Decomposition rates of plant residues in Alfisols under different uses

Mónica Avilés[A], Ángel Faz[B], Roberto Soto[A], Ángel López[A] and Eduardo Salcedo[C]

[A]Institute of Science in Agriculture, Autonomous University of Baja California, Mexicali, Baja California, México, Email monikaviles@hotmail.com
[B]Superior Technical School of Agromic Engeenier, Technical University of Cartagena, Cartagena, Murcia, Spain,
[C]Agronomy Unity, University of Guadalajara, Guadalajara, Jalisco, México.

Abstract
In this study, we evaluated variations of decomposition due biochemical quality of crop residues and land use. Alfisols under different uses (woodland, grassland and cultivated soils) were mixed with alfalfa (*Medicago sativa* L.) and wheat (*Triticum aestivum* L.) in doses of 10 ton of dry matter per/ha, incubated in the lab, in triplicate. CO_2 emanated from the soils was measured after 20, 40, 60, and 80 hours of incubation, and the amount of released C was calculated (mg C/g soil). The difference between the amount of C added by the plant residue and C liberated as CO_2, was named residual C. The C loss was greater and residual C retained was lower ($p<0.05$) for Alfisols where alfalfa was applied than for those were wheat straw was added, which was a function of the biochemical composition differences between the alfalfa and wheat straw residues. Regarding the land use, residue C loss was greater ($p<0.05$) in woodland (*Haematoxylon Campechianum* and *Bucida buceras*) soils and lower in grassland (*Gramineae*), and cultivated soils (*Sorghum vulgare* and *Yucca sp.*). We conclude that the rate of decomposition increases in order of woodland > grassland > cultivated soils, and less residual C is retained.

Key Words
Crop residues, residue decomposition rates, Alfisols, land use

Introduction
Intensive management practices and low addition of organic residues may decrease the content of the soil organic matter (SOM), which negatively affects the sustainability of agricultural production systems. The management of organic residues has been a means of increasing the potential sink for carbon of cultivated soils (Six *et al.* 1999). There has been considerable research into the effects of organic residues, C/N relation, temperature, humidity, and management on decomposition rates; but there have been relatively few attempts to relate the soil C pool, as a result of management and soil characteristics, to decomposition rates in crop residue incorporation systems. Decomposition rates, mostly calculated from the net mineralization of C or N, usually, but not always, show an initial rapid mineralization, after which mineralization becomes much slower (Ajwa and Tabatabai 1994). Decomposition rates vary with the composition of the organic residues, the experimental conditions, and the nature of the soil (Hadas *et al*. 2004). Theng *et al*. (1989) points out that besides the aspects related to SOM quality, its decomposition rate may also be modified by the reaction of SOM on the surface of clays, or by physical barriers, such as materials that remain occluded inside the soil aggregates. These results were attributed to the mineral structure of clays, which is known to interact with organic C of the soil, thus protecting it from decomposition. The protective effect of clays on organic matter is significant, but the soil's respiration might depend on the re-supply of labile substrate apart from the organic carbon reserve (Wang *et al*. 2003). As a result, an understanding of the processes that control SOM dynamics and their response to crop residues management is essential for informed use of agricultural land. As a consequence, the aim of this research was to evaluate the variation of the decomposition by biochemical quality of crop residues under different uses in a representative area with Alfisols.

Methods
We selected six Alfisols from the State of Campeche in Mexico, and samples were collected under different use (medium forest, woodland, grassland and cultivated soils). Soils were classified according to Soil Taxonomy (Soil Survey Staff 2006) (Table 1). From each soil, 10 subsamples were taken from the surface 20 cm, in order to form composite samples. These were dried outdoors in the shade, ground and sieved through a mesh of 2mm. pH was measured with the potentiometric method, soil/water ratio 1:2, and electrical conductivity, with a conductimeter at a soil/water ratio of 1:5 (v/v).

Table 1. Classification and land use of soils.

