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Performance of Vegetative Filters to Control Loadings of Sediment and Nutrients in to Surface water Bodies in a Hawaiian Watershed

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Résumé

L'objectif principal de cette étude était de déterminer l'effet de trois terrain couvrents, Sunn hemp, Sudex et l'avoine commune plantées comme des bandes de filtre végétatives sur la réduction de sédiment et le chargement nutritif de eaux de ruissellement de surface dans le "watershed" de Kaika-Waialua sur l'île d'Oahu, Hawaii. Les échantillons de ruissellement ont été recueillis et analysés pour le sédiment suspendu, N and P. Les résultats montrent que pendant tous les traitements de terrain couvrents ont réduit on moins 73% le sédiment de façon significative en comparaison du traitement en jachère. L'analyse de concentrations nutritives dans les échantillons de ruissellement ont montree seulement qu'une augmentation significative dans les concentrations de N dans le traitement de sunnhemp a cause de son azote fixant capacité. Il y avait une forte corrélation (R2 = 85 %) entre les quantités de chute de pluie et les volumes de ruissellement.

Introduction

Modern agricultural practices have contributed significantly to non-point source pollution. Pollutants leaving agricultural catchments in surface and groundwater have caused severe declines in the water quality of associated streams, rivers and lakes. These pollutants carried in runoff lower the quality of the overall environment by decreasing oxygen levels in surface water bodies, increasing turbidity levels and sedimentation of coastal reefs, degrading prime fish nursery habitat, causing algal blooms and eutrophication, destroying recreational activities, and causing a health hazard to humans. Cropped vegetative filter strips have been shown to effectively reduce concentrations of sediments and nutrients in runoff. Cover crops have been used as part of best management practices to reduce splash erosion from raindrop impact, to reduce soil surface sealing and crusting, to increase infiltration, to add organic matter to soils, to immobilize and reduce sediment and nutrient loading, and to convert atmospheric nitrogen to biomass (Dabney 1998).
Hawaii is currently facing a constant threat to its surface and coastal waters from pollutants carried in agricultural runoff. Sediment loading of streams and bays is a major concern along many of the coastlines of the Hawaiian Islands. Kaiaka and Waialua bays, two adjacent water bodies on the north shore of Oahu, have been classified by the Hawaii Department of Health (DOH) as water quality limited segments. Data from the Department of Health's monitoring program show levels of total phosphorus, nitrate, total nitrogen, and turbidity exceeding the maximum allowable levels. Sediment loads from agricultural lands are the major source of pollution. Sediment losses are generated from intensively farmed areas on the North Shore which use a crop/fallow rotation. Heavy rains in the winter months cause surface waters to become inundated with concentrated runoff.

The objectives of this study were 1) to evaluate the effect of 3 land covers (Sunn Hemp- *Crotalaria juncea*, Sudex, a sorghum-sudangrass hybrid- *Sorghum bicolor x S. bicolor var. sudanese*, common oats- *Avena sativa*) and soil hydrology of a volcanic Hawaiian soil on Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) in surface runoff; 2) to evaluate the effects of land cover on nutrient concentrations (nitrate, ammonium, total nitrogen, phosphorous) in surface runoff and; 3) to determine the effect of cover crop treatments on runoff quantities.

Materials and Methods

The study was conducted on a commercial farm on the north shore of the island of Oahu, Hawaii during the spring and early summer of 2004. The site was approximately 1 ha in size with a complex slope of 8-12%. Site preparation included tilling each plot to a depth of 30 cm and seeding at 37 Kg ha^{-1} for sudex, 50 Kg ha^{-1} for sunn hemp, and 70 Kg ha^{-1} for oats. The experimental design used was a randomized complete block (RCBD) with three replications. Each treatment plot was 7 m wide and 9 m long and directly adjacent to the other treatments within each block. Runoff collection troughs included the installation of sheet metal guides (.3 m x 3 m) along the boundaries of each treatment plot 2.5 m from each plot edge and extending the entire plot length. Trough design allowed for the sediments to be transported from a 4 m by 8 m sediment source area above each plot, while also creating a 2.5 m buffer zone on both sides of the collection area for the purpose of minimizing any edge effects (El-Swaify et al., 1989). Rainfall was measured throughout the study period using an automated rain gage and data logger. Runoff sample collection occurred after each runoff generating rainfall event. Laboratory analysis for total suspended and dissolved solids using EPA methods (Method #160.1 and 160.2) for dissolved and suspended solids (EPA 1971), respectively. Nutrient analysis of runoff for total nitrogen, nitrate, ammonium, and phosphorous was conducted using standard methods. Soil saturated and unsaturated hydraulic conductivity measurements were taken at 15 cm and 30 cm below the soil surface for each of the 4 treatments using a tension disc infiltrometer. Soil samples were analyzed for nitrogen, phosphorous, potassium and calcium using standard methods.

