Application of SWAT: Assessing environmental efficiency of various land use scenarios in Haean catchment
South Korea

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Contents

1. General issues of the Haean Catchment
2. Objectives
3. Model Setup (Input Maps)
4. Results
5. Conclusion
**General issues of the Haean Catchment**

- High Economic Activity Based on agriculture
- Yield oriented land use system increasing Urbanization and Deforestation
- Intensive dry and wet land Agriculture system
- Excess use of Fertilization
- Expert large amount of nutrients and Sediment

**Location of Study Area**

- Haean Catchment Geographically located at 128°5' to 28°11'E, 38°13' to 38°20'N
- In Gangwon Provience near Demilitarized Zone (DMZ) between south and north korea.
- Watershed Area: 62 Km²
  - Annual Dry land: 26.5%
  - Forest and Ochard: 62.5%
  - Wet land/Paddy: 8.5%
- Elevation range 340 - 1320 m
- Annual precipitaion of 1650 mm mostly concentrated (70%) within June - August.
- Consider as hot spot for muddy water discharge to Soyang reservoir.
2. Objectives

- To evaluate different land use system to determine environmentally efficient Land Use in retaining sediment and nutrients to the stream network.
- To evaluate economic efficiency - based on cost benefit analysis of environmentally efficient land use system
- To recommend best land use system by trade off analysis with other land use system.

Experimental Setup: Field Campaigns 2009-2014

Time Step Measurements

- Meteorological Data
- LAI and Biomass/Yeild
- Field level Erosion
- Stream discharge and sediment
4. Model Setup (Input Maps)

- Study area: Haean catchment, South-korea
- Watershed area: 62.7 km²
- Total number of sub-watershed: 21
- Number of HRU formation: 792
- MULTIPLE HRUs LandUse/Soil/Slope OPTION : THRESHOLDS : 0 / 0 / 0 [%]
- Number of calibration points: 5 (S1, S2, S3, S4W, S5 and S7)

**Soil type Map**

**Land Use Map**

**DEM**
B. Sediment Calibration and Validation

- Site S1:
  - R² = 0.9805
  - NSE = 0.673
  - PBIAS = 8.8
- Site S4W:
  - R² = 0.9427
  - NSE = 0.2325
  - PBIAS = 11.2
- Site S5:
  - R² = 0.9546
  - NSE = 0.5984
  - PBIAS = 33.6
- Site S5:
  - R² = 0.8331
  - NSE = 0.5244
  - PBIAS = 68.1
- Site S7:
  - R² = 0.822
  - NSE = 0.576
  - PBIAS = -48.7
- Site S7:
  - R² = 0.9097
  - NSE = 0.9004
  - PBIAS = 11.3

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**Land Use**
- AGRR: AGRICULTURAL
- RICE: RICE
- URBN: URBAN
- RYE: RYE
- CARG: CARG
- RADI: RADI
- CORN: CORN
- SOYB: SOYB
- FRSD: FRSD
- SUNF: SUNF
- FRSE: FRSE
- TOBC: TOBC
- ORC-D: ORC-D
- WATR: WATR
- PEPR: PEPR
- POTA: POTA
- RICE: RICE
- WATR: WATR

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**Map**

- Watershed
- Stream
- Monitoring Points
- Weather Station

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**t-Stat (Sensitivity of the Sediment Parameters)**

- 

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**Figure**

- Sediment Calibration 2009-2010
- Sediment Validation 2011
- Precip (in mm/day)

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**Table**

- Site: S1, S4W, S5, S7
- R², NSE, PBIAS values

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7/19
Development Of Land Use Scenario (Expansion Scenario)

Four major Dry land crops

- Cabbage
- Soybean
- Radish
- Potato

Crop Choice based on

- Market price
- Labour
- Farmers attitude toward
- Subsidies/Intervention
- others

