This paper was peer-reviewed for scientific content.
Pages 1039-1043. In: D.E. Stott, R.H. Mohtar and G.C. Steinhardt (eds). 2001. Sustaining the Global Farm. Selected papers from the 10th International Soil Conservation Organization Meeting held May 24-29, 1999 at Purdue University and the USDA-ARS National Soil Erosion Research Laboratory.

Comparing Erosion and Redeposition Rates and Patterns Upslope of a Grass Hedge Determined Using ^{137}Cesium and Field Survey Techniques

*Jerry C. Ritchie**

ABSTRACT

Many conservation techniques have been used to reduce and slow soil loss from agricultural fields, especially erosion from areas of concentrated flow. Recently there has been increased interest in the application of narrow, stiff grass hedges as a biological barrier to slow runoff and reduce soil loss caused by concentrated flow erosion. However, few quantitative data are available on the effectiveness of hedges for trapping eroded soil. This study was designed to measure quantitatively the deposition of soil upslope of a narrow, stiff grass hedge. Topographic surveys made in 1991, 1995, and 1998 measured 1 to 2 cm yr^{-1} of recent sediment deposited upslope of the grass hedge. ^{137}Cesium (^{137}Cs) analyses of soil samples were used to determine the medium-term (45 years) soil redistribution patterns. Erosion and deposition patterns estimated from the redistribution of ^{137}Cs were related to the original topography with low areas having the greatest deposition rates. Deposition rates and patterns determined using ^{137}Cs reflect net soil loss near the hedge where topographic surveys show high deposition rates suggesting that deposition measured by the topographic surveys is due to recent deposition associated with the hedge.

INTRODUCTION

Soil erosion is a major problem in many parts of the world (Morgan, 1995) leading to concern about the future sustainability of soils. Erosion occurring along narrow flow paths where water concentrates in shallow drainage ways and causes incised channels and gullies is of special concern. Grass filters and buffer strips (5 to 15 m wide) have been widely used for trapping eroding soils and chemicals (Daniels and Gilliam, 1996). However, the effectiveness of grass strips is reduced as flow rates increase, particularly, in areas of concentrated flow (Flanagan et al., 1989). Planting narrow stiff grass hedges on the contour across areas of concentrated flow is an alternative conservation practice for slowing runoff and reducing erosion and soil loss (Kemper et al., 1992).

Grass hedges differ from other types of grass barriers (i.e., buffer strips, filter strips). They are narrow and designed to slow water movement and stimulate the formation of terraces from deposited materials. These dense stands of grass, having stiff stems planted on the contour in narrow strips across flow paths, reduce flow rates of the water allowing time for entrained soil particles in the flow to deposit. These deposited materials fill low places in the field so that water in future runoff events is even more broadly dispersed and less erosive.

The purpose of this study was to quantitatively determine the deposition patterns upslope of a grass hedge using conventional topographic survey techniques and using the redistribution of fallout ^{137}Cs to determine rates and patterns of deposition and erosion.

Study Site

The study site is located on the South Farm at the Beltsville Agricultural Research Center (BARC), United States Department of Agriculture (USDA), Agriculture Research Service (ARS) near Beltsville, Maryland, USA in a field where concentrated flow erosion channels had developed (Fig. 1). The field has a history of row cropping on the contour with alternating years of corn [*Zea mays* L.] and soybeans [*Glycine max* (L.) Merrill]. Contour strips are approximately 36 m wide with 10-15% slopes. Corn is no-till seeded into the soybean stubble while soybeans are planted after minimum tillage (surface disking <10 cm depth) to breakup and incorporates the corn residue. The development of concentrated flow erosion channels was observed starting near the crest of the slope and crossed three cropping strips before joining near the base of the slope to exit from the field. On April 17, 1991, miscanthus [*Miscanthus sinensis* Andress] was transplanted into four (4) hedges in the borders between strips of crops where concentrated flow channel development was evident. Miscanthus was transplanted using clumps (2-5 cm in diameter) at 10 to 15 cm intervals. Transplants were made in the borders between strips of crops to minimize interference with farm operations and to reduce disturbance to hedges during the farm operations. However, despite these efforts, the grass hedge at Site B (Fig. 1) was destroyed during farm operations in 1992. In 1993, miscanthus was transplanted to fill gaps in the original hedges at the other three hedges. In 1994, eastern gamagrass [*Tripsacum dactyloides* (L.) L.] was seeded to fill other gaps and extend the length of the existing hedges at the three remaining hedges.

