Determining sediment sources in the Hanalei River Watershed, Kaua'i, Hawaii

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1. Abstract

The Hanalei River in Kaua'i, Hawaii delivers suspended sediments and organic matter to Hanalei Bay with impacts on the sustainability of coral reefs and their associated species in the Bay. Understanding the sources of sediments from the watershed is necessary for the development of management strategies for reducing suspended sediment loads to the Bay. The objective of this study was to determine the sources of sediments within a watershed, such as upland soils, stream bank, channels, and mass wasting. In order to understand the relative contribution from each of these sources, soil samples were collected from these various geomorphic surfaces within the Hanalei River Watershed and analyzed for ^{137}Cesium. Fallout ^{137}Cs can be used as a tracer or fingerprint to identify potential sediment sources and as a marker to determine floodplain deposition patterns and rates within a watershed. For this study, recently deposited sediments on floodplains and the Hanalei bay, and stream samples were compared to upland sediment sources (upland soils and mass wasting sites) and stream bank samples using simple mixing models to determine sediment sources. ^{137}Cesium concentrations in the different geomorphic sources varied with upland soils > colluvial slopes > floodplain deposits > stream banks > Bay sediments. Preliminary results indicate that stream banks are probably the most significant sources of sediments deposited on the floodplains and in the Bay.

2. Introduction

The Hanalei River, located on the island of Kaua'i in Hawaii USA, drains the eastern slopes of Mount Waialeale into the Hanalei Bay (Fig. 1). The watershed (~50 sq. km) drains the area of the world's highest recorded rainfall (averaging more than 11,680 mm of rain per year over the last 32 years, with a record 17,340 mm in 1982), and plunges from its headwaters at 1569 m above sea level to sea level in 27 km. Its high rates of discharge (6.12 cubic meters per second) delivers suspended sediments and organic matter to Hanalei Bay with important implications for the sustainability of the coral reefs and their associated species in the Bay.

The purpose of this study was to investigate sediment sources in the watershed using ^{137}Cs as a tracer or "fingerprinting" tool. Fingerprinting compares physical, chemical, or radionuclide properties of potential sediment source with suspended sediment properties to identify potential sediment sources in the watershed. These properties are evaluated for the source areas and the suspended sediments using mixing models (Walling, 2003, 2005; Slattery et al., 1995; Walling et al. 1993; Walling and Woodward, 1992).

The objective of this research was to use radioactive fallout ^{137}Cs to identify source of sediments in the Hanalei River watershed. If likely eroding sites could be determined, then potential sediments sources could be determined and management efforts could be targeted to the geomorphic surfaces of the watershed that were producing the suspended sediments.

3. Methods and Materials

Soil samples were collected from 5 different geomorphic surfaces (upland soils, colluvial soil areas, floodplains, streambanks, and stream deposits). Surface soil samples (0-5 cm) were collected at all sites. Profile samples were collected at some of the upland soil and floodplain sample sites. The samples were dried, sieved to pass a 2-mm screen, and ^{137}Cs was determined. Since ^{137}Cs is attached to the fine particles and only moves attached to soil and organic particles, by comparing ^{137}Cs content of the different geomorphic surfaces with the ^{137}Cs content of sediments deposited in the stream backwater (surrogate for suspend sediments) the likely sources of ^{137}Cs and thus the suspended sediments can be determined.

Analyses for ^{137}Cs were made by gamma-ray analysis using a Canberra Genie-2000 Spectroscopy System that receives input from three Canberra high purity coaxial germanium crystals (HpC >30 % efficiency) into 8192-channel analysers. 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. Measurement precision for ^{137}Cs is ± 4 to 6 % and is expressed in Becquerels per kilogram (Bq kg^{-1}).

