moldavian Plateau, soil losses by erosion were diminished below the allowable limit of 3-4 t/ha/year only in case of 4 year-crop rotations with one or two reserve fields, cultivated with legumes and perennial grasses, which protect soil.

Key words: cropping systems**,** fertilization, soil erosion, organic carbon, wheat.

Soil degradation has a direct impact on water and air quality, on biodiversity and climatic changes. The legislation proposed in September 2006 (Directive COM (2006) 232), by the amendment to the Directive 2004/35/EC, has as aim soil protection and conservation of soil capacity, in order to fulfill its economic, social, cultural and environment functions. The Directive COM (2006) 232 concerning soil protection in EU has identified the areas of erosion risk and organic matter decrease, as well as those affected by compaction, acidification and other degradation factors. The long-term experiments carried out at the Agricultural Research Station of Podu Iloaiei, Iasi County, have tried to establish some fertilization systems for getting efficient yield increases, which maintain or increase the content of organic carbon from soil.

The positive effect of applying crop residues, together with moderate nitrogen rates, on crop yield and soil physical, chemical and biological characteristics was found in many regions with different climatic conditions and soils (Linden et al., 2000; Campbell et al., 2005; Liu, 2006; Russell, 2006). Investigations, carried out under different climatic conditions, have shown that the use of crop rotations with legumes and perennial grasses determined a very good capitalization of fertilizers and contributed to the improvement of physical, chemical and biological characteristics of soil (Acosta, 2004; Wilhelm, 2004; Lixandru., 2006; Russell., 2006; Wright , 2007; Ailincăi, 2009; Jitareanu, 2009). The crop residues, which remain on soil surface or are incorporated into soil, protect soil against erosion, determine yield increases and improve soil physical and biological characteristics. In many areas, applying crop residues, together with moderate nitrogen rates, have resulted in improving physical, chemical and biological soil characteristics (Blair et al., 2000; Reicosky, 2002; Campbell, 2005).

MATERIAL AND METHOD

The investigations carried out during 1998 - 2009 on a Cambic Chernozem at the Agricultural Research and Development Station of Podu - Iloaiei, Iasi County, have followed the influence of different fertilization systems on yields, in wheat crops placed in a three year rotation (pea – wheat – maize). For each crop, three fertilization systems were experienced: mineral fertilization with nitrogen and phosphorus rates until N_{140} P_{100}, manure fertilization (20, 40 and 60 t/ha) with and without mineral fertilization and mineral fertilizers + hashed crop residue applied in autumn under the base plowing. Experiments were situated on a 16% slope, according to the method of Latin rectangle, with split plots. We have studied the influence of mineral fertilizers, manure and residues from wheat and maize crops on yield and soil chemical characteristics. The typical Cambic Chernozem from Podu - Iloaiei was formed on a loessy loam, has mean humus content (2.56 - 3.48 %), is well supplied with mobile potassium (215 - 296 ppm) and moderately with phosphorus (24-69 ppm) and nitrogen (0.146 – 0.175 %). In wheat, we have used Gabriela varieties. The determination of water runoff, soil, humus and nutritive element losses by erosion in different crops was done by means of loss control plots, which are isolated from the rest of the area by metallic walls and have basins and devices for division; we sampled water and soil from plots, for determining the partial turbidity and for analyses on chemical elements. The total nitrogen, nitrate, phosphorus and potassium content were determined in soil and water samples, lost by erosion in different crops, thus establishing nutritive element losses. Chemical analyses were done according to the following methods: pH - in watery suspension; humus – by wet oxidation, according to Walkely-Black Method, modified by Gogoaşă; total nitrogen by Kjeldahl Method; mobile phosphorus – by extraction, in solution of ammonia lactate acetate (P-AL); mobile potassium – by extraction in solution of ammonia lactate acetate (P-AL), according to Egner-Riehm-Domingo Method and dosing by flame photometry.

