

Erosion Control Using Soil Amendments and Other Low Cost Methods Prior to Establishment of Vegetation

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Abstract: Disturbed areas especially as they occur on sloping land are highly erodible in humid environments until vegetation can be established. These critical areas produce considerable amounts of sediment and pollutants that can be carried either attached to the sediment or in soluble forms. The cost of many “engineering based” erosion control strategies is very high and often they fail in erosive events prior to stabilization of the area with vegetation. Methods such as hydromulching/hydroseeding on construction cut and fill slopes along highways in the USA are a frequent sight in spite of the expensive treatments since the underlying processes that lead to runoff and soil erosion still occur. We have been researching the use of various soil amendments that can positively affect erosion processes occurring at the soil/air/water interface that can be applied at low cost to serve as erosion control prior to establishment of vegetative cover. The objective of this work was to prevent runoff from occurring or reduce its magnitude or to slow the movement of water on slopes after it has occurred. Various materials studied included inorganic gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), and anhydrite (CaSO_4), and organic polyacrylamide (PAM) and a biodegradable waste paper material. We applied these materials in field and laboratory studies at many different scales and slopes to determine what their effect was on various soil erosion processes with natural and simulated rainfall and with flowing water. The inorganic materials surface were applied normally at 5 MT/ha proved effective in lengthening the time to runoff and reducing the total runoff volume due to interrill erosion processes. These materials were effective by providing electrolytes to the low electrolyte rainwater thus promoting clay dispersion and prevention of surface sealing. These materials were also found to be beneficial by promoting the exchange of Ca ions over Mg and monovalent ions that tended to promote clay dispersion. However, once runoff did occur these materials behaved similarly to soil aggregates and were washed off the surface and had no effect on rill erosion processes. The organic materials studied included an anionic PAM with a medium molecular weight (45,000 gm/mol) and a medium hydrolysis (~35%) surface applied at a rate of 20kg/ha in liquid form and a product composed of waste newspaper and a C:N ratio of 20:1 balanced with dry poultry litter which was shallowly incorporated at 20 MT/ha. Both materials proved to be beneficial on lengthening the time to runoff, reducing total runoff volume and at reducing soil erosion from both interrill and rill erosion processes. The use of PAM in combination with gypsum on 2:1 slopes proved the most effective treatment at controlling erosion and also in establishment of vegetation. The waste paper product significantly reduced soil erosion, decreased total runoff and reduced sediment concentrations and the soluble reactive phosphorus in runoff after runoff occurred. Additionally, the waste paper product because of the optimal C:N ratio and added nitrogen source from the poultry litter led to a more rapid establishment of vegetation following disturbance.

Additional low cost methodologies was the use of a new erosion control devices called Nu-Till™ and the “Aqueel™” which imprints depressional storage on the land and prevents

runoff from concentrating. During rainfall events the small depressions collect runoff and keep the water near where it falls. It also provides a small interconnected ridge for planting which allows the soil to warm up and dry out thus promoting germination and establishment of vegetation. Nu-Till™ is a modified form of no-till where some tillage is performed in the row leaving residue between and places nutrients during planting.

The use of soil amendments/and or Nu-Till™ and the Aqueel™ as a short-term, low cost alternative to other costly engineering approaches seems to be a feasible alternative helping to lead to the establishment of vegetation. The use of the various types of amendments will depend on the type of erosion process that needs to be addressed. For example, the use of the inorganic materials such as gypsum or anhydrite will have no effect on areas where concentrated flow is expected, but highly effective on those areas producing runoff. Whereas, the use of organic materials such as PAM and paper mulch will be effective on reducing both. The economics of the use of all the amendments, of course, will be dependent upon the availability, cost, transportation and the labor to apply them in the field. The cost though through using low cost “waste” materials appears to be much more cost effective than present high cost engineering approaches for critical areas. Recommendations for further study include determining the critical slope degrees and the ratio of both inorganic and organic materials that are needed to protect disturbed areas from a probabalistic erosion event.

Keywords: conservation tillage, gypsum, polyacrylamide, poultry litter, water quality

1 Introduction

Soil erosion is a global problem that tends to become more extreme with the extreme variations in weather. This fact coupled with low farm commodity prices World wide make the development of low cost control methods for farmers imperative to help reduce the problem and sustain agriculture. These methodologies must not only be of low cost, but they must be practical in order for the adoption by the farmers.