4. Results

Floodplain sites showed depth distributions of ^{137}Cs indicating deposition rates of 0.1 to 0.5 cm per year over the past 40-50 years (Fig. 2). These rates would indicate that the floodplains are capturing some of the soil that is being moved in the watershed. These rates are consistent with low to medium rates of deposits found at other locations. Surface floodplain soils had lower concentrations of ^{137}Cs than the surface soils indicating that depositing materials were coming from multiple sources not just surface soils (Table 1) in the watersheds.

Upland soils had ^{137}Cs concentrated in the surface layer (0-5 cm) (Fig. 3). The depth distribution pattern in the soils is typical of that measured in undisturbed soil sites with an exponential decrease of ^{137}Cs with depth. The concentration of ^{137}Cs in the surface soil layer varied in the different sample sites indicating different soil losses at different sites. Colluvial soils sites had similar ^{137}Cs concentrations as upland soils indicating that these soils were probably coming from surface soil areas (Table 1). $^{137}Cesium$ concentrations in the different geomorphic sources varied with upland soils > colluvial slopes > floodplain deposits > stream banks > Bay sediments. Preliminary results indicate that stream banks are probably the most significant sources of sediments deposited on the floodplains and in the Bay.

Streams sediments were low in ^{137}Cs, indicating that they were probably coming mainly from non-surface soil areas (i.e., streambanks, land slide areas). Based on a simple mixing model and our limited data set, the sediments in the streams do not appear to be coming from areas of upland soil surface erosion (sheet erosion) but rather from streambank, gully, or land slide areas (areas where subsurface soils with low ^{137}Cs concentrations are exposed to water erosion). Preliminary results indicate that management efforts should be targeted at stream banks and other non sheet erosion sources to reduce sediment loads to the floodplains and the Bay.

Table 1 ^{137}Cs by weight in different geomorphic surface layer

Geomorphic Surface	^{137}Cs (Bq kg^{-1})	Comparison[1]
Upland Soil	70.0 ± 32.7	A
Colluvial Soils	72.0 ± 48.1	A
Floodplain Soils	41.6 ± 25.0	AB
Streambanks	13.5 ± 1.0	B
Stream Deposits	7.8 ± 0.6	B

1. Columns with different letters a significantly different at the 0.05 level by the Tukey's HSD test

Figure 1 View of Mount Waialeale

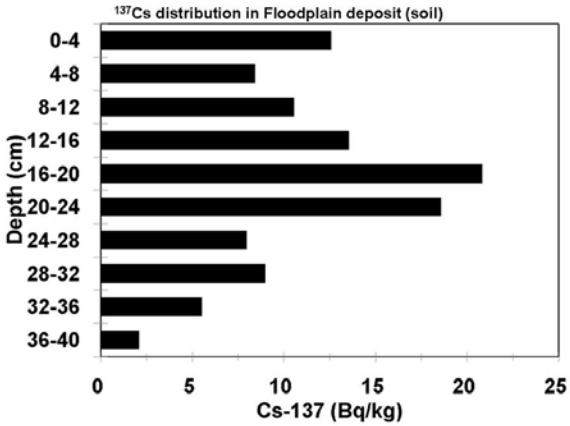

Figure 3 Cs-137 distribution in floodplain deposits

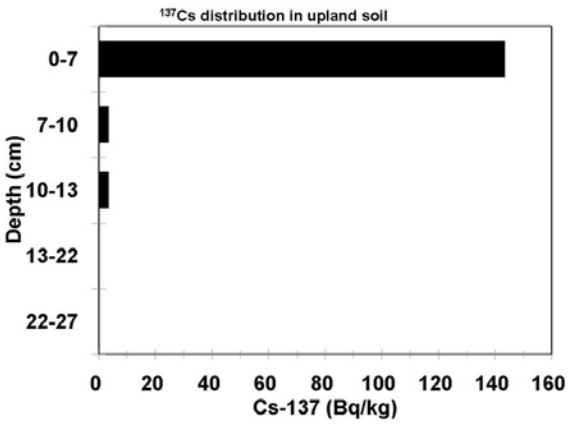

Figure 2 Cs-137 distribution in upland soil.

5. References

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