RESULTS AND DISCUSSIONS

The climatic conditions from the Moldavian Plain are characterized by a multiannual mean temperature of 9.6^{o}C and a mean rainfall amount on 82 years of 544.3 mm, of which 381.5 mm during January-August and 162.8 mm during September-December. The climatic conditions during 1998-2009 were favorable to wheat growing and development in seven years and unfavorable, because of low rainfall amount, in the other five years. In the last 12 years, the deficit of rainfall registered during January- June, as compared to the multiannual mean of the area (246 mm), was between 50.9 and 116.6 mm in five years. Since 1964, at the Agricultural Research and Development Station of Podu-Iloaiei, investigations were conducted on the influence of different crop structures and fertilizers on yield and soil fertility.

On weakly eroded lands, the mean wheat yields obtained during 1998-2009, were comprised between 1894 kg/ha (100 %) at the unfertilized control and 4923 kg/ha (160 %) at rates of 70 kg N + 70 kg P_2O_5 + 60 t/ha manure (*Table 1*) Under these conditions, by applying rates of 100 kg N + 100 kg P_2O_5 or 140 kg N +100 kg P_2O_5/ha, the mean yield increases obtained were of 1973 (104 %) and 2491 kg/ha (132 %), respectively.

On highly eroded soil, the mean wheat yield, obtained during 1998-2009, in wheat placed in pea-wheat-maize rotation, was of 1238 kg/ha, under unfertilized, and of 3627 kg/ha at high mineral fertilizer rates ($N_{140}P_{100}$) (*Table 2*). In wheat, the application of mean rates of mineral fertilizers (70 kg N + 70 kg P_2O_5) with 40 t/ha manure has resulted in getting yield increases of 197 % (2436 kg/ha), compared to the unfertilized variant. Applying rates of 140 kg N + 100 kg P_2O_5 resulted in getting yield increases of 132 % (2491 kg/ha) in wheat, placed on weakly eroded lands, and 193 % (2389 kg/ha) in wheat placed on highly eroded soil, compared to the unfertilized variant.

In wheat placed on weakly eroded lands, the mean yield increases obtained for each kg of a.i. of applied fertilizers have varied according to applied fertilizers rates, between 9.4 and 10.4 kg grains ($N_{70}P_{70}$-$N_{140}P_{100}$). On highly eroded lands, the mean wheat yield obtained under unfertilized was of 1238 kg/ha, while the mean yield increases, obtained by applying 40 or 60 t/ha manure, were of 36.8-32.3 kg grains per ton of applied manure.

On highly eroded lands, the mineral fertilizers ($N_{70}P_{70}$-$N_{140}P_{100}$) resulted in getting mean yield increases of 8.6- 9.9 kg grains/kg a.i. of applied fertilizer. Very close yield results were also obtained by applying, for 44 years, rates of 70 kg N + 70 kg P_2O_5/ha +6 t/ha stalks of maize or straw of wheat, variants at which yield increases have varied, according to soil erosion, between 1817 and 2073 kg/ha (96-109 %) on weakly eroded lands and between 1613 and 1908 kg/ha (130-154 %) on highly eroded lands.

The analysis of results obtained has shown that the erosion process, by decreasing soil fertility, has determined the differentiation of the mean wheat yield, according to slope and erosion, from 3830 (100%) to 3020 kg/ha (78.9%). Mean annual losses of yields registered in wheat in the last 12 years, caused by erosion, were of 810 kg/ha (21.1%). Among the factors influencing yield and soil fertility, the fertilization and crops rotation have the greatest contribution to the improvement in the balance of soil nutritive elements. Analyses conducted on soil profiles, at the beginning of testing period and after 44 years, on a slope of 16% and the length of valley side of 310 m, demonstrated that on the entire length of valley side, soils had a very different fertility, being influenced by erosion and silting. For increasing the efficiency of fertilizers and diminishing the losses of mineral elements, by leaching, runoff or elements fixing, the applied rates must be established differentiate according to soil characteristics, plant management, climatic conditions and demands of grown genotypes.

