第 II 部門 Development of Integrated Surface-Subsurface Flow Model Considering Evapotranspiration and its Application to Shigaraki Forest Watershed

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1 Introduction In this study, we developed a 3-D physically-based surface-subsurface flow model considering evapotranspiration. Developing such model is important to predict hydrodynamic processes phenomena. We applied the developed model to 3 basins in Shigaraki Forest Watershed as a testing place by utilizing the observed data at the site, and we compared the simulated result with the observed value of water content.

2 Overview of the Model We combined two models of surface-subsurface flow model and evapotranspiration model. The surface-subsurface flow model was developed by An and Yu[1)]. For subsurface flow component, Richards equation is used as governing equation, shown in Eq.(1), while Eq.(2) known as St. Venant Equation is utilized for surface flow component. Both combined systems employed backward Euler time discretization and Newton iteration.

$$\frac{\partial \theta(\psi)}{\partial t} - \nabla \cdot (K(\psi)\nabla(\psi + z)) - q - q_{\mathrm{e}} = 0 \qquad (1)$$

Here, ψ: pressure head, θ: volummetric moisture content, K: hydraulic conductivity, t: time, z: vertical dimension where positive value is in upward direction, q: general source term, q_{e}: exchange rate with the surface.

$$\frac{\partial h}{\partial t} - \nabla \mathbf{v} h - q_{\mathrm{sur}} - q_{\mathrm{sur,e}} = 0 \qquad (2)$$

Here, h: surface water depth, $\mathbf{v}$: depth-averaged velocity vector, q_{sur}: general source term of surface flow, $q_{\mathrm{sur,e}}$: exchange rate with subsurface.

As for evapotranspiration model, we adapted the previous work of Imai[2)], in which he constructed by referred to the governing equation used in Simple Biosphere Model (SiB)[3)]. Parallel computation method by OpenMP is employed to reduce the computation time in our model.

3 Site Description Shigaraki Forest Watershed is located in Koga City, Shiga Prefecture, with total area about 24.6 hectare. In our testing site, an observation tower with height about 45 meter was installed to monitor some meteorological phenomena such as rainfall, temperature, ground surface temperature, humidity, solar radiation, wind speed. Those observed data were utilized for the model input. We compared the calculated result to the observed value of soil moisture content from 7 observation points located at 3 basins in Shigaraki Forest, refer to Figure1.

4 Simulation Condition We used sandy loam soil type, where saturated moisture content θ_{s}: 0.41, residual moisture content θ_{r}: 0.065, saturated hydraulic conductivity k_{s}: 1.228×10^{-5} m s^{-1}, and van Genuchten parameter α and n: 7.5 and 1.89, respectively, in all soil layers

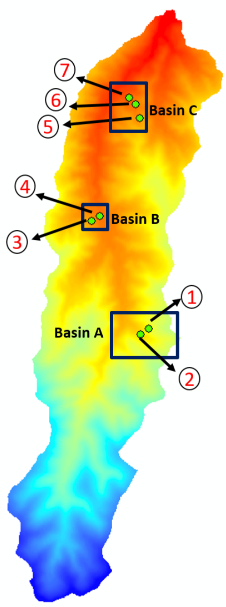

Figure 1 Shigaraki Forest Watershed

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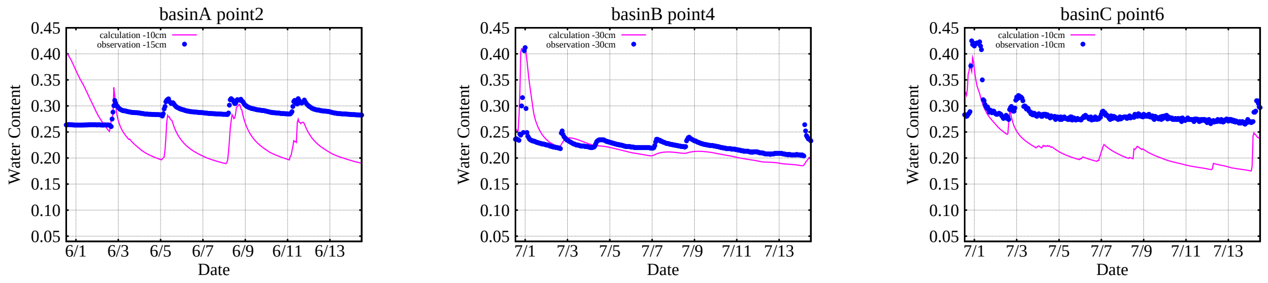

(a) Basin A-point 2 (b) Basin B-point 4 (c) Basin C-point 6

Figure 2 Comparison between calculated result and observed value. Purple line shows the simulated result and blue dot represents the observed value.

Table 1 Total number of cells in each basin

No. of Cells	Basin A	Basin B	Basin C
X direction	70	42	42
Y direction	34	45	64
Z direction	10	10	10
Total	23800	18900	26880

for two weeks simulation. ArcGIS software was used to create the elevation data obtained from 地盤地図情報 for model input. The cell size in X and Y direction is 1 meter, while in Z direction is 0.2 meter.

For the total number of cells in each basin is shown in Table1. Uniform pressure head value was set as 0.1 meter as hydrostatic condition in all cells for one day spin-up simulation. We set the seepage boundary condition in front, back, right, and left side of the domain, and impermeable layer in the bottom cells. We executed spin up simulation by setting no rainfall and evapotranspiration event for one day to achieve steady state condition, and used that callibration result as initial condition in the subsurface soil layer.

5 Result of Simulation Three of the results from each basin were shown in the Figure2. In Figure2(a), which showed the result of Basin A in point 2 from 10 cm depth, we can see quite big gap between our calculated result and observed data. However, during the rainfall event, the calculated result was closer to the observed value. Figure2(b) showed the result of for point 4 in the 30 cm depth of soil layer. Our calculated result obtained excellent result which was similar to the observed value. In basin C point 6 from 10 cm depth, we can see good comparison for simulated result and observed value especially in the initial period. However, the gap value was gradually increasing in the longer simulation period.

6 Conclusion In the present study we focus on developing a 3-D surface-subsurface flow model with consideration of evapotranspiration component. We chose 3 basins located in Shigaraki Forest as our testing place to examine the model performance, and the observed data at the site were taken as the input.

From the simulation result that we obtained for 2 weeks simulation, we can understand that our model gave good result which was consistent with the observation value, especially in the deeper soil layer. It is thought that our model can perform suitable condition simulation of the real condition at the site.

References

1) An, H., and Yu, S.: Finite volume integrated surface-subsurface flow modeling on nonorthogonal grids, *Water Resour. Res.*, Vol. 50, pp. 2312–2328, doi:10.1002/2013WR013828, 2014.

2) 今井 伸太郎: 蒸発散を考慮した 3 次元飽和・不飽和流モデルの開発と実流域への適用, *master thesis*, Kyoto University, 2016.

3) Sellers, P. J., Mintz, Y., Sud, Y. C., and Dalcher, A.: A simple biosphere model (SiB) for use within general circulation models, *Journal of the Atmosphere Science*, Vol. 43, No. 6, pp. 505–531, 1986.