Classification of Soil Moisture on Vegetated Earthen Levees Using X and L Band Synthetic Aperture Radar (SAR)

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ABSTRACT

Earthen levees protect large areas of land in the US from flooding. Timely detection of damages and subsequent repairs can reduce the potential for catastrophic failures. Changes in spatial and temporal patterns of soil moisture can reveal signs of instability and help identify zones of weakness. Since analytical and empirical models have shown a relationship between SAR backscatter and soil moisture, we are using SAR to classify soil moisture on levees. Estimation of soil moisture from SAR is challenging when the surface has any significant vegetation. For the levee application, the soil is typically covered with a uniform layer of grass.

An area of Mississippi River levees near Vicksburg, MS is the study site. Two sources of SAR imagery are tested in this research: (1) fully polarimetric L-band data from NASA's UAVSAR; and (2) dual-polarimetric X-band data from the DLR's TerraSAR-X satellite. To classify the soil moisture a back propagation neural network is used with the following methodology:

* segmentation of levee and buffer area from the background
* extracting the backscatter and texture features such as GLCM (Grey- Level Co-occurrence Matrix) and wavelet features.
* training the back propagation neural network classifier.
* the area of interest and validation of the results using ground truth data.

Preliminary results show classification accuracies of about 50% for the UAVSAR image and 23% for the TerraSAR-X image in vegetated areas.The poorer accuracy for the X band TerraSAR data is not unusual because of the limited penetration capability of its shorter wavelength.

INTRODUCTION

Soil moisture plays a significant role in many applications such as agriculture, atmospheric science, and hydrology. The estimation of soil moisture using synthetic aperture radar has been investigated in recent decades by many researchers. The radar backscattering coefficients are affected by soil moisture, surface roughness, and incidence angles. In addition, the backscatter data also are sensitive to low vegetation and trees.

Different approaches have been developed to estimate soil moisture using SAR data. Most empirical models developed are for soils without significant vegetative cover. The presence of vegetation increases the complexity of the backscattering.

The study area encompasses portions of levees built along the Mississippi River. Parts of this levee system are occasionally weakened by combinations of extreme meteorological and hydrologic events. These can result in slope failure in the form of slough slides on the riverward side and as sand boils behind the landward slope of the levee. Since increase in soil moisture usually precedes these failures, monitoring the moisture content can provide an indication of vulnerability and impending failure of a levee segment.

DATA

SAR Data:

UAVSAR Data: quad-polarized L-band (23.79 cm) measurements collected over a 22 km wide swath at a 25-60° look angle range; The ground cell size of the multi-look, orthorectified radar data was approximately 5 by 7 meters (data acquisition time is April 28, 2011) .

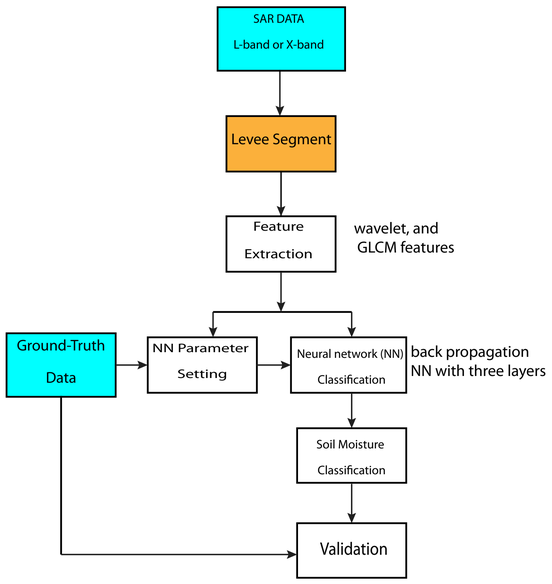
TerraSAR-X Data: SAR sensor imaging X-band (3.2 cm) with variable incidence angle and ground resolution. The TerraSAR-X images acquired for our study are dual polarized HH/VV at an incidence angle of 330 and ground resolution of 1 meter. (data acquisition time is April 23, 2011)

Ground-Truth Data:

Volumetric soil moisture: using the ThetaProbe manufactured by Delta-T (sensing the apparent dielectric constant of the soil).

