Modeling of runoff water and pesticide runoff in upland bare soil
畑土壌における表面流出と農薬流出のモデル化

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Introduction: SPEC,[1)] a pesticide fate and transport model for assessing Soil-PEC (Predicted Environmental Concentrations in agricultural soils) was developed to simulate pesticides in upland field and successfully validated. However, there are still some limitations in this model. It simulates pesticide only in 2 soil layers; runoff module as well as pesticide concentration in runoff was inappropriately developed; simulating sediment yield and pesticide in sediment were not available. The objectives of the study were (1) to develop a pollutant runoff module which simulates runoff water, sediment concentration and yield in runoff water and, pesticide concentrations in runoff water and in sediment; and (2) applied this model to validate for the case study of plot scale monitoring of pesticide runoff from bare soil under artificial rainfall condition.

Materials and Methods: In this SPEC version, the Curve Number (CN) method was applied to simulate cumulative runoff which was improved by using of cumulative rainfall in small time step and input of initial abstraction ratio. The sediment simulation used the Modified Universal Soil Loss Equation (MUSLE) with modification of *"coefficient"* and *"exponent"* applied for bare soil condition. The pesticide simulation in runoff water and sediment used the mass balance method with two additional parameters accounting for the difference in pesticide concentrations in runoff, percolation and soil waters. Four statistical indexes (RMSE, R^2, NSE and PBIAS) as well as Monte Carlo simulation were integrated in SPEC model for sensitivity analysis, calibration/validation procedures and model performance evaluation. The andisol bare soil case study with two 2 plots data sets (1m x 5m, 5% slope) was used for calibration and validation of runoff pollutant. The residues of two types of pesticide (Clothianidin and Imidacloprid) on the day of simulation were 249.0 and 294.9 g/ha respectively. The artificial rainfall with intensity of 70 mm/h and duration of 70 minutes were applied for both plots. The input time steps for rainfall, temperature, evaporation and solar radiation were 1 minute, 1 hour and 1 day respectively.

Results and Discussion: For runoff water, the calibrated initial abstraction ratio of 0.06 in the study was found lower than the original value; it was similar to those in the previous studies. The calibrated CN for both plots was 59 which was found lower than the typical values for bare soil implied the less runoff for the Andisol soil in study area. The statistical indexes for the cumulative runoffindicated a very good model performance ($R^2 > 0.8$, NSE > 0.75, PBIAS < ±20%), and those for the runoff rate indicated a resonable model performance ($R^2 > 0.8$, NSE > 0.5, PBIAS < ±10%).

For modification of MUSLE, the *"coefficient"* and *"exponent"* of MUSLE were 20924.9 and 1.053 respectively. The statistical indexes for sediment yield indicated a very good agreement between simulated and observed data ($R^2 = 0.97$, NSE = 0.97, PBIAS = -0.04 % and RMSE = 12.7 %). The calibrated soil erodibility factor was 0.2856 which was within the validated range (0.1 to 0.5). The statistical indexes for the sediment yields indicated a very good model performance ($R^2 > 0.8$, NSE > 0.75, PBIAS < ±15%). For sediment concentrations, although the NSE values were negative, the R^2 values for sediment concentrations were high ($R^2 \geq 0.76$) and PBIAS values for sediment concentrations were low (PBIAS < ±30%).

For pesticide concentrations in sediment and in runoff water, it was found that the ratios of pesticide concentrations in mobile and static water (α) were 1.11 and 1.28 for Clothianidin and Imidacloprid, respectively, and the ratios of pesticide concentrations in runoff water and percolation water (β) were 0.02 and 0.06 for Clothianidin and Imidacloprid, respectively. The higher values of α and β for Imidacloprid confirmed the higher observed Imidacloprid concentrations in runoff water as compared to those for Clothianidin. With the additional parameters (α and β), the SPEC model could generate the percent mass difference in runoff water for two types of pesticide and thus those concentrations in runoff water fitted with the observed data and improved the model performance. Compared to applied pesticide mass, average percent mass loss (in calibration and validation) of Imidacloprid in runoff water (0.68%) was higher than that of Clothianidin (0.35%).

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The results of Clothianidin concentrations in sediment and runoff water were shown in **Fig. 1**. The concentrations of Clothianidin in sediment and in runoff water were decreased from the start to the end of runoff for both calibration and validation. These trends were confirmed with the previous studies.[2] The statistical indexes for Clothianidin concentrations in sediment ($R^2 > 0.8$, NSE > 0.2, PBIAS < ±25%) and those in runoff water ($R^2 > 0.7$, NSE ≈ 0.5, PBIAS < ±25%) indicated an acceptable model performance.