Table 1

Influence of mineral and organic fertilizers on wheat yields, in weakly eroded lands

Fertilizer rate	Yields		Differ.
	kg/ha	%	kg/ha
N_0P_0	1894	100	0
$N_{70}P_{70}$	3216	170	1322
$N_{100}P_{100}$	3867	204	1973
$N_{140}P_{100}$	4385	232	2491
$N_{70}P_{70}K_{70}$	3327	176	1433
$N_{100}P_{100}K_{100}$	4298	227	2404
$N_{140}P_{100}K_{100}$	4638	245	2744
20 t/ha manure	3022	160	1128
40 t/ha manure	3514	186	1620
60 t/ha manure	3953	209	2059
$N_{70}P_{70}$+20 t/ha manure	4152	219	2258
$N_{70}P_{70}$+40 t/ha manure	4806	254	2912
$N_{70}P_{70}$+60 t/ha manure	4923	260	3029
$N_{70}P_{70}$+6 t/ha hashed straw	3967	209	2073
$N_{70}P_{70}$+6 t/ha stalks of maize	3711	196	1817
$N_{70}P_{70}$+3 t/ha stalks of pea	3724	197	1830
$N_{70}P_{70}$+3 t/ha stalks of soybean	3712	196	1818
Mean	3830	100	-
LSD 5%=301, LSD 1% =402, LSD 0.1% = 511 kg/ha			

Table 2

Influence of mineral and organic fertilizers on wheat yields, in highly eroded soil

Fertilizer rate	Yields		Differ.
	kg/ha	%	kg/ha
N_0P_0	1238	100	0
$N_{70}P_{70}$	2438	197	1200
$N_{100}P_{100}$	3230	261	1992
$N_{140}P_{100}$	3627	293	2389
$N_{70}P_{70}K_{70}$	2630	212	1392
$N_{100}P_{100}K_{100}$	3515	284	2277
$N_{140}P_{100}K_{100}$	3697	299	2459
20 t/ha manure	2168	175	930
40 t/ha manure	2708	219	1470
60 t/ha manure	3176	257	1938
$N_{70}P_{70}$+20 t/ha manure	3208	259	1970
$N_{70}P_{70}$+40 t/ha manure	3674	297	2436
$N_{70}P_{70}$+60 t/ha manure	3876	313	2638
$N_{70}P_{70}$+6 t/ha hashed straw	3146	254	1908
$N_{70}P_{70}$+6 t/ha stalks of maize	2851	230	1613
$N_{70}P_{70}$+3 t/ha stalks of pea	3105	251	1867
$N_{70}P_{70}$+3 t/ha stalks of soybean	3047	246	1809
Mean	3020	78.9	-810
LSD 5%=286, LSD 1% =385, LSD 0.1% = 496 kg/ha			

From research conducted since 1962, Gumpenstein (Austria) on a sandy loam soil showed that the cultivated land for 13 years with cereals (barley) 62%, rape 23% for forage and grains, peas 8% and 7% flax (fiber crop), organic carbon content in the soil layer 0-20cm was 20.40 g / kg soil in the plot fertilized with 240 kg N, 240 kg P_2O_5 (super phosphate) and 360 kg K_2O (KCl) and of 32.85 g / kg soil in the variant treated with manure (240 kg N / ha / year) (Rajinder, 2005).

The analysis of agrochemical data shows that nitrogen fertilizers (ammonium nitrate) have determined the pH decrease. A significant diminution was recorded in the ploughed layer, at rates of 140 kg/ha N, where the pH value has reached 5.6, after 44 years (*Table 3*). After 44 years of testing, the pH value decreased, according to applied fertilizer rates, from 6.2 to 5.6, at a depth of 0-20 cm. Maintaining under favorable limits for plant growing and development of main soil chemical characteristics was done only in case of organic and mineral fertilization. On slightly eroded lands, maintaining a good supply in soil nutritive elements was done by the annual use of fertilizer rates of at least $N_{140}P_{80}$ or $N_{70}P_{70}$+ 40 t/ha manure, applied once in two years or $N_{70}P_{70}$ + 6 t/ha straw (*Table 4*). The annual application of rates of N_{140}+100 P_2O_5, in a three year crop rotation (peas-wheat-maize) has determined the accumulation of a reserve of mobile phosphates in soil of 68 mg/kg on highly eroded fields and of 89 mg/kg on weakly eroded soils (*table 3,4*). On weakly eroded fields, keeping the organic carbon content at over 19.1 g/kg was done by annual application of average mineral fertilizer rates ($N_{70}P_{70}$), together with 6 t/ha of wheat and maize residues, in annual legumes-wheat-maize rotation. On highly eroded fields, the organic carbon content was kept at values of 20.2 g/kg only by the annual application of a rate of 60 t/ha manure or $N_{70}P_{70}$+ 60 t/ha manure. The annual application for 44 years, of 6 t/ha crop residues (wheat and maize), together with 70 kg/ha nitrogen and 70 kg/ha P_2O_5, has kept the organic carbon content from soil at values of 18.8-19.1 g/kg on weakly eroded fields and of 18.4-18.5 g/kg on highly eroded soils.

