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# Use of Filter Strips for Improved Surface Water Quality

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Sediments and nutrients from agricultural and urban catchments often have caused severe declines in the water quality of associated streams, groundwater, and coastal and near-shore aquatic environments in Hawai'i (De Carlo et al. 2004, Ryder and Fares 2008). For example, the southern shoreline of the island of Moloka'i, once the most productive reef system of the island, is now covered in meters of sediment. The sediment is almost entirely terrigenous in origin, from fallow fields left idle after the sugar and pineapple plantations ended operations in the late 1980s (Ogston et al. 2004).

Vegetative filter strips have proved to be a crucial part of best management practices (BMPs) for improving soil properties, reducing soil erosion, adding organic matter to soils, immobilizing and reducing sediment and nutrient loading of water resources, and (where legumes are involved) converting atmospheric nitrogen to biomass. The term vegetative filter strips is often interchangeably used in the scientific literature with other terms, such as buffer zones, buffer strips, vegetative buffers, or riparian buffers. Buffer zones are defined as perennial, cultivated grasslands adjacent to watercourses, streams bordering farmlands, agricultural lands, or urban areas.

In order to demonstrate sustainable BMPs to farmers and landowners in Hawai'i, we evaluated an affordable and efficient practice that uses vegetative filter strips of sunnhemp (*Crotalaria juncea*) and common oats (*Avena sativa*) to reduce sediment and nutrient loading in runoff from unfertilized, idle, and/or fallow fields. Our approach involved measuring and comparing total suspended solids (TSS), total dissolved solids (TDS), and concentrations of nutrients (phosphorous, total nitrogen, ammonium, and nitrate) in surface runoff from fields planted with filter strips, compared to runoff from fallow fields without filter strips.

## Sunnhemp and common oats

Sunnhemp and common oats are potential candidates for vegetative filter strips due to their availability in Hawai'i, affordability, adaptation, hardiness, drought tolerance (i.e., minimal water requirements), minimal nutrient requirements, and viability as green manures to add organic matter and nutrients to the soil. The cultivar 'Tropic Sun' sunnhemp (Rotar and Joy 1983, Valenzuela and Smith 2002a, b) is a tall, branching, annual legume that grows rapidly and achieves a height of 4–6 ft in 60 days under favorable conditions. In Hawai'i, sunnhemp can be grown year-round at elevations ranging from sea level up to 2000 feet. Common oats is an upright annual grass that reaches a height of 2–5 ft during a growth cycle equal to that of sunnhemp (i.e., 60 days). Common oats can be grown year-round at elevations ranging from sea level to 4000 ft.

## Use of planted sunnhemp and common oats filter strips in Hawai'i

### *Field experiment*

Field experiments using filter strips with sunnhemp or oats were conducted in a prime agricultural land site located on the North Shore of O'ahu in the Kaiaka and Waialua watersheds (21° 33' 8" N, 158° 7' 44" W). These watersheds feed both the Kaiaka and Waialua bays, two adjacent water bodies on the North Shore that have been classified by the Hawai'i Department of Health (HDOH) as water quality limited segments with levels of total phosphorus, nitrate, total nitrogen, and turbidity exceeding the maximum allowable limits. The land (8–12% slopes) was used for sugarcane during most of the twentieth century, ending in 1988. Since 1988 the site has remained idle. The soil is the Kaena clay (a very fine, montmorillonitic, isohyperthermic, Typic Pelludert).