The original miscanthus hedge at Site A (Fig. 1) grew rapidly and expanded and was two meters tall at the end of the first (1991) growing season. Beginning with 2-5 cm clumps planted 10 to 15 cm apart in 1991; the hedge at Site A had grown to a width of 20-30 cm and a height of 1.5 to 2.5 m by 1994. The hedge has remained at approximately this size since 1994. Each spring, the hedge is trimmed to a height of approximately 30 cm. Trimmed material is left in the field. From a management view, no evidence of viable seed produced by miscanthus has been seen so its spread has been vegetative only.

* Jerry C. Ritchie , USDA-ARS Hydrology Laboratory BARC-West Bldg-007 Beltsville, MD 20705. jritchie@hydrolab.arsusda.gov

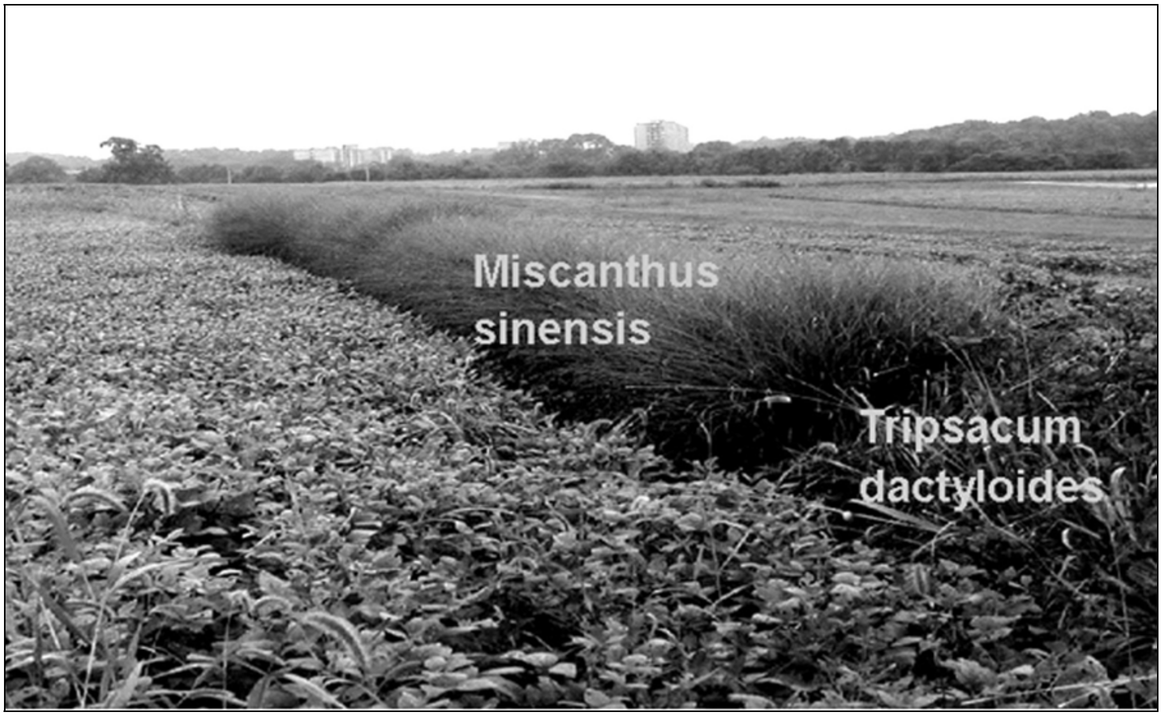

Figure 1. Grass hedge at Site A between soybeans and corn. Trimmed hedge is part of another experiment to determine effects of the hedge on production.

