THE UNIVERSITY of ADELAIDE

Assessing Natural and Management-Induced Patterns of Herbicide Sorption and Risks in Catchments: A *Soil Landscape Modeling* Approach

A thesis submitted to the University of Adelaide in fulfillment of the requirements for the degree of Doctor of Philosophy in Science

BENG P. UMALI

M.Sc. Forestry, University of the Philippines Los Baños

Ecology, Evolutionary Biology and Landscape Science

School of Earth and Environmental Sciences

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Abstract

The overall aim of this thesis was to study the natural and landscape-induced patterns of herbicide sorption and risks of leaching and off-site transport of herbicides in an intensively managed orchard system. The questions for this thesis were: a) How can contour-derived digital elevation models be enhanced? b) To what extent do topographic and management factors influence the distribution of soil properties in an apple orchard? c) How do landscape topography, soil properties and land management factors influence the spatial distribution of diuron sorption affinity? and d) How is the fate of diuron influenced by the spatial variability of soil and key fate properties?

The objectives of this thesis were: a) to determine whether a 'smoothing' algorithm can enhance the accuracy of a contour-derived digital elevation model; b) to evaluate the role of topography and management practises in predicting the distribution of soil properties using a soil-landscape modeling approach; c) to evaluate the effects of topography, soil properties and management practises on the sorption affinity of diuron; and d) to assess the integrated effect of topography, management practises and herbicide sorption on the leaching potential of diuron in a spatially variable landscape using the Leaching Estimation and Chemistry Model (LEACHM) and surface runoff using the Organization for Economic Cooperation and Development (OECD) model.

A study site in the Mount Lofty Ranges, South Australia, was selected for its wide variation in landscape and soil properties under intensive horticultural management. The site was a section of an apple orchard with a strong texture contrast soil and landform with a relief difference of 50 m. The accuracy of digital elevation models (DEMs) of the site was first evaluated. Then the relationship between terrain

parameters and critical soil properties that were easily determined in the field (e.g. soil colour and texture) was determined. A strong relationship was found and therefore the experiment was expanded to take into account the effects of management and terrain on soil properties that influence pesticide sorption, such as total organic carbon, soil pH, electrical conductivity, clay content, and soil texture. Sorption of the herbicide diuron was determined on the soil through traditional laboratory and chemometric analyses using mid-infrared (MIR) spectroscopy. A strong correlation was found between diuron sorption coefficient values determined by traditional laboratory methods and those predicted using MIR spectroscopy (R^2 = 0.79) .

Then, the determination of the effects of terrain properties and management practises on diuron sorption distribution was evaluated within the context of soil-landscape analysis and geostatistical mapping. Soil properties varied significantly between alley and tree line regions and among different establishment ages of the orchard trees. Unique spatial patterns for soil properties, particularly total organic carbon (TOC), occurred within zones of the orchard. The variability in spatial distribution of the soil properties was reflected in the amount of diuron sorbed to the different soils. In the tree-line, where the soil was kept bare, diuron sorption affinity was significantly 16% lower than in the alley, where sod strips protected the soil surface all year round.

Finally, leaching of diuron was estimated using LEACHM and the potential for surface runoff of diuron was determined using the OECD model. Management practises, the level of TOC and slope were found to influence leaching and runoff potential of diuron.

The findings imply that, for intensively managed horticultural operations on complex landscapes, the influence of terrain on the distribution of soil properties and *consequently on diuron sorption affinity was masked by management factors. Assessments of sorption distribution and, therefore, the environmental fate of pesticides must include stratification strategies based on management factors. The leaching estimation also suggests variable risk of diuron for mobility based on management and TOC. Therefore, a differential herbicide and pesticide application or management regime might need to be observed to minimise off-site impact of pesticides.*

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Declaration

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Publications and Conference Papers and Presentations arising from this thesis

Journal Article (published, accepted or in preparation)

Umali, B.P., Oliver, D.P., Forrester, S.T., Chittleborough, D.J., Hutson, J.L., Kookana, R.S. and Ostendorf, B.F. 2012. The effect of terrain and management on the spatial variability of soil properties in an apple orchard. Catena. 93: 38-48.

Umali, B.P., Oliver, D.P., Ostendorf, B., Forrester, S., Chittleborough, D.J., Hutson, J.L. and Kookana, R.S. 2012. Spatial distribution of diuron sorption affinity as affected by soil, terrain and management practises in an intensively managed apple orchard. J. Haz. Mat., 217-218: 398-405.

Umali, B.P., Clarke, K., Ostendorf, B. Quality Assessment of a Topographically Derived High-Resolution Digital Elevation Model of a South Australian Sloping Landscape. Submitted to the Journal of Spatial Science.

Umali, B.P., Hutson, J.L., Oliver, D.P., Ostendorf, B., and Kookana, R.S. Field-scale variability of simulated diuron leaching and surface runoff in an intensively managed apple orchard. Manuscript in preparation.

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Umali, B., Chittleborough, D., Ostendorf, B., Oliver, D., Huston, J., and Kookana, R. 2010. DEM and terrain analysis to predict spatial pattern of SOC. *In: Proceedings of the 19th World Congress of Soil Science: Soil solutions for a changing world*. 1-6 Aug 2010. Brisbane, Australia. Published on DVD.

Conference Presentation

Umali, B., Oliver, D., Forrester, S., Ostendorf, B., Chittleborough, D., Huston, J., and Kookana, R. 2011. Spatial variability of diuron sorption in a hilly apple orchard. *ASA-CSSA-SSSA International Annual Meetings. Fundamental for Life: Soil, crop and environmental sciences.* 16-19 October 2011. San Antonio, TX (oral presentation).

You have only to ask the cattle, for them to instruct you, and the birds of the sky, for them to inform you. The creeping things of earth will give you lessons, and the fish of the sea provide you an explanation: there is not one such creature but will know that the hand of God has arranged things like this! In his hand is the soul of every living thing and the breath of every human being!

Job 12: 7-10