In the USA and many parts of the World, engineering approaches to control erosion have dominated largely through subsidies. These measures were largely effective but only temporary in nature because they treated only the problem and not the cause of the problem. As subsidies are reduced or removed these are no longer viable options for most farmers in an economic sense. Additional issues facing these same farmers are not only the erosion and sediment leaving their farm, but also the nutrients and pesticides that they use moving into surface water bodies causing eutrophication or contaminating drinking water supplies for the large non-farm populations. From previous research at NSERL, it was learned that soil amendments need not be applied to the entire tilled zone which most research on soil conditioners/amendments was conducted. It is only the very soil/air/water interface that surface seals due to the interaction of the soil with the low electrolyte rainwater and its absorption of the kinetic energy of the rainfall. The combination of these processes were found to lead to very low infiltration rates and runoff even in low energy rainfall events in a wide range of soils. With all this in mind, the purpose of this paper is to describe some of the past and present research conducted at the USDA-ARS NSERL (<http://topsoil.nserl.purdue.edu>) aimed at more efficient and lower cost erosion control methods.

2 Materials and methods

For more than 10 years, in a wide range of soils and soil conditions we have studied inorganic and organic waste materials that have a low or sometimes negative cost associated with them in their ability to control soil erosion. The inorganic material used included fluidized bed combustion bottom ash (FBCBA), flue gas desulfurization (FGD) sludge and forced oxidized (FO) FGD. The FBCBA is largely anhydrite, FGD is various forms of $\text{CaSO}_3 \cdot x\text{H}_2\text{O}$ and FO is 99.9% pure gypsum. The All of these materials are electrolyte sources and are produced as a by-product of desulfurization of stack gases from coal-fired power producing facilities and are commonly land-filled. The rates applied varied from 1 MT/ha to 10 MT/ha. The inorganic amendments studied included anionic polyacrylamide (PAM) (~35% hydrolysis and MW 45,000 g/mol) at a rate of 20 kg/ha surface applied in liquid form (Green *et al.*, 2000) and a

product produced from composting waste newsprint paper and poultry litter with a balanced C:N ration of 20:1 at approximately 20 MT/ha. All amendments were surface applied in order to treat the air/soil/water interface, thus reducing the amounts needed except for the paper product which was shallow incorporated with tillage.

In addition to soil amendments, two tillage systems are being studied to determine the benefit for erosion control. One is a new type of zone tillage called Nu-Till™ which is a form of minimum tillage or conservation tillage than includes strategic placement of nutrients. The other is a form of reservoir tillage that creates uniform depressional storage on a variety of tillage devices where the soil is disturbed call the Aqueel™. These two different approaches have been used successfully in the field in a wide range of soil and cropping conditions, however, their effect on reduce soil erosion has not yet been documented.

3 Results and discussion

Surface sealing can have a considerable effect on reduction of water entry into soils (Norton, 1987) (Fig.1). We found under simulated rainfall that infiltration rates on tilled soils frequently reached a steady state of between 1-5 mm/hr. Results have shown that by adding FBCBA on the surface at 5 MT • ha⁻¹ infiltration rates can be significantly increased even at rain intensities up to 110 mm/hr (Reichert, *et al.*, 1994, Reichert and Norton, 1994a, Reichert and Norton, 1996). This held true for soils that had a wide range of clay compositions except for soils with a negative delta pH where FBCBA increased dispersion. The addition of FBCBA improved infiltration by promoting clay flocculation and maintaining aggregate stability (Reichert and Norton, 1994b). Although FBCBA provided positive results by supplying electrolytes and preventing dispersion and was a low cost material with good handling properties it contained un-reacted Ca questionable.

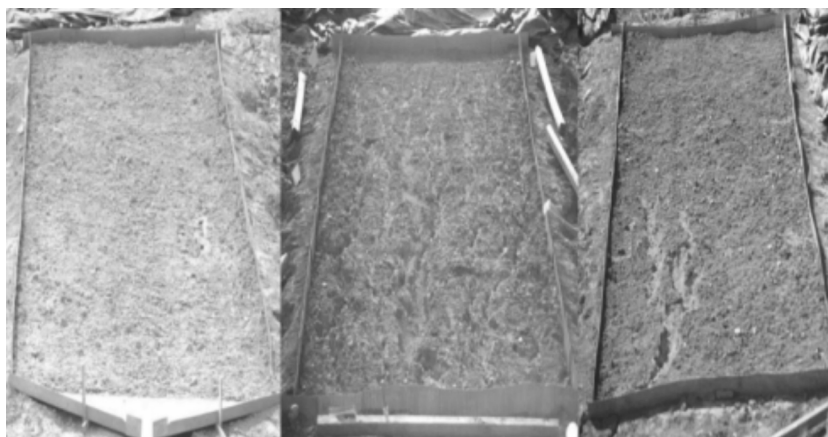


Fig.1 Representative plot conditions after completion of entire sequence of rainfall applications. The rills were painted for greater clarity. Soil amendment treatments were left to right: PAM+Gypsum (left), Control (center), and PAM (right). The shading represents not only the location of the rilling, but also the depth. O and had a pH of 12.5 (Norton, 1995) making its use in crop production