Classification (Great Group)	Use	Scientific name
Ferrudalf	Woodland	*(Haematoxylon Campechianum)*
Ferrudalf	Woodland	*(Bucida buceras)*
Kandiudalf	Grassland	*(Gramineae)*
Kandiudalf	Yucca Crop	*(Yucca sp)*
Kandiudalf	Sorghum	*(Sorghum vulgare)*

Crop residues used were alfalfa (*Medicago sativa*, C/N ratio 13) and wheat straw (*Triticum aestivum* L., C/N ratio 77). Residues were previously dried at 65°C, ground and sieved through a 40 mesh sieve. Amounts of residue applied to soil were equal to 10 t /ha of dry matter; each treatment was repeated three times. In the plant residues, total N was determined by the semimicro-Kjeldahl method (Bremner 1965), and organic C by wet digestion with the Walkey and Black method (Nelson and Sommers 1982). Protein was estimated indirectly from the total N content (AOAC 1975). Total fiber content (hemicellulose, cellulose and lignin) was determined by the procedure of neutral and acid detergent fiber (Van Soest 1963). Soils were incubated according the Isermeyer method, quoted by Alef (1995) modified by Avilés (2000). Samples were incubated under 65% of field capacity at a temperature of 30°C for 80 hours. CO_2 emanated from the soils was measured after 20, 40, 60, and 80 hours of incubation, and the amount of released C was calculated (mg C/g soil). The difference between the amount of C added by the plant residue and C liberated as CO_2, was named residual C. This was considered as an indirect measure of the C pool present in each soil. The residual C after incubation was related to each type of crop residue applied to soil. The tendency was described by a lineal function (y = -bt + a) where a is the amount of C added in the residue, b is the rate of carbon loss by decomposition, and y is the residual C. With the values of b determined from linear regression, a statistical means trial test was carried out (Tukey α=0.05) to determine if there were significant residue decomposition effects related to soil use.

Results

Soil pH values were from 5 to 8, and electrical conductivity was equal or less than 1 dS/m, thus, we avoided extreme values of acidity or alkalinity that could affect the decomposition processes. The characterization of residues applied is shown in Table 2. The C/N ratio of residues was 13 and 77 for alfalfa and wheat straw, respectively.

Table 2. Characterization of alfalfa (*Medicago sativa* L.) and wheat straw (*Triticum astevium* L.) residues.

Organic residue	Organic C %	N %	C:N	Protein%	Fibers[A] %	Hemicellulose (---%---	Cellulose	Lignin ---)
Alfalfa	44.68	3.35	13	20.9	27.4	1.7	21.2	4.5
Wheat straw	46	0.6	77	3.8	71.1	23.1	39.6	8.4

[A]Percentage of fibers (hemicelluloses +cellulose + lignin)

In order to analyze the tendency of time of residence of plant residues evaluated for different conditions of land use, rates of residue decomposition were determined by regression of the carbon loss from 0 to 20, 40, 60, and 80 hours. The mean coeffecient of determination was r^2 = 0.98 for the 30 trials. Table 3 shows the the rate of residue C loss, coefficient *b*. The more negative is the value of the slope (b), the less is the amount of plant residue that remains after time t. There was a significant relation between the rate of plant residue loss and the residue C:N ratio for each condition of land use. Values of residue C loss with the application of alfalfa were -0.81 to -1.37 µg/g/day, and in contrast those obtained with wheat straw were -0.12 to -0.42 µg/g/day. The alfalfa residue (C:N=13) broke down quicker in time, so that C that remained was less compared to wheat straw (C:N=77). This was ascribed to the biochemical composition of the residues; alfalfa showed a C/N ratio, with more protein content (20.9%) and less fiber content (cellulose+ hemicellulose+lignin=27.4%), facilitating microbial decomposition (emanated C), thus diminishing residual C more rapidly than wheat straw.

In contrast, the biochemical composition of wheat straw showed a high C/N ratio (77), less protein content (3.8%) and more fiber content (71.1%), limiting the activity of microbial biomass and thus diminishing breakdown and retaining more residual C in the soil. Kumar and Goh (2000), mention that residues with a high C/N ratio decompose at a slower rate than those with a low C/N proportion. However, the biochemical features may only explain the initial decomposition rate of the residues, because C coming from the residue

Table 3. Rates of carbon loss from added residues by each land use.