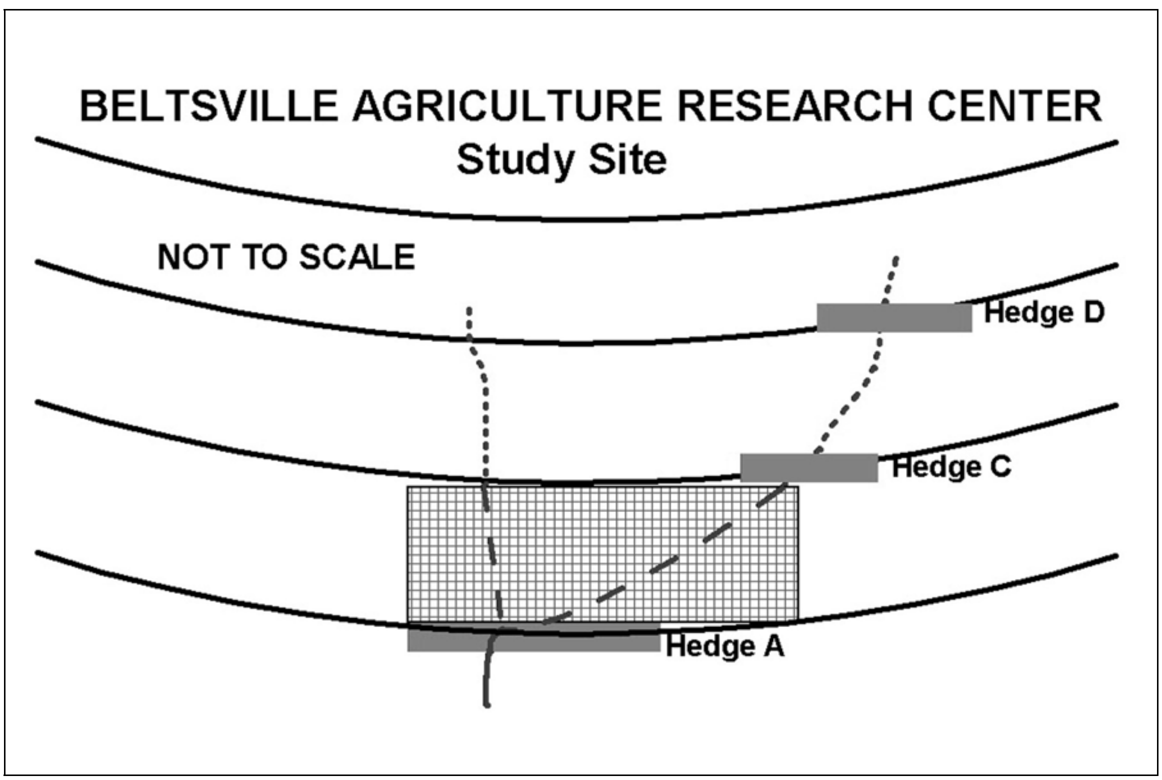

Figure 2. Location of grass hedges at the BARC South Farm study site. Letters and boxes indicate location of miscanthus and eastern gamagrass plantings in 1991 and 1994. Solid lines represent borders between cropping strips and dotted lines represent concentrated flow areas. Soil samples for ^{137}Cs analyses were collected in a 35 x 36 m grid pattern in the contour upslope of the hedge at Site A.

Eastern gamagrass also grew rapidly to form a hedge 30-60 cm tall and 10-15 cm wide by the end of the 1994 growing season. The eastern gamagrass hedge continues to grow and has developed into hedges of 20-30 cm wide and 1.0 to 1.5 m tall.

METHODS

On April 22, 1991, shortly after the original transplanting of the miscanthus hedge, a field survey was made of the topography for each of the hedges using conventional surveying techniques with a level and rod. In 1995 and 1998, these topographic surveys were repeated to determine changes. Survey lines were made 5 cm downslope and 5 cm and 100 cm upslope of the hedges. The 1998 survey was expanded to cover an area 100 x 36 m upslope of the hedge at Site A (Fig. 2). Measurements were made a 1 m interval in this grid.