In peas-wheat-maize rotation, the mean rate fertilization with mineral fertilizers, together with 60 t/ha manure, has resulted in increasing the organic carbon content from 18.8 to 21.6 g/kg soil (*Figure 1*). On strongly eroded lands, maintaining a good plant supply in mineral elements was done at rates of $N_{140}P_{100}K_{80}$, $N_{70}P_{70}$+6 t/ha hashed straw or $N_{70}P_{70}$ + 60 t/ha manure. Under these conditions, the organic carbon content from soil, after 44 years of experiencing, was maintained at the initial value and there were not found nutrition troubles with microelements in plants (*Figure 2*). Both on weakly and highly eroded fields, the mineral fertilization with lower rates than $N_{100}P_{100}$

kg/ha have resulted in diminishing the organic carbon content from soil until 16.5- 18.2 g/kg (*figure 1,2*). The results of chemical analyses have shown that in the peas-wheat-maize rotation, by the annual application rate of $N_{100}P_{100}$, the decrease in the organic matter content from soil could not be prevented, its level increasing only at the variants where mineral fertilizers were applied with manure or crop residues.

Table 3

Impact of fertilizers on organic carbon and phosphorus content, in weakly eroded lands

Fertilizer rate	pH, H_2O	C org., g/kg	P-AL, ppm
N_0P_0	7.1	16.6	15
$N_{100}P_{100}$	6.2	18.2	79
$N_{140}P_{100}$	5.6	18.4	89
$N_{100}P_{100}K_{100}$	6.3	18.3	81
$N_{140}P_{100}K_{100}$	5.7	18.4	92
40 t/ha manure	7.1	21.1	71
60 t/ha manure	7.2	21.3	74
$N_{70}P_{70}$+40 t/ha manure	6.9	21.4	87
$N_{70}P_{70}$+60 t/ha manure	7.0	21.6	95
$N_{70}P_{70}$+6 t/ha hashed straw	6.9	19.1	66
$N_{70}P_{70}$+6 t/ha stalks of maize	6.7	18.8	64
$N_{70}P_{70}$+3 t/ha stalks of pea	6.8	18.5	59
Mean	6.6	19.3	73
LSD 5%	0.21	0.10	4.7
LSD 1%	0.32	0.14	7.1
LSD 0.1%	0.47	0.18	9.8

Table 4

Effect of soil erosion and fertilization system on organic carbon in highly eroded soil

Fertilizer rate	pH, H_2O	C org., g/kg	P-AL, ppm
N_0P_0	6.9	14.6	10
$N_{100}P_{100}$	6.1	16.5	61
$N_{140}P_{100}$	5.5	16.7	68
$N_{100}P_{100}K_{100}$	6.2	16.5	62
$N_{140}P_{100}K_{100}$	5.6	16.7	69
40 t/ha manure	7.0	19.8	65
60 t/ha manure	7.1	20.2	68
$N_{70}P_{70}$+40 t/ha manure	6.7	19.6	72
$N_{70}P_{70}$+60 t/ha manure	6.8	20.2	78
$N_{70}P_{70}$+6 t/ha hashed straw	6.7	18.5	59
$N_{70}P_{70}$+6 t/ha stalks of maize	6.5	18.4	56
$N_{70}P_{70}$+3 t/ha stalks of pea	6.7	18.3	52
Mean	6.5	18.0	60
LSD 5%	0.19	0.09	4.5
LSD 1%	0.31	0.13	6.8
LSD 0.1%	0.45	0.16	8.8