Land Use	Vegetation	Residue	C loss rate (value of b=rate) mg/g/day	MSD
Sorghum Crop	*Sorghum vulgare*	Wheat	-0.28a	
		Alfalfa	-1.36b	0.11
Grassland	*Gramineae*	Wheat	-0.42a	
		Alfalfa	-1.34b	0.16
Yucca Crop	*Yucca sp.*	Wheat	-0.37a	
		Alfalfa	-1.37b	0.09
Woodland	*Haematoxylon Campechianum*	Wheat	-0.12a	
		Alfalfa	-1.02b	0.19
Woodland	*Bucida buceras*	Wheat	-0.14a	
		Alfalfa	-0.81b	0.14

Mean values with different letters (a and b) in the same pair of rows are statistically different, Tukey (α=0.05). MSD=Minimum Significant Difference

declines as time goes by (Trinsoutrot *et al.* 2000). Ladd *et al*. (1992) report that release as $C^{14}O_2$ of C^{14} applied to different soils, went from 15 to 27% after an incubation of 3 days, with significant differences among the studied soils. Similarly, Ajwa and Tabatabai (1994) point out that the amount of total mineralized organic C in soils treated with organic material, showed variations as a function of the kind of organic material that had been applied.

Table 4. Rates of carbon loss from added residues by biochemical composition.

Plant residue	Land Use	Vegetation	C loss rate (value of b=rate) mg/g/day	MSD
Alfalfa	Woodland	*Haematoxylon Campechianum*	-0.81a	
	Woodland	*Bucida buceras*	-1.02b	
	Grassland	*Gramineae*	-1.34c	
	Sorghum Crop	*Sorghum vulgare*	-1.36c	
	Yucca Crop	*Yucca sp.*	-1.37c	0.18
Wheat	Woodland	*Haematoxylon Campechianum*	-0.12ab	
	Woodland	*Bucida buceras*	-0.14abc	
	Sorghum Crop	*Sorghum vulgare*	-0.28bcde	
	Yucca Crop	*Yucca sp.*	-0.37de	
	Grassland	*Gramineae*	-0.42e	0.12

Mean C loss rate values with different letters in the same column, for alfalfa and for wheat trials, are statistically different, Tukey (α=0.05). MSD=Minimum Significant Difference

In order to evaluate how the organic C pool of the soils was affecting the decomposition of plant residues, the C loss rates from each set of land use trials were compared for the two kinds of plant residue by ANOVA. The variance ratio (F) was significant ($p<0.05$) for both alfalfa and wheat straw trials (Table 4). Results showed that in woodland soils, the daily loss of C was from -0.81 to -1.02 µg/g with alfalfa and from -0.12 to -0.14 µg/g with wheat straw. In contrast, in grassland and cultivated soils (*Sorghum vulgare* and *Yucca sp.)* the values were from -1.34 to -1.37 µg/g with alfalfa and from -0.28 to -0.42 µg/g with wheat straw.

The application of a same residue to Alfisols under different use (from natural vegetation to intensive cultivation) show clear differences in the availability and recycling of organic matter in the soils, as well as in soil C pool level. In this sense, Lee *et al*. (2007) found that approximately 45% of added C with manure application was respired; and a large portion was retained in the soil. Campbell *et al*. (2005) showed that changes in SOC depend on the degree to which the soil has been degraded: the greater the previous degradation, the greater the likelihood that a change in management will reverse the process. The results obtained in this study, give us evidence that the decomposition of C that is added to the soil by means of the plant residues not only depends on the quality of the residue, but also by the land use, which is affecting the organic pool and plays an important role.