Soil samples for ^{137}Cs analyses were collected in February 1998. Soil samples were collected upslope of and centered on the grass hedge at Site A (Fig. 2) at 1and 2 m from the hedge and then at 2 m intervals upslope and at 5 m intervals across the slope. The total area sampled was 35 x 36 m. This sampling design allowed sampling of the total area upslope of the grass hedge at Site A. Profile soil samples were collected in 6 cm increments to a depth of 36 cm at 30 selected sites. Bulk samples of the 0-30 cm layer were collected at other sites. At random sites, soil samples were collected to 48 cm. Reference soil samples for ^{137}Cs analyses were collected in a grass and a grass-oak savanna area where BARC farm records showed no tillage activity since the 1940's.

Soil samples were dried at 90° C for 48 hours and weighed. The samples were passed through a 2-mm screen. Materials greater than 2 mm were discarded. A 1-liter Marinelli Beaker was filled with 1000 g of the sieved soil and sealed for gamma ray analyses. Gamma-ray analyses are made using the Canberra Genie-2000 Spectroscopy System. This is a Windows based software/hardware package that receives input into two (2) 8192 channel systems from two solid state crystals. One crystal is a Canberra Lithium-drifted Germanium crystal (Geli - 15% efficiency) and the other is a Canberra High purity coaxial Germanium crystal (HpC - 30% efficiency). The system is calibrated and efficiency determined using an Analytic mixed radionuclide standard (10 nuclides) whose calibration can be traced to U.S. National Institute of Standards and Technology. Estimates of radionuclide concentrations of the soil samples are made using the Canberra Genie-2000 software. ^{137}Cesium is detected at 662 kev and count time for each sample is 30,000 seconds, providing a measurement precision of + or 4 to 6% on most samples.

Using ^{137}Cs to estimate erosion and deposition rates is base on a comparison of ^{137}Cs concentration at a sample point with local fallout input of ^{137}Cs as measured at the reference site where no loss of ^{137}Cs has occurred (Ritchie and McHenry, 1990). Sample sites with ^{137}Cs concentrations less that the reference site are eroding and sampling sites with higher concentration are sites of deposition. Actual estimates of erosion and deposition rates based on ^{137}Cs concentrations are made using the models and software developed by Walling and He (1999).

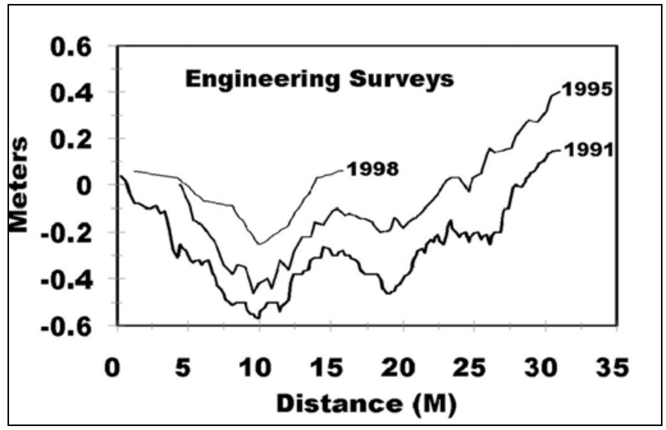

Figure 3. Topographic survey at Site A, BARC South Farm. Survey line was 5 cm upslope of the hedge at Site A.

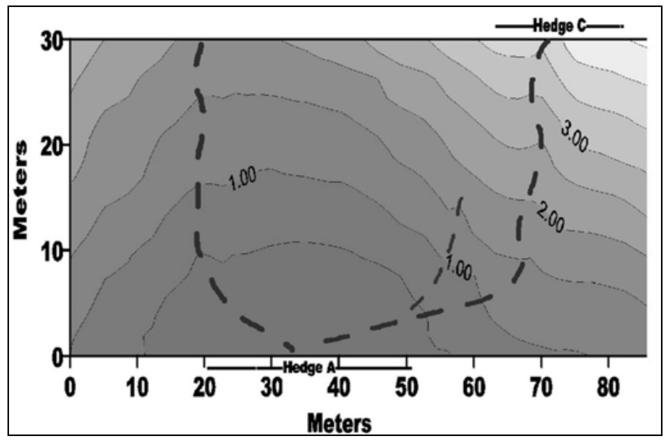

Figure 4. Digital Elevation Map of the surveyed area upslope of the hedge at Site A relative to an arbitrary datum. Note the evidence of a concentrated flow area between Site A and Site C.