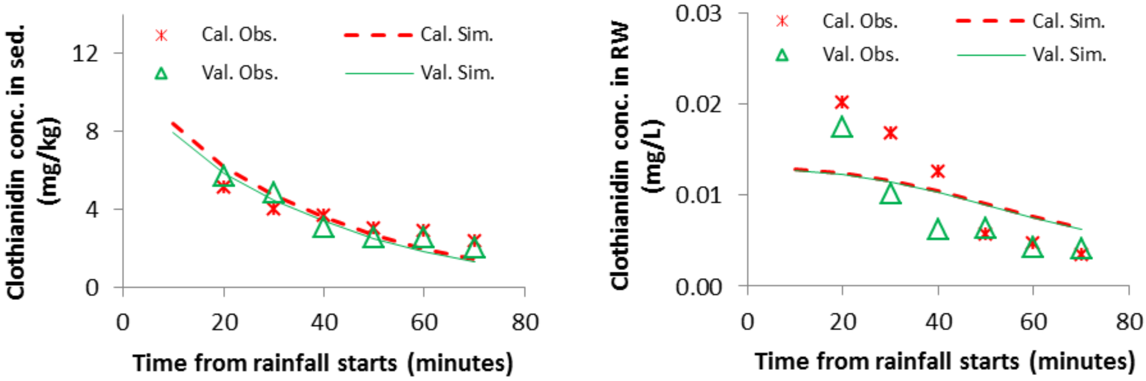

Fig. 1. Clothianidin concentrations in sediment and runoff water in calibration and validation

The results of Imidacloprid concentrations in sediment and runoff water were shown in **Fig. 2**. Similarly to Clothianidin, the concentrations of Imidacloprid in sediment and in runoff water were decreased from the start to the end of runoff for both calibration and validation. These trends also matched the observed trends and were confirmed with the previous studies.[2] The statistical indexes for Imidacloprid concentrations in sediment ($R^2 > 0.8$, NSE > 0.75, PBIAS < ±25%) indicated a very good model performance. Although the NSE value was negative in validation for Imidacloprid concentration in runoff water, the R^2 ($R^2 \geq 0.57$) and PBIAS (PBIAS < ±40%) indicated an acceptable performance for both calibration and validation.

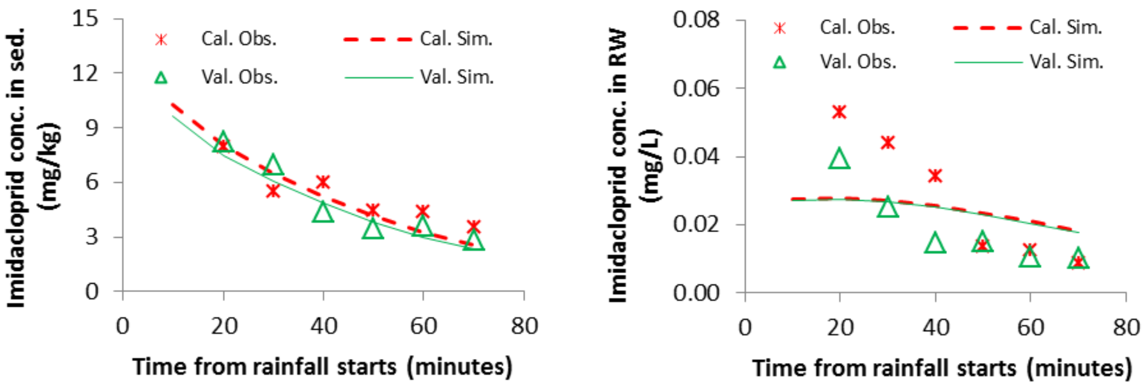

Fig. 2. Imidacloprid concentrations in sediment and runoff water in calibration and validation

Conclusion: The pollutant runoff module was successfully coded and integrated in the SPEC model. The additional codes for Monte Carlo Simulation as well as statistical indexes were integrated in the SPEC model to support the procedures of sensitivity analysis, calibration and validation as well as to evaluate the model performance. The simulation results of the case study implied the model's capacity to predict the runoff water (for both runoff rate and cumulative runoff), the sediment yield, and pesticide concentrations in runoff sediment and in runoff water under artificial rainfall condition. The future research should be conducted with other rainfall intensities and pesticide to test the pollutant runoff module performance.

References

1) Boulange J., Thuyet D. Q., Jaikaew P., Ishihara S., and Watanabe H.: *J. Pestic. Sci.* **41**, 152–162 (2016).

2) Watanabe H. and Grismer M. E.: *J. Hydrol.* **247**, 183–199 (2001).