Base line Land use land cover map was analyze for 4 Major Crops

- Crops grown dominated in **Moderate Steep Dry farmland** and **Flat Dry farmland** with soil texture of **Sand – Silt**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Texture</th>
<th>Hydrologic group</th>
<th>Area (km²)</th>
<th>Percentage catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat dryland soil</td>
<td>Sand – Silt</td>
<td>D</td>
<td>8</td>
<td>12.8</td>
</tr>
<tr>
<td>Forest soil</td>
<td>Loam – Sand</td>
<td>C</td>
<td>32.6</td>
<td>51.9</td>
</tr>
<tr>
<td><strong>Moderate steep dry land</strong></td>
<td>Sand – Silt</td>
<td>D</td>
<td>9.2</td>
<td>14.7</td>
</tr>
<tr>
<td>Rice paddy soil</td>
<td>Sand</td>
<td>C</td>
<td>6.6</td>
<td>10.5</td>
</tr>
<tr>
<td>Sealed ground</td>
<td>caly</td>
<td>D</td>
<td>1.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Very steep forest soil</td>
<td>Loam – Sand</td>
<td>C</td>
<td>4.7</td>
<td>7.5</td>
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</tbody>
</table>
Application of Crop Expansion Scenarios

LULC Map 2010

<table>
<thead>
<tr>
<th>Category</th>
<th>AREA (km²)</th>
<th>Initial % Area</th>
<th>Cabbage Expansion</th>
<th>Potatoes Expansion</th>
<th>Soybeans Expansion</th>
<th>Potato Expansion</th>
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</thead>
<tbody>
<tr>
<td>AGRR</td>
<td>1.46</td>
<td>2.3%</td>
<td>---</td>
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<td>---</td>
<td>---</td>
</tr>
<tr>
<td>CABG</td>
<td>0.70</td>
<td>1.1%</td>
<td>25.4%</td>
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<td>---</td>
<td>---</td>
</tr>
<tr>
<td>CORN</td>
<td>0.18</td>
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</tr>
<tr>
<td>PEPR</td>
<td>0.15</td>
<td>0.2%</td>
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</tr>
<tr>
<td>POTA</td>
<td>1.56</td>
<td>2.5%</td>
<td>---</td>
<td>24.1%</td>
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<tr>
<td>RYE</td>
<td>0.50</td>
<td>0.8%</td>
<td>---</td>
<td>---</td>
<td>24.6%</td>
<td>---</td>
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<tr>
<td>RADI</td>
<td>1.21</td>
<td>1.9%</td>
<td>---</td>
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<td>---</td>
<td>24.3%</td>
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<tr>
<td>SOYB</td>
<td>1.42</td>
<td>2.3%</td>
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<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>SUNF</td>
<td>0.30</td>
<td>0.5%</td>
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<td>TOBC</td>
<td>1.61</td>
<td>2.6%</td>
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</tr>
<tr>
<td>WPAS</td>
<td>7.56</td>
<td>12.1%</td>
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<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>BERM</td>
<td>1.56</td>
<td>2.4%</td>
<td>2.49%</td>
<td>2.49%</td>
<td>2.49%</td>
<td>2.49%</td>
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<tr>
<td>FRSD</td>
<td>35.56</td>
<td>56.6%</td>
<td>56.69%</td>
<td>56.69%</td>
<td>56.69%</td>
<td>56.69%</td>
</tr>
<tr>
<td>FRSE</td>
<td>0.07</td>
<td>0.12%</td>
<td>0.12%</td>
<td>0.12%</td>
<td>0.12%</td>
<td>0.12%</td>
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<tr>
<td>ORCD</td>
<td>3.55</td>
<td>5.67%</td>
<td>5.67%</td>
<td>5.67%</td>
<td>5.67%</td>
<td>5.67%</td>
</tr>
<tr>
<td>RICE</td>
<td>5.17</td>
<td>8.24%</td>
<td>8.24%</td>
<td>8.24%</td>
<td>8.24%</td>
<td>8.24%</td>
</tr>
<tr>
<td>WATR</td>
<td>0.15</td>
<td>0.25%</td>
<td>0.25%</td>
<td>0.25%</td>
<td>0.25%</td>
<td>0.25%</td>
</tr>
</tbody>
</table>
Output Indicator for Different Scenario