RESULTS AND DISCUSSION

Field surveys of topography at the miscanthus hedge at Site A made in April 1991, August 1995, and April 1998 at 5 cm upslope of the center of the hedge (Fig. 2) showed a 2-12 cm depth of deposition (Fig. 3) over the time period. Deposition is greatest in areas where concentrated flow had eroded the deepest channels prior to the establishment of the hedge. There does appear to be a general leveling along the survey line especially with the 1998 survey line but even the August 1995 survey line shows many of the lower areas being filled. A Digital Elevation Model (DEM) created from more extensive topographic survey in 1998 upslope of the hedge at Site A shows the general topography (Fig. 4). The location of the concentrated flow channel between Site A and Site C is still evident on the DEM. Field observations noted an extensive area of deposition approximately 20 m upslope and 40-50 m west of the center of the hedge at Site A. Whether this deposition area is due to the hedge is not clear but it has developed since the hedge was established. The development of new concentrated flow areas downslope

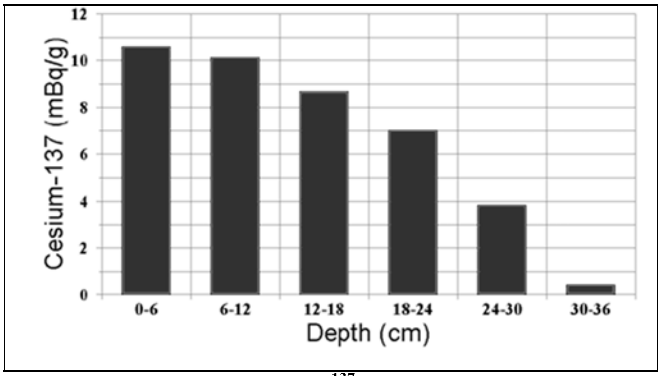

Figure 5. Depth distribution of ^{137}Cs for four soil profiles from reference sites.

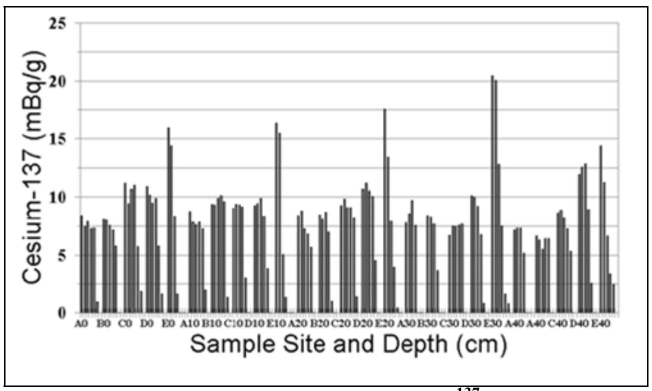

Figure 6. Examples of depth distribution of ^{137}Cs under plowed soil collected upslope of the hedge at Site A. A to E represents soil samples collected at 1, 2, 4, 8, and 16 meters upslope of the hedge and 0 to 40 represents 10 meter intervals along the slope. Each bar in a cluster (i.e., A0) represents a 6 cm depth interval.