Because of the high pH concern of FBCBA other materials were evaluated as electrolyte sources including phosphogypsum (PG) a by-product of fertilizer production, two sources of FGD (Norton *et al.*, 1993). The solubility of the FGD was much lower than FBCBA and PG and the effect on infiltration much less. Therefore, efforts turned to FO gypsum which is a very pure form of FGD that has been processed in aeration ponds to convert the FGD over to nearly pure gypsum of neutral pH. At the same time the use of the organic polymer PAM was being researched to stabilize the soil/air/water interface (Becker, 1997). Field application of this pure gypsum at 1 MT/ha proved effective in improving infiltration and reducing erosion while also increasing corn yields by more than 10% (Wallace, 2001).

These results have led to the adoption of the use of by-product gypsum in production agriculture in the Midwest USA cornbelt in a large scale.

In addition to the use of electrolyte sources, organic amendments have proven successful as low cost alternatives to control erosion. Fig.1 shows the effect of adding surface applied gypsum+PAM, PAM alone compared to the control to plots under simulated rainfall (Chaudhari, K., 1999). The amount of seedling emergence and growth was also significantly greater in the treated plots in another natural rainfall study where gypsum+PAM > gypsum > control (Chaudhari, K., 1999). As can be easily seen in Fig.1, for this 2:1 slope, the amount of rilling has been significantly reduced by addition of PAM but also combination of PAM+gypsum has almost eliminated rill erosion. These results were also found for interrill erosion where PAM+FBCBA also had a synergistic effect on reducing erosion and improving infiltration (Norton and Donstsova, 1998).

Waste newsprint is a major problem in the USA as is the disposal of poultry litter. A new product has been developed which combines the two with a balanced C:N ratio of 20:1 similar to most soil organic matter. This product was tested in the field under rainfall simulation along with gypsum on a high clay soil in Texas and was found to not only control erosion but also reduce significantly phosphorous runoff, a major environmental concern (Fig.2).

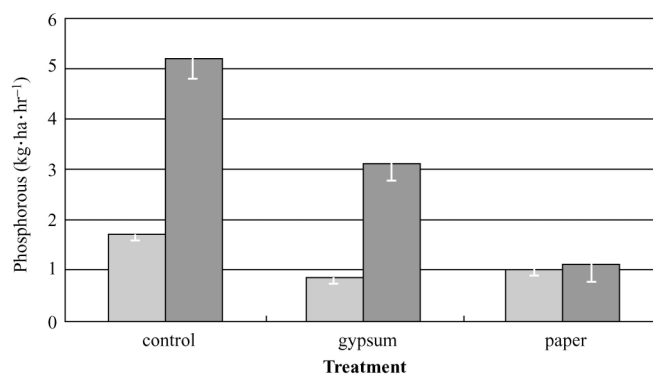


Fig.2 Soluble reactive phosphorous (yellow) and total phosphorous (red) in sediment from simulated rainfall at a target intensity of 64 mm/hr

Amending soil has shown to be a viable low cost alternative to expensive engineering approaches by treating the problem at the source and promoting infiltration and stabilizing the soil, however, this is just one approach. Other approaches being studied include managing soil roughness and conservation tillage. One of the problems with adoption of no-till is that yields are lower in many areas and thus its adoption has been limited. This is due to many problems such as poor germination, wet/cold soils, disease, weed pressure etc. A modified form of no-till called Nu-Till™ is being studied as well as a reservoir till system call the Aqueel™ to control erosion. Nu-Till™ zone tills the soil to allow it to warm up and provides faster germination as a result of warmth and strategic placement of nutrients. The Aqueel™ is a highly flexible system that is an add on to either a planter or tillage device that imparts depression storage to the seedbed condition (Fig.3). Both systems show promise and are being test in the field and laboratory.

4 Conclusions

The concept of using low cost materials that treat the cause of erosion at the source has been proven viable and is being adopted in a large scale in the USA by producers. The utilization of hither to for wastes, both inorganic and organic show great promise in control erosion and its off-site environmental problems. New technologies such as the Nu-Till™ system and the Aqueel™ will add to the producers

arsenal of tools in addition to soil amendments to help control erosion as a low cost by treating the problem at its source while producing food for the ever growing population.



Fig.3 An Aqueeled surface following a rotoavator cultivation. Each reservoir has the capability to hold about 1 L of water. This device has shown to prevent runoff completely in a storm event up to 12 inches per hour on a 12 percent slope

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