The analyses conducted on cambic chernozem soil, on which pea-wheat-maize rotations were used for 44 years, have shown that these crop structures were not sufficient for erosion control and maintaining soil fertility. The results on water runoff and soil losses in different crops from the Moldavian Plateau, determined by control plots, have shown that, in the last 12 years, of the total amount of 594.6 mm rainfall, 374.3 mm (62.9%) produced runoff, which was between 11.6 mm in perennial grasses, on the second year of vegetation, and 38.7- 39.2 mm, in maize and sunflower crops. The annual soil losses due to erosion, recorded at the same period, were between 0.184 t/ha in perennial grasses, on the second year of vegetation, and 7.548 – 7.816 t/ha in maize and sunflower crops (*table 5*).

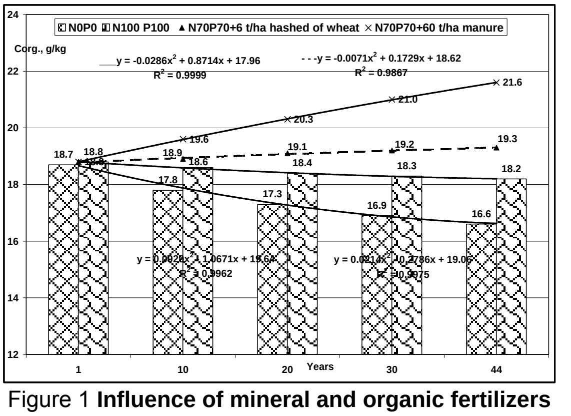

Figure 1 **Influence of mineral and organic fertilizers on organic carbon content, in weakly eroded lands, after 44 years of experiments**

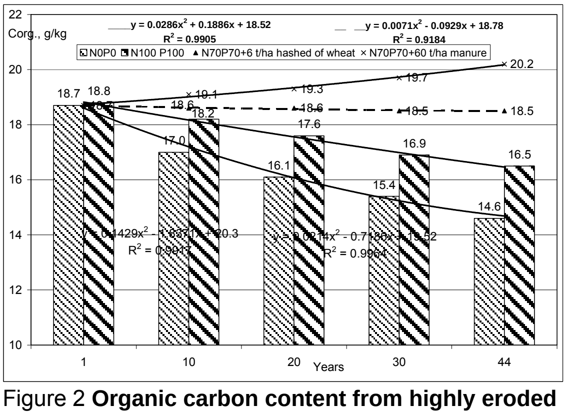

Figure 2 **Organic carbon content from highly eroded soil, after 44 years of applying different fertilizer rates**

From the investigations carried out on erosion, based on direct determinations, we found out that the erosion in the Moldavian Plateau, in peas-wheat-maize rotation, had a mean value of 3.297 t/ha (*figure 3*). At 3- year crop rotations, which included good and very good cover plants for protecting soil against erosion, the amounts of eroded soil and nutrients lost by erosion were very close to the allowable limit for this area. The obtained results on erosion in different crop rotations have shown that under conditions of

16% slope lands of the Moldavian Plateau, the diminution in soil losses below the allowable limit of 3-4 t/ha was done only in 3-4 year crop rotations with one or two outside fields, cultivated with perennial grasses and legumes that protect better soil against erosion. On 16% slope lands, the use of a crop structure made of 20% peas, 20 % wheat, 20% maize and 40% perennial grasses and legumes, has determined the diminution by 70.6% (5.331 t/ha) of soil losses by erosion and the reduction by 64.4 % (11.8 kg/ha) of mineral element losses, compared to maize continuous cropping *(figure 3*). Erosion has affected soil fertility by removing, once with eroded soil, high amounts of humus and mineral elements, which reached 7.895 kg/ha nitrogen, 0.38 kg/ha phosphorus and 0.77 kg/ha potassium in peas-wheat-maize rotation (*table 6*).