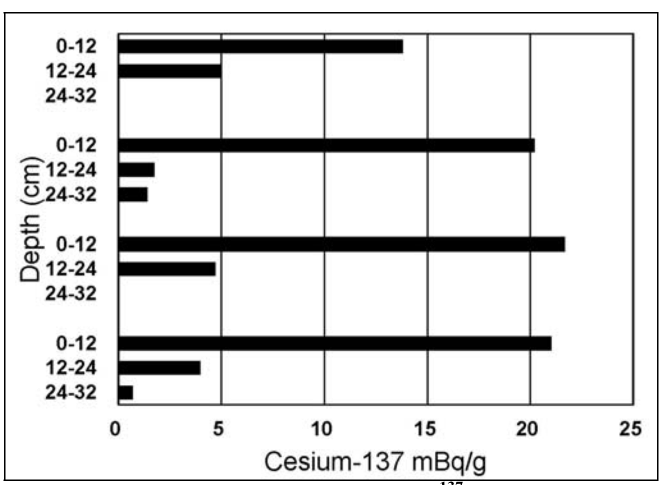

Figure 7. Average depth distribution of ^{137}Cs for the 25 soil samples shown in Figure 5.

of the hedge at Site A is a concern for the management of these hedges.

Based on deposition rates of 1 to 2 cm per year measured by the field survey and a bulk density of 1.2 g cm^{-3}, a deposition rate of 12 to 24 kg m^{-2} yr^{-1} is calculated for the area near the hedge at Site A. Based on this data, the hedge is acting as a filter to retain eroding soil in the field upslope of the hedge.

Reference soil samples were collected from grass (pasture/lawn) and grass-oak savannah areas on the BARC farm where records showed no tillage operations since the 1940's. Thirteen samples were collected at each site along 100 meter transects at each site. The ^{137}Cs ranged from 1786 to 4159 Bq m^{-2} with an average of 2896 ± 765 Bq m^{-2} for 26 samples. The distribution of ^{137}Cs in reference soil profiles (Fig. 5) is typical of an undisturbed soil profile with highest concentration in the surface soil layer. Total concentration levels in the reference profiles are consistent measured fallout input for the northeastern United States. The distribution of ^{137}Cs by depth for the soil samples upslope of the hedge at Site A is shown in Figure 6. The pattern, in general, is typical of tilled soils with uniform distribution in the upper 20-25 cm. There are exceptions where distributions are more like untilled soils (i.e., E20, E30). The tilled depth during the 1960's, 1970's and early 1980's is estimated to be 20 cm. Since 1985 this field has been under minimum tillage management with the maximum depth tillage being 10 cm or less occurring every other year. The highest concentrations by surface layer and the minimum depth distribution are on the row E, 16 m upslope of the hedge. In general, the minimum concentrations by layer and greatest depth distribution were found nearest the hedge where the concentrated flow was greatest before the hedge was planted and the location where we measured 2-12 cm deposition since 1991. The average ^{137}Cs distribution of all the soil profiles (Fig. 7) shows concentrations decreasing with depth. There was no significant difference between the 0-6 and 6-12 cm layers, the layers tilled in the last 12 years, but the other layers were significantly lower and different from each other. More than 50% of the profiles did not have ^{137}Cs below 30 cm. Selected sites were sampled to lower depths (36-42 and 42-48 cm) but no ^{137}Cs was found below 36 cm at any of sites. Average ^{137}Cs concentration for all the sample sites (n=152) was 3249 ± 642 Bq m^{-2} that are higher than the reference sites (2896 Bq m^{-2}) indicating that there has been a net movement of ^{137}Cs into the area.

Average ^{137}Cs concentration per square meter was lowest near the hedge and was more uniform at greater distances from the hedge. The first two rows (1 and 2 m upslope of the hedge) were the area where the maximum development of the concentrated flow erosion channels had occurred before hedge establishment. This concentrated flow had eroded much of the surface soil. While field surveys show significant deposition in the area since 1991, it is evident that over the longer time period (45 years) measured by the ^{137}Cs technique there is still a net loss of soil near the grass hedge. Again the ^{137}Cs data is reflecting the long term erosion pattern and not just the conditions that have occurred since the grass hedge was established in 1991.

Based on these ^{137}Cs data, redistribution rates of soil upslope of the hedge at Site A were calculated using the Proportional Model of Walling and He (1999). Particle size analyses of the samples found no significant difference in eroding and depositing sites. The pattern of long-term erosion measured by ^{137}Cs (Fig. 8) reflects the areas of concentrated flow erosion evident in the field (Fig. 4) when the grass hedge was established. The pattern of deposition in the field represents the long-term effects of the contour farming that has been in place in the field for the past 30 years.

