5.1 DETERMINATION OF EQUILIBRIUM MOISTURE CONTENT FOR SEVERAL FINE FUELS IN HAWAII

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1. INTRODUCTION

The concept of equilibrium moisture content (EMC) is simple. Given enough time, under constant temperature and relative humidity, the moisture content of a dead fuel particle will become constant indicating that the net moisture exchange with the atmosphere surrounding the particle is zero. This concept is seldom achieved in nature as temperature and relative humidity change constantly. EMC is an intermediate variable used to predict fuel moisture content In the National Fire Danger Rating System (NFDRS) and in several fire behavior prediction tools in The United States. The equations used to predict EMC were developed from Sitka spruce data collected in the 1930s. Because EMC plays a critical role in fire behavior and danger calculations, EMC values have been determined for several nonwoody species on the U.S. mainland since the early 1970s. The focus of this earlier work was on fine fuels found in the western and southeastern U.S. EMC values have been derived for some Australian fuels as well. A high resolution version of the NFDRS is being implemented in the Hawaiian Islands. The version currently includes the existing fuel moisture equations for the NFDRS. Hawaii has a variety of fine fuel types that have not been previously tested to determine if EMC values are similar to Sitka spruce or to other fine fuels that have been previously studied.

2. LITERATURE REVIEW

Moisture content of fine forest fuels has long been recognized as an important variable that influences a wildland fire's ability to ignite and propagate. As a result, there is a large body of knowledge available.

3. METHODS

The Hawaiian Islands have a wide variety of native and introduced vegetation. Given the wide variety of species available, we asked fire management personnel from the Hawaii Division of Forestry and Wildlife within the Department of Lands and Natural Resources and from the National Park Service at Hawaii Volcanoes National Park to identify the fine fuels of most concern (Weise et al 2005). The sampling locations were located on four of the major islands and ranged from near sea level to over 2000 m elevation (Fig. 1). Loblolly (Pinus taeda L.), slash (P. elliottii Engelm.), and Monterey (P. radiata D. Don) pine needles, and eucalyptus leaves (Eucalyptus robustus Sm.) comprised the litter fuels. Eight native and exotic grasses were sampled: velvet grass (H. lanatus L.), alpine hairgrass (Deschampsia nubigena Hbd.), buffelgrass (Pennisetum ciliare (L.) Link), guineagrass (Urochloa maxima (Jacq.) R. Webster), Hawaiian lovegrass (Eragrostis atropioides Hbd.), broomsedge (Andropogon virginicus L.), beardgrass (Schizachyrium condensatum Kunth (Nees)), and fountaingrass (Pennisetum setaceum (Forsk.) Chiov.). A native Hawaiian plant, uluhe (Old World forked fern, D. linearis (Burm.) underwood), was the only herbaceous fuel sampled. All sampled fuels were dead—either cured grass or uluhe fronds, cast leaves or needles on the surface of the litter.

An environmental chamber was used to determine EMC. The dimensions of the chamber are 122 cm W x 69 cm D x 61 cm H. Temperature and relative humidity can both influence EMC; however, only relative humidity could be controlled in the environmental chamber. The chamber was located in a building where temperature is maintained throughout the year at approximately 25°C. We measured temperature and relative humidity in the chamber in a 5 x 3 x 3 (width x height x depth) lattice with a nominal temperature of 25°C and 50% relative humidity. The temperature ranged from 23.4 to 26.6 (mean = 25.4°C) and relative humidity ranged from 46.9 to 51.3 (mean = 49.8%). The chamber increases relative humidity using a humidifier and decreases humidity by pumping air over several columns of dessicant. While there is some variation in the chamber, the conditions are generally uniform. Fuel samples were placed on scales across the bottom of the chamber.

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Since it is well-known that adsorption and desorption curves are slightly different, each fuel was exposed to increasing and decreasing relative humidity. Prior to adsorption runs, fuels were dried to remove all moisture. Four samples of a single fuel were placed on identical electronic scales in the chamber. Relative humidity setpoints of 10, 20, 40, 60, 80, and 95% were used. Fuels were allowed to equilibrate with conditions before the humidity setting was changed. Weight was recorded continuously every 15 minutes using LabView* software.