Results

Over the duration of the study period, ten runoff generating events occurred, variable in duration ranging between 1 and 3 days in length. These runoff events were dominantly composites of rainy periods that extended over the course of 2-3 days. Average intensities ranged between 3 and 7 mm hr^{-1}. There were 5 rainfall events that occurred at intensities greater than 8 mm hr^{-1}. The highest daily rain event occurred at a rate of 23.7 mm hr^{-1}, and resulted in 292 mm of rain in under 11 hours. A removal efficiency parameter was used to present the effect of land cover on TSS, TDS, and nutrients. The removal efficiency is defined as the net improvement in (decrease in loading) of a cover crop treatment in comparison to the fallow "control" treatment. All three cover crop treatments improved TSS removal efficiency (i.e. reduced levels) relative to the fallow treatment plots. No differences were detected among the three cover crop treatments. With regard to TDS, there was there was a general trend for higher levels in the cover crop treatments. However, phosphorous levels were very low overall and the differences detected were not significant for practical purposes. Run-off concentrations for total nitrogen, ammonium, and nitrate showed a trend for higher concentrations in the cover crop over the fallow treatments. In general, the sunn hemp treatment had significantly higher levels of ammonium and TN in comparison to all three other treatments, and this phenomenon was attributed to the nitrogen fixing capacity of the leguminous sunn hemp. The oats and sudex treatments were generally not different from the fallow treatment or each other in total or ionic nitrogen concentrations. Hydraulic conductivity in the clay soil was extremely low, but was increased under the sunn hemp and oat treatments relative to the control.

Discussion

TSS removal efficiencies recorded in this study meet and exceed removal rates reported in previous studies results (Robinson 1996). Average treatment removal rates of 74%, 77%, and 85% for sudex, sunn hemp, and oats, respectively (Table 1), are strong evidence of the ability of the crops to effectively decrease amounts of sediment leaving vegetative filter strips, even without an increase in infiltration rates. All three cropped treatments reduced TSS levels significantly, showing that all three cover crops could be used to reduce suspended solids loading into streams within the Kaika-Wailua watershed. The significant differences reported for nitrate and TN concentrations were mainly due to the -53% removal efficiency reported in surface runoff of the sunn hemp treatment. These negative removal efficiencies mean that nitrogen levels increased in sunn hemp treatment plots as compared to the fallow treatment. This was not surprising as sunn hemp is a legume and a nitrogen fixer. During the study period roots of the sunn hemp crop were examined and nodules were observed in high density which exhibited the characteristic pink color seen in actively nitrogen fixing nodules. These results show that sunn hemp can add significant amounts of nitrogen to agricultural fields. Even though sunn hemp has the potential to make a good cover crop, because of its nitrogen fixation capacity its use as a vegetative filter can increase nitrogen levels in runoff, making it a poor choice for pollution prevention in most cases. However, if the main purpose is to reduce erosion from in-field sources, sunn hemp will not only do so effectively but will also add valuable nitrogen to the soil for the next crop.

Conclusion

In conclusion, this study demonstrated the benefits that cropped filter strips could have on TSS reductions, and the negative effect that a heavy clay soil can have on potential nutrient reduction. Even under situations where potential infiltration rates are extremely low, total suspended solids in runoff can be effectively reduced by using cropped vegetative filter strips. Sediments in surface waters cause the inundation of coastal reef systems, degradation of streams and rivers, threaten aquatic species and can be potential health threats. In order to effectively reduce nutrient levels in surface runoff under these conditions, further research into management practices must be conducted.

References

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Table 1: Removal Efficiencies for Total Suspended Solids (TSS) and Total Nitrogen (TN) and Nitrate (NO_3^-) in surface water runoff.

Treatment	TSS	TN	NO_3^-

Sudex	74	13	-12
Sunn Hemp	77	-47	-53
Oats	85	22	-23