The area of erosion along the grass hedge estimated from ^{137}Cs (Fig. 8) is the location of the concentrated flow erosion, which was evident in the field when the decision was made to establish grass hedges to control the flow channels developing in the field. While topographic surveys show deposition in this area since 1991, the ^{137}Cs data indicate a long-term net loss of soil in this part of the field. The other areas of erosion in the middle of the area and along the 35-meter area (Fig. 8) are in the region where the concentrated flow erosion channels had developed. The areas of deposition represent low places and eddy areas along water flow paths across the field. The management strategy of using contour strips has resulted in the net accumulation of soil sin 1954 over much of the site that was sampled. While concentrated flow areas were occurring that were becoming a critical management concern in this field, in general the net effect of the contour farming had been positive in controlling soil loss.

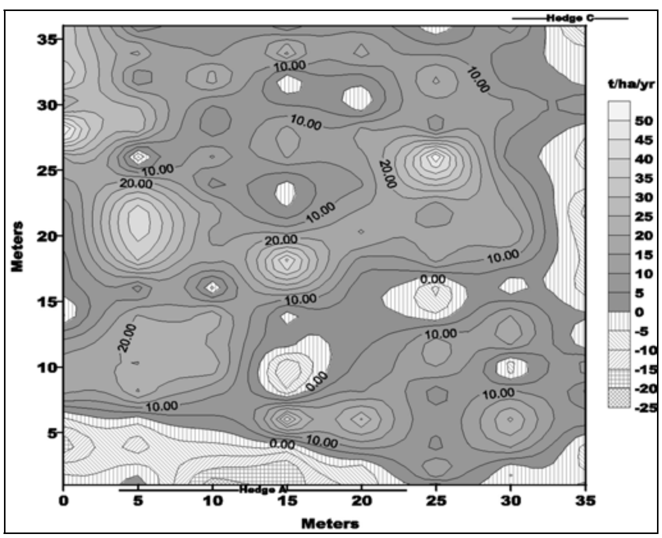

Figure 8. Spatial distribution of erosion and deposition determined from ^{137}Cs measurements and a proportional model (Walling and He, 1999).

CONCLUSIONS

This study shows the importance of understanding the history and management of a study area as we interpret soil redistribution patterns using ^{137}Cs. Topographic surveys show significant recent deposition rates near grass hedges while ^{137}Cs data show a long term net erosion in the same area indicating that the hedges are acting as filters and capturing some of the recently eroding material. This study also reinforces one of the basic concepts on the use of the ^{137}Cs technique for soil redistribution that ^{137}Cs provides estimates of medium-term (45 years) erosion rates not short terms erosion rates. One interesting possibility from this study site is that with the rapid rate of deposition now occurring near the grass hedges we may be able to return to this site in a couple years and with another set of ^{137}Cs redistribution rates make an estimate of recent deposition rates.

ACKNOWLEDGMENT

This paper represents a contribution to the International Atomic Energy Agency Programs D1.50.05 and F3.10.01.

LITERATURE CITED

Daniels, R.B. and J.W. Gilliam. 1996. Sediment and chemical reduction by grass and riparian filters. Soil Sci. Soc. Am. J. 60:246-251.

Flanagan, D.C., G.R. Foster, W.H. Neibling and J.P. Burt. 1989. Simplified equations for filter strip design. Trans. Am. Soc. Agric. Eng. 32:2001-2007.

Kemper, D., S. Dabney, L. Kramer, D. Dominick and T. Keeps. 1992. Hedging against erosion. J. Soil Water Conserv. 47:284-288.

Morgan, P.C. 1995. Soil Erosion and Conservation. Longman Scientific and Technical, London, England.

Ritchie, J.C. and J.R. McHenry. 1990. Application of radioactive fallout cesium-137 for measuring soil erosion and sediment accumulation rates and patterns: A review. J. Environ. Qual. 19:215-233.

Walling, D. and Q. He. 1999. Improved models for estimating soil erosion rates from Cesium-137 measurements. J. Environ. Qual. 28:611-622.