Over the course of the study, we have encountered problems with dessicant becoming saturated, the humidity controller breaking, and a pump breaking. As a result, the data were filtered to remove problem data. Any time that the measured relative humidity differed from the setpoint by 2%, the data were excluded from further analysis to calculate the EMC values. For each time step, the mean and standard error of moisture content were calculated from the four scales. Equilibrium moisture content for each setpoint was defined as the maximum value achieved for adsorption and the minimum value achieved for desorption.

4. RESULTS AND DISCUSSION

Adsorption and desorption results for beardgrass, broomsedge, fountaingrass, radiata pine, and loblolly/slash pine will be presented here. Based on the problems encountered with equipment, the samples will be rerun in order to determine in the results are reproducible. Thus, the results presented here are preliminary.

The mean values of the two to four samples before filtering is presented in Fig. 2 for each of the species. Note for the three grasses that the moisture content reached equilibrium during the desorption phase. Within a time step, the variation between the four samples was small. Mean standard error for the five species was generally less than 2%.

Preliminary EMC values for the five species are found in Table 1. All species except fountaingrass had EMC values for desorption that were greater than the corresponding EMC value for adsorption. The larger desorption values for fountain grass cast doubt on the validity of this data set as it is well known that adsorption EMC values are smaller than desorption values because of hysteresis (Britton et al 1973). There was general agreement in EMC values for the highest relative humidity. Disregarding fountaingrass, the grasses had lower EMC values that the litter fuels.

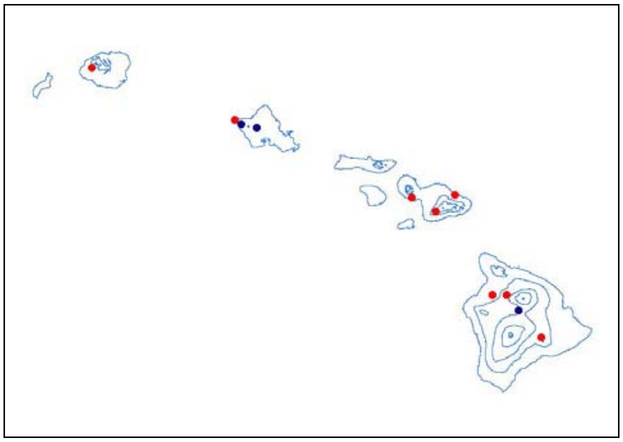

Figure 1. Collection locations for equilibrium moisture content samples in Hawai'i. Contour interval is 500 m. Color denotes year of collection.

Species	Sorption	20	40	60	80	95
Beardgrass	A	4	6	8	13	22
	D	5	7	10	14	
Broomsedge	A	4	6	8	11	21
	D	5	8	10	13	
Fountaingrass	A	14	16	20	25	
	D	10	12	15	16	20
Loblolly/Slash	A	7	10		19	21
	D	9	12	14	18	
Radiata pine	A	7	10		19	21
	D	9	12		19	

Table 1. Estimated equilibrium moisture content for five grass and litter fuels found in Hawai'i.

5. SUMMARY

Fuel moisture response of several native and introduced fine fuels are being examined. Preliminary calculations of equilibrium moisture content for some grass and litter fuels are promising; however, additional absorption and desorption trials are needed to overcome prior experimental problems and to confirm EMC values.

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* Commercial names are provided for informational purposes only and do not constitute endorsement by the U.S. Department of Agriculture.

