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An expert based system to predict soil attributes using geomorphic mapping, remote sensing, and soil databases in the desert southwest, USA

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We present an expert based system to rapidly predict the soil attributes that control dust emission (those in the upper 50 cm of the soil profile) in the arid southwest United States. Our system's framework integrates components of geomorphic mapping, remote sensing, and the assignment of soil properties to geomorphic map units using a soil database which imports the data directly into geographic information systems (GIS) data layers. To date, the database contains descriptions of 813 georeferenced soil observation sites, amounting to 4,116 pedological horizon descriptions from the Mojave and Sonoran Deserts, US, Negev Desert, Israel, and selected sites in southwest Asia. This expert based system is based on soil state factor-forming model parameters that include: (1) climate, derived from digital grid estimates of PRISM climatic data; (2) landform or geomorphic surface, identified using terrain-data in the form of digital elevation models (DEM) and multispectral satellite imagery; (3) parent material or lithology, identified from a subset of ASTER multispecral data by the analysis of reflectance (AST07XT) and emissivity (AST05) of rock/soil compositions; and (4) soil age, determined from geomorphic mapping and the assignment of relative age classes based on cross-cutting relations, topographic relief, and surface roughness. The four soil-forming data layers are integrated together to query the soil database by the use of an interactive GIS tool with pull-down menus, which searches the database for the most representative soil attributes.

To validate the accuracy of the expert based model and resultant predictive soil map, we performed a blind test at Cadiz Valley in the Mojave Desert, California. The desert terrain in Cadiz Valley consists of a wide variety of alluvial fans, large areas of sand dunes, and playa features affected by eolian processes. The test began with three users independently mapping an area of over 335 km^2 using 1:40,000-scale base maps to rapidly create geomorphic and age class layers, and then integrating these with climatic and lithologic data layers. The results of the four data layers were then queried in the soil data base and soil attributes assigned to map unit layers. The time taken by the three users to complete the predictive soil map was 8.5 hr, 14 hr, and 24 hr. We then collected field data by describing and sampling test pits on 8 geomorphic surfaces, and reviewed the accuracy of map unit boundaries. Lastly, we compared the field data with the predicted soil attributes using validation criteria consisting of soil texture, genetic horizon designations, and age of soil. Of the 24 total possible validation criteria combinations, the users had prediction accuracies of 79%, 83%, and 64%.

The soil-forming model presented here is geomorphic-based, and considers soil age as a significant factor in accurately predicting soil conditions in hyper arid to mildly arid regions, which differs from most pedometric derived predictive soil maps. This work comprises a successful first step in the development of a rapid and efficient expert based system to map shallow soil conditions associated with distinct geomorphic features, and which will be capable of producing cost-effective and high resolution predictive soil maps to support dust emission models in remote and poorly characterized desert regions.