Table 5

Average annual water and soil runoff by erosion registered in different crops

Crop	Water runoff, mm	Erosion, t/ha	Total NPK, kg/ha	Organic carbon kg/ha
Field	52.4	15.896	34.24	324.5
Sunflower	39.2	7.816	19.12	159.1
Maize	38.7	7.548	18.37	154.5
Bean	31.2	3.986	11.17	81.4
Soybean	24.8	3.098	8.92	63.2
Pea	21.6	1.794	5.93	36.6
I[st] year grasses	21.2	1.832	5.77	37.4
Rape	19.8	1.423	5.21	29.1
Wheat	15.1	0.549	2.99	11.2
II[nd] year grasses	11.6	0.184	1.65	3.8

Table 6

Annual average losses of organic carbon and nutritive elements by erosion in different crops rotation (kg/ha)

Crop rotation	Organic Carbon	Total N	P-AL	K-AL
*Mcc	155	15.517	1.034	1.819
W-M	83	9.156	0.548	0.978
P-W-M	68	7.895	0.377	0.772
P-W-M + G	53	6.537	0.340	0.616
S-W-M + 2G	51	6.227	0.317	0.585
P-W-M + 2G	45	5.722	0.285	0.522
R-W-M + 2G	44	5.595	0.278	0.513

**Mcc= maize continuous cropping, W-M= Wheat-maize rotation, P-W-M =Pea-wheat-maize rotation; P-W-M+G = Pea-wheat-maize +reserve field, cultivated with legumes and perennial grasses, S-W-M+2G = Soybean-wheat-maize + two reserve field, cultivated with legumes and perennial grasses, R-W-M + 2G = Rape-wheat-maize + two reserve field, cultivated with legumes and perennial grasses*

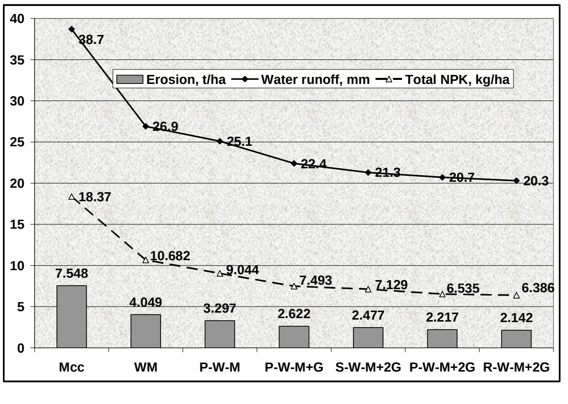

Figure 3 **Soil, water and mineral element losses by erosion in different crop rotations**

CONCLUSIONS

On highly eroded soils from the Moldavian Plain, the mean yields obtained in the last 12 years were lower by 810 kg/ha (21.1%) in wheat, compared to the yields obtained on weakly eroded soils.

On highly eroded lands, the mean wheat yields obtained during 1998-2009**,** were comprised between 1238 kg/ha at the unfertilized control and 3674 kg/ha at rates of 70 kg N + 70 kg P_2O_5 + 40 t/ha manure.

The long- term use (44 years) of high nitrogen rates (N140) has determined a pH decrease from 7.1 to 5.6.

On weakly eroded soils, the annual application of crop residues, which resulted from peas, wheat and maize crops, together with the rate of $N_{70}P_{70}$, have determined maintaining the content of organic content from soil at values of 19.3 g/kg soil.

On highly eroded soils, the increase in the organic carbon content from soil from 18.8 to 21.6 g/kg soil was recorded by the long-term application of the rate of $N_{70}P_{70}$+60 t/ha manure.

Annual soil losses by erosion, registered during 1998-2009, in the Moldavian Plateau, were between 0.184 t/ha in perennial grasses on the second year of vegetation and 7.816 t/ha in sunflower.

On 16% slope lands, the crop structure which determined the diminution in mean soil losses by erosion until 2.662 t/ha included 25 % pea, 25% wheat, 25% maize and 25 % perennial grasses and legumes.

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