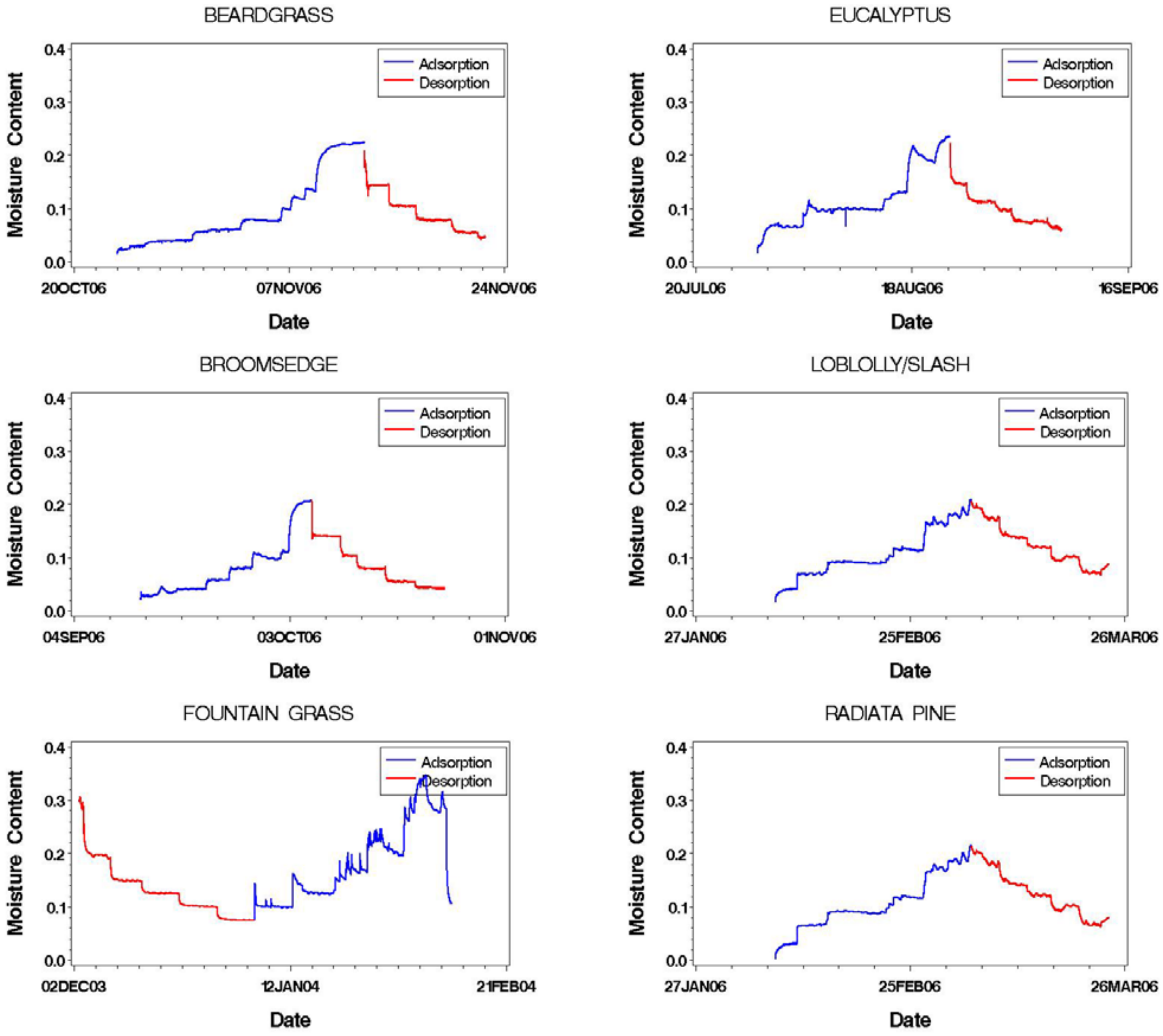

Figure 2. Unsmoothed mean moisture content of several fuels in Hawai'i subjected to stepwise changes in relative humidity with constant air temperature.

6. LITERATURE CITED

Britton, C.M., Countryman, C.M., Wright, H.A., Walvekar, A.G., 1973, The effect of humidity, air temperature, and wind Speed on fine fuel moisture content. Fire Technology, **9(1)**, 46-55.

Weise, D.R., Fujioka, F.M., Nelson, R.M., Jr., 2005., A comparison of three models of 1-h time lag fuel moisture in Hawaii. Agricultural and Forest Meterology, **133**, 28-39.