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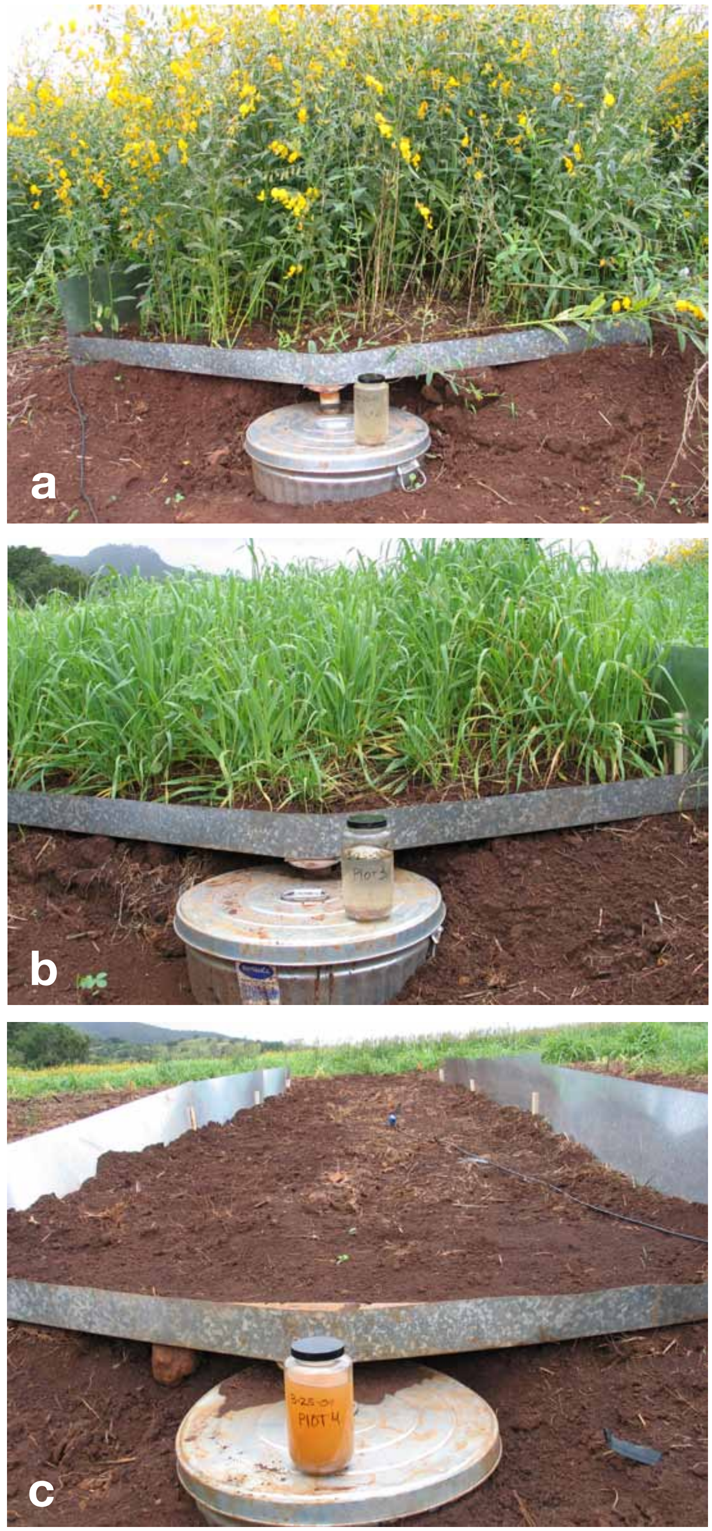
Following the design reported by El-Swaify (1989), demonstration plots with ‘Tropic Sun’ sunnhemp, common oats, and fallow lands were established with runoff collection troughs (photos, at right) installed using sheet metal guides (1 ft   10 ft) along the boundaries of each treatment plot. Sheet metal guides extended the entire plot length and width. A 13-ft by 23-ft sediment source area above each plot was fallow and kept free of vegetation. At the base of each plot, an 8.2-ft wide triangular collection trough was installed so that the edges of the collection trough were overlapping and flush with the sheet metal guides. Sheet metal guides and triangular collection trough ensured that all runoff generated in the plots was collected in the buried bucket collector.

Experimental plots were first plowed to a depth of approximately 12 inches, and then each plot was broadcast-seeded at the rate of 44.7 lb/acre for sunnhemp and 62.5 lb/acre for oats, and the seeds were incorporated into the soil. No fertilizer was added to the plots for two reasons: (1) to predict a common scenario found in fallow and idle fields in Hawai‘i, and (2) to test if sunnhemp and oats were able to reach maturity and function as an effective filter with no added inputs, making them much more affordable and hence more likely to be adopted by local farmers.

Sunnhemp and oats reached maturity within 45–65 days, and the sampling period was timed to begin at this point and end at the onset of the dry season. All samplings of runoff were conducted immediately after the rainfall event. Runoff events sampled were dominantly composites of rainy periods that extended over the course of 1–3 days. Rainfall was measured throughout the sampling period using an automated rain gauge and data logger, which effectively measured rainfall amounts every 5 minutes to 0.01 inch. Soil saturated and unsaturated hydraulic conductivity for each plot were measured using a tension disc infiltrometer. Collected samples were analyzed at the UH-CTAHR Watershed Hydrology Laboratory, using EPA methods no. 160.1 and 160.2 for TSS and TDS, respectively. Total nitrogen, nitrate, ammonium, and phosphorous in runoff samples were analyzed at the CTAHR Agricultural Diagnostic Service Center using standard methods.