Surface runoff

Biomass/Yield

Crop Yield Linking
Farm Income

Sediment
Presumption/Constrains

Farm Income Calculation Based on Crop Price
Field Survey in 2010

Field Survey (300 farms)

Production Cost: $f$ (fertilizer, tillage, seed, labor)

Crop Price (Price taker) Regional Price
Crop allocation difficult
Assumption of Extreme Scenario

Biomass/yield: $f$ (micro climate/water/nutrients)

Income = \( \sum_{i=1}^{N} (MYld \times P - PC)A_i / A \)

Where,
Income = Won/ha
MYld = Marketable Yield ton/ha
P = Price Won/kg
PC = Production cost Won/ha
N = Total Number of HRU
A_i = Area of Hru
A = Total Area

Production cost estimates for potato, cabbage, radish, and soybean

<table>
<thead>
<tr>
<th>Crop</th>
<th>Price (Won/kg)</th>
<th>Production cost (Won/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radish</td>
<td>516</td>
<td>784,444</td>
</tr>
<tr>
<td>Cabbage</td>
<td>263</td>
<td>711,327</td>
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<tr>
<td>Potato</td>
<td>790</td>
<td>916,201</td>
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<tr>
<td>Soybean</td>
<td>4770</td>
<td>585,945</td>
</tr>
</tbody>
</table>

Crop Income:
Yield Revenue – Prod Cost

SWAT Scenario

Surface Runoff / Sediment

Agri Based Economy

Agri Based Environmental Effect
## Results for Crop Expansion Scenarios

<table>
<thead>
<tr>
<th>Expansion scenarios</th>
<th>Surface runoff (mm)</th>
<th>Sediment (ton/ha)</th>
<th>Crop Yield (ton/ha)</th>
<th>Farm income (Million Won/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base line</td>
<td>553.92</td>
<td><strong>10.7</strong></td>
<td>1.6</td>
<td>50.3</td>
</tr>
<tr>
<td>Cabbage Expansion</td>
<td>565.49</td>
<td><strong>19.01</strong></td>
<td>2</td>
<td>16.9</td>
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<tr>
<td>Potato Expansion</td>
<td>552.88</td>
<td>15</td>
<td><strong>4.8</strong></td>
<td>43</td>
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<tr>
<td>Radish Expansion</td>
<td>546.4</td>
<td>14.22</td>
<td>2</td>
<td>59.1</td>
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<tr>
<td>Soybean Expansion</td>
<td>563.24</td>
<td>14.94</td>
<td>1.6</td>
<td><strong>67.4</strong></td>
</tr>
</tbody>
</table>

### Weighted mean Discharge (mm)

- Base line
- Expansion Scenario

### Weighted Mean Sediment (ton/ha)

- Base line
- Expansion Scenario

### Weighted Mean Yield (ton/ha)

- Base line
- Expansion Scenario

### Weighted Mean Income (million won/ha)

- Base Income
- Expansion Income

## Graphs

- Surface runoff
- Sediment
- Crop Yield
- Farm income

- % Change from Base Line Scenario

- Weighted mean Discharge (mm)

- Weighted Mean Sediment (ton/ha)

- Weighted Mean Yield (ton/ha)

- Weighted Mean Income (million won/ha)
### Land Use Optimization Sheet and Flow Chart

