Estimating soil moisture at sub-watershed scale for mine rehabilitation monitoring: a remote sensing approach

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1. BACKGROUND: *Soil Moisture – The missing piece of the puzzle?*

- Both mining and post-mining rehabilitation are eco-sensitive processes.
- These processes affect sub-catchment hydrology, microclimatology, land form and native habitat of the area [1, 2].
- Observing the near surface soil moisture (SM) is useful in monitoring the plant water availability, floods, changes in hydrology and climatology.
- Point-scale in-situ measurements and coarse-scale (~10s of kms) satellite products are unable to capture the sub-catchment variability of SM as required in mine-rehabilitation processes.

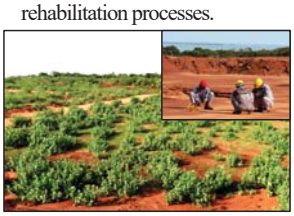

Fig. 1: Restoration of local vegetation is an integral part of mine rehabilitation. (Photo: Re-vegetation at limestone mines, Aruwakkalu, Sri Lanka.

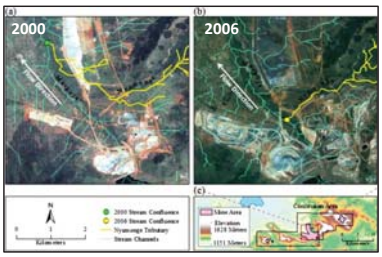

Fig. 2: The affect of mining on local hydrology at Geita Mine, Tanzania [1].

Objectives

- The aim of this work is to develop a downscaling model to enhance the spatial resolution of satellite SM products.
- The downscaling model is validated by using a high resolution L-band airborne SM retrievals.

2. STUDY AREA

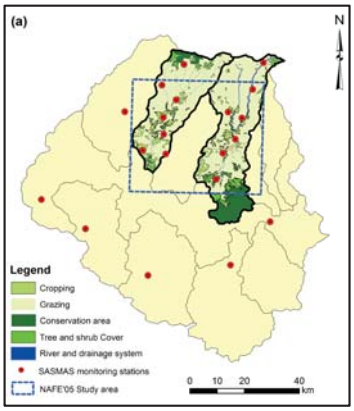

Fig. 3: The study area, Goulburn River catchment.

Twenty-six SM and soil temperature monitoring stations have been established over the Goulburn River catchment under SASMAS (Scaling and Assimilation of Soil Moisture and Streamflow) project in 2002 [3].

3. THEORY

The downscaling model is based on the thermal inertia (TI) theory. TI is the resistance of an object to changes in temperature..

$$\Delta T = f\left({}^{1}/_{TI}\right) \qquad \Delta T \approx T_{PM} - T_{AM}$$

Water has high specific heat capacity, hence a high thermal inertia compared to the dry soil. Therefore, higher the SM content, higher the diurnal temperature difference of soil (ΔT).

The relationship between ΔT and daily mean SM ($\theta\mu$) was used to build the downscaling model.

4. DATA AND METHODS

4.1 Datasets

- **SASMAS in-situ data**
  Hourly soil temperature and daily SM at 0-5 cm profile – 2003-2014.
  http://www.eng.newcastle.edu.au/sasmas/SASMAS/sasmas.htm
- **MODIS Aqua daily land surface temperature data (MYD11A1)**
  (1 km resolution) - 2005
  Land Processes Distributed Active Archive Center (LP DAAC)
- **MODIS 16-day NDVI composites (MYD13A2)**
  1 km resolution - 2003-2014
  LP DAAC
- **The National Airborne Field Experiment 2005 (NAFE'05) SM data (NAFE'05)**
  1 km resolution -31 Oct, 07, 14 and 21 Nov 2005
  http://www.nafe.monash.edu
- **National Soil and Landscape Grid**
  Clay content - 90 m resolution
  CSIRO (Commonwealth Scientific and Industrial Research Organisation)

4.2 Methodology

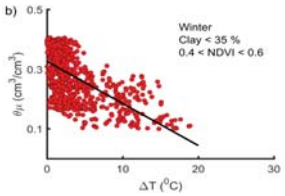

Fig. 4: A rule-based regression tree (RT) was developed between ΔT and $\theta\mu$ using SASMAS in-situ observations at 0-5 cm soil profile from 2003 to 2014. The RT was classified based on the season, vegetation density and soil clay content.

Developing ΔT- θ μ regressions using SASMAS in-situ data.
(Modulating factors: NDVI, Soil Clay Content, Austral Season)

↓

Estimating SM at 1 km by using MODIS derived ΔT values.

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Downscaling θ_{SAT} simulations from average SM over 40x40 km NAFE'05 area.

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Validation of downscaled SM using NAFE'05 observations of 1 km resolution.

$$\theta_{ds,p} = \theta_{est,p} + [\theta_{SAT} - \frac{1}{N}\sum_{i}^{N}\theta_{est(i)}]$$

Where $\theta_{ds,p}$ and $\theta_{est,p}$ are the downscaled SM and the SM estimated from the RT at 1 km pixel p, θ_{SAT} is the spatial average of the NAFE'05 soil moisture observations within the 40 × 40 km area (θ_{SAT} represents a coarse resolution SM pixel value). N is the number of 1 km pixels (i=1:N) within the NAFE'05 study area.

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5. RESULTS AND CONCLUSION

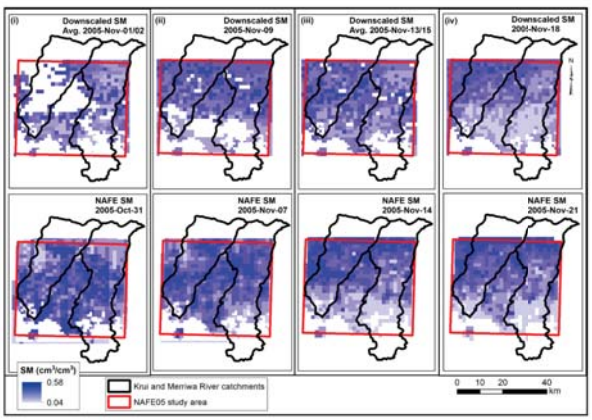

Fig. 5: The comparison between NAFE'05 SM data and the downscaled SM products

- A RMSE of 0.07 cm^3/cm^3 was found when the downscaled SM products were compared with the NAFE'05 airborne observations.
- The model proposed in this work can be applied to estimate soil moisture at high resolution for the mine rehabilitation monitoring processes.

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