**Sunnhemp (a), oats (b), and fallow (c) demonstration plots for evaluating effectiveness of vegetative filter strips on the reduction of sediment and nutrient loads of surface runoff. Note that the water collected from the fallow plot is more turbid.**

## Performance of the planted filter strips

### *Rainfall and runoff*

During the experiment period (February 25 2004 to May 18 2004), average rainfall intensities generally ranged between 0.12 and 0.28 inches per hour. However, averages for hourly periods masked brief periods, 5 minutes or less, of high-intensity rainfall of up to 1 inch per hour. In general, small rain events of less than 0.2 inch were at the lower end of the intensity spectrum, with values of 0.08 inches per hour or less. Runoff volumes from sunnhemp and oats plots were nearly identical for the majority of 10 sampling events, and thus they were not statistically different. Runoff volumes varied directly with rainfall amounts. Correlations of measurement data for TSS, TDS, and nutrients with data on rainfall intensity, either average or maximum, were not significant.

### *Total suspended and dissolved solids*

Based on the average sediment removal efficiencies, concentrations, and quantity of TSS found, sunnhemp and oats filter strips reduced suspended solids levels over those seen in the fallow fields. Filter strips containing only oats performed the best, and sediment removal efficiency was 42% to 97% greater than that of fallow fields. Soil hydraulic conductivity data showed extremely low infiltration rates within sunnhemp and oats plots. However, average sediment removal efficiencies were 77% and 85% greater than those of fallow fields for sunnhemp and oats, respectively. These observations demonstrate the ability of these crops to effectively decrease amounts of sediment leaving vegetative filter strips, even without an increase in infiltration rate. Because both sunnhemp and oats filter strips reduced TSS levels significantly compared to fallow plots, these crops are effective at curbing the impact that runoff from idle and fallow farmlands has had and will continue to have on streams and other water bodies bordering farmland, as well as coastal and near-shore ecosystems.

### *Nitrogen and phosphorous*

Nutrient levels (phosphorous, total nitrogen, nitrate, and ammonium) in runoff from sunnhemp and oats plots were low compared with fallow plots. Because no fertilizer had been added to the plots, and the crops took up some of the available soil nutrients, all the nutrients measured were either leached from the soil or carried on soil particles in runoff. The nutrient concentrations measured reflect residual nutrient levels found in the soil, as well as any additions from crop decomposition. Phosphorous concentrations were lower than 1 ppm for sunnhemp and oats plots, while total nitrogen concentrations were below 7 ppm, except in the sunnhemp treatment, where total nitrogen concentration was less than 10 ppm. In general, sunnhemp plots had higher levels of ammonium and total nitrogen compared to oats and fallow plots. Roots of sunnhemp were examined, and nodules exhibiting the characteristic pink color seen in actively nitrogen-fixing nodules were observed in high density. Hence, it is suggested that sunnhemp can add significant amounts of nitrogen to agricultural fields, while also significantly curbing TSS loading.

## Conclusions

Sunnhemp and common oats planted as vegetative filters can effectively reduce sediment and nutrient loads coming from idle and fallow fields in Hawai‘i. These crops are affordable, available, and can be planted with minimal effort and no addition of fertilizer. This experiment demonstrated that during 7 out of 10 runoff events, both sunnhemp and oats filter strips significantly reduced soluble solids carried in runoff compared to fallow plots. Even under situations where potential infiltration rates are extremely low and rainfall amounts and intensities are high, soluble solids in runoff can effectively be reduced by using sunnhemp and oats vegetative filter strips. Average sediment removal efficiencies were 77% and 85% greater than those of fallow fields for sunnhemp and oats plots, respectively. Phosphorous, total nitrogen, nitrate, and ammonium nutrients in runoff from sunnhemp and oats plots were low compared with fallow plots. A significant increase in the nitrogen concentration under sunnhemp showed the nitrogen-fixing capacity of sunnhemp.

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