Soil conductivity measure : using an electromagnetic soil conductivity meter, model EM38-MK2 made by Geonics Corporation

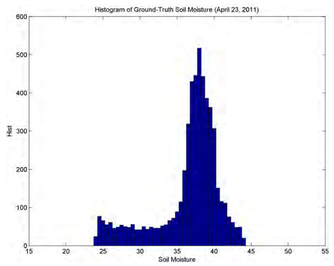
METHODOLOGY



The classification is performed by a three layer back propagation neural network, which is trained using samples from a portion of the study area about one-third of the total area. The test and validation uses the other two-thirds of the area.

RESULT

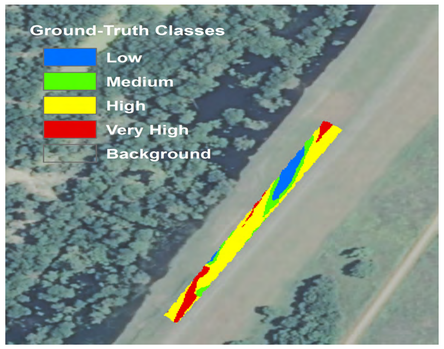
X-band SAR (TerraSAR-X)

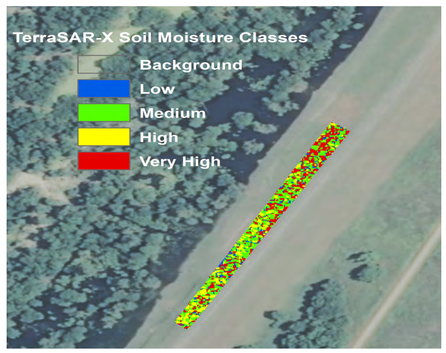


Volumetric Soil Moisture Histogram

Soil Moisture Class Label	Soil Volumetric Moisture Range (VWC%)
Low	X <30
Medium	30≤X<36
High	36≤X<40
Very High	40≤X

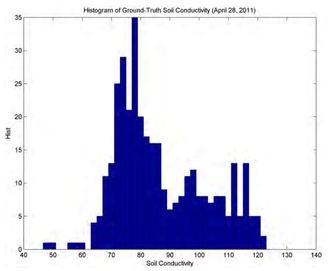
Class Label





Ground-Truth \ Estimate	Low	Medium	High	Very High	Accuracy
Low	64	294	96	207	0.1
Medium	65	360	76	268	0.46
High	256	1414	613	780	0.20
Very High	46	305	181	212	0.28
Accuracy	0.15	0.15	0.63	0.14	0.24

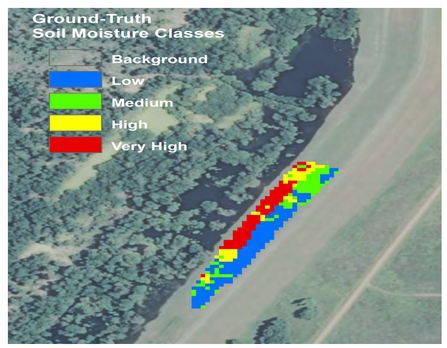
L-band SAR (UAVSAR)

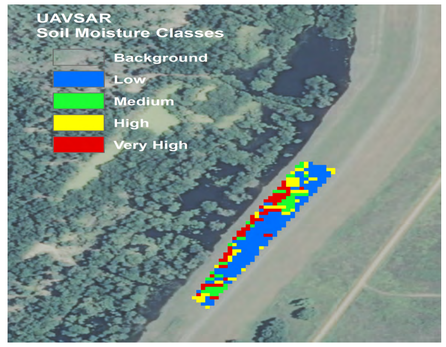


Soil Conductivity Histogram

Soil Moisture Class Label	Soil Conductivity Range (mS/m)
Low	X <80
Medium	80≤X<90
High	90≤X<100
Very High	100≤X

Class Label





Ground-Truth \ Estimate	Low	Medium	High	Very High	Accuracy
Low	108	18	22	12	0.67
Medium	39	14	10	5	0.20
High	14	5	13	9	0.31
Very High	15	9	9	34	0.50
Accuracy	0.61	0.30	0.24	0.56	0.50

Soil moisture classification and confusion matrix for L-band (UAVSAR), and X-band (TerraSAR-X)

Acknowledgment

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