Conclusion

The C loss was greater and residual C retained was lower ($p<0.05$) for Alfisols where alfalfa was applied than for those were wheat straw was added, which was a function of the biochemical composition differences between the alfalfa and wheat straw residues. Regarding the land use, residue C loss was greater ($p<0.05$) in woodland (*Haematoxylon Campechianum* y *Bucida buceras*) soils and lower in grassland (*Gramineae*), and cultivated soils (*Sorghum vulgare* and *Yucca sp.*). We conclude that the rate of decomposition increases in order of woodland > grassland > cultivated soils, and less residual C is retained.

References

Ajwa HA, Tabatabai MA (1994) Decomposition of different organic material in soils. *Biology Fertility of Soils* **18**, 175-182.

Ajwa HA, Rice CW, Sotomayor D (1998) Carbon and nitrogen mineralization in tall grass prairie and agricultural soil profiles. *Soil Science Society of American Journal* **62**, 942-951.

Alef K (1995) Respiration Soil. In 'Methods in applied soil microbiology and biochemistry' (Eds K Alef, P Nannipieri) pp. 30-33 (Academic Press: Great Britain).

AOAC-Association of official agricultural chemists (1975) 'Official Methods of Analysis 12th Edition'. (Association of Agricultural Chemists: Washington, DC).

Aviles MSM (2000) La respiración del suelo como indicador de la mineralización de las reservas orgánicas edáficas activas en suelos calcáreos. Master thesis, (Postgraduates College: Montecillo, Mexico).

Bremner JM (1965) Inorganic forms of nitrogen. In 'Methods of soil analysis Part 2 Agronomy Monograph 9' (Ed Black CA) pp. 1179-1237 (ASA and SSSA: Madison, Wisconsin).

Campbell CA, Janzen HH, Paustian K, Gregorich EG, Sherrod L, Liang BC, Zentner RP (2005) Carbon, storage in soils of the North American Great Plains: Effect of cropping frequency. *Agronomy Journal* **97**, 349-363.

Hadas A, Kautsky L, Goekand M, Kara EE (2004) Rates of decomposition of plant residues and available nitrogen in soil, related to residue composition through simulation of carbon and nitrogen turnover. *Soil Biology and Biochemistry* **36**, 255-266.

Kumar K, Goh M (2000) Crop residues and management practices: effects on soil quality, soil nitrogen dynamics, crop yield, and nitrogen recovery. *Advances in Agronomy* 68, 197-319

Ladd JN, Jocteur-Monrozier L, Amato M (1992) Carbon turnover and nitrogen transformations in an Alfisol and Vertisol amended with [^{14}C] glucosa and [^{15}N] ammonium sulfate. *Soil Biology and Biochemistry* **24**, 359-371.

Nelson DW, Sommers LE (1982) Total Carbon, organic carbon and organic matter In: 'Methods of Soil Analysis Part 2Agronomy Monograph 9'. (Ed Page AL), pp. 539-579. (ASA and SSSA: Madison, Wisconsin).

Six J, Elliot ET, Paustian, K (1999) Aggregate and soil organic matter dynamics under conventional and no-tillage systems. *Soil Science Society of American Journal* **63**, 1350-1358.

Theng BKG, Tate KR, Sollins P (1989) Constituents or organic matter in temperate and tropical soils. In 'Dynamics of soil organic matter in tropical ecosystems' (Ed Coleman DC) pp. 5-31. (University of Hawaii Press: HI).

Trinsoutrot I, Recous S, Bentz B, Lineres M, Cheneby D, Nicolardot B (2000) Biochemical quality of crops residues and carbon and nitrogen mineralization kinetics under no limiting nitrogen conditions. *Soil Science Society of American Journal* **64**, 918-926.

Soil Survey Staff (2006) 'Keys to Soil Taxonomy'. (United States Department of Agriculture: Natural Resources Conservation Service).

Van Soest PJ (1963) Use of detergents in the analysis of fibrous feeds II A rapid method for the determination of fiber and lignin. *Journal of the Association of Official Analytical Chemists* **46**, 829-835.

Wang WJ, Dalal RC, Moody PW, Smith CJ (2003) Relationships of soil respiration to microbial biomass, substrate availability and clay content. *Soil Biology and Biochemistry* **35**, 273-284.