#### Data Base of 4 SWAT Project

#### Land Use System Optimize for
- Minimum Environmental Impact
- Maximize Farm Income
- Trade off

#### Land Use System Optimize for

## Table:

<table>
<thead>
<tr>
<th>HRU no</th>
<th>S1 Project</th>
<th>S2 Project</th>
<th>S3 Project</th>
<th>Baseline</th>
<th>LUS Optimization</th>
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<tbody>
<tr>
<td></td>
<td>LULC1</td>
<td>Env</td>
<td>Income</td>
<td>LULC2</td>
<td>Env</td>
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<tr>
<td>1</td>
<td>FRSD</td>
<td>------</td>
<td>------</td>
<td>FRSD</td>
<td>------</td>
</tr>
<tr>
<td>2</td>
<td>URBN</td>
<td>------</td>
<td>------</td>
<td>URBN</td>
<td>------</td>
</tr>
<tr>
<td>3</td>
<td>CABG</td>
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<td>------</td>
<td>CABG</td>
<td>------</td>
</tr>
<tr>
<td>4</td>
<td>RICE</td>
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<td>------</td>
<td>RICE</td>
<td>------</td>
</tr>
<tr>
<td>......</td>
<td>CABG</td>
<td>------</td>
<td>------</td>
<td>RADI</td>
<td>------</td>
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<td>------</td>
<td>......</td>
<td>------</td>
</tr>
<tr>
<td>792</td>
<td>CABG</td>
<td>------</td>
<td>------</td>
<td>RADI</td>
<td>------</td>
</tr>
</tbody>
</table>

**NOTE:**
- **Farm Income status:** Simulate swat
- **Env status:** Simulate swat
- **Farm Income N Env status:** Simulate swat

The table represents a land use optimization sheet for four different projects (S1, S2, S3, S4). Each project lists the soil types, crops grown, and land use classification (LULC) for different HRUs (Harvest Reference Units). The flow chart above illustrates the optimization process for land use, considering both environmental impact and farm income, with a trade-off approach.
Optimize Land Use System

**LU System for Minimize SR**

- AGR 0.02% 2.33%
- URB 2.49% 2.49%
- CABG 0.00% 1.11%
- CORN 0.01% 0.29%
- FRS 56.69% 56.69%
- FRSE 0.12% 0.12%
- ORCD 5.67% 5.67%
- RYE 0.31% 0.80%
- RADI 20.02% 1.93%
- SOYB 0.03% 2.26%
- SUNF 0.02% 0.47%
- TOBC 0.02% 2.56%
- WATR 0.25% 0.25%
- WPAS 6.29% 12.02%

**LU System for Minimize Sediment**

- AGR 0.10% 2.33%
- URB 2.49% 2.49%
- CABG 0.05% 1.11%
- CORN 0.07% 0.29%
- FRS 56.69% 56.69%
- FRSE 0.12% 0.12%
- ORCD 5.67% 5.67%
- PEP 0.24% 0.24%
- POTA 1.80% 2.48%
- RICE 8.24% 8.24%
- RYE 0.80% 0.80%
- RADI 9.23% 1.93%
- SOYB 1.07% 2.26%
- SUNF 0.02% 0.47%
- TOBC 1.11% 2.56%
- WATR 0.25% 0.25%
- WPAS 12.05% 12.05%

**LU System for Maximize Yield**

**LU System for Maximize Income**
Results for Optimize Land Use System

Surface Runoff (mm)

<table>
<thead>
<tr>
<th></th>
<th>Base line</th>
<th>Minimize SR</th>
<th>Minimize sed</th>
<th>Maximize yield</th>
<th>Maximize income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Runoff</td>
<td>553.92</td>
<td>545.23</td>
<td>548.02</td>
<td>552.88</td>
<td>563.11</td>
</tr>
</tbody>
</table>

Sediment (ton/ha)

<table>
<thead>
<tr>
<th></th>
<th>Base line</th>
<th>Minimize SR</th>
<th>Minimize sed</th>
<th>Maximize yield</th>
<th>Maximize income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment</td>
<td>10.7</td>
<td>12.06</td>
<td>10.19</td>
<td>14.94</td>
<td>14.87</td>
</tr>
</tbody>
</table>

Crop Yield (ton/ha)

<table>
<thead>
<tr>
<th></th>
<th>Base line</th>
<th>Minimize SR</th>
<th>Minimize sed</th>
<th>Maximize yield</th>
<th>Maximize income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop Yield</td>
<td>1.6</td>
<td>1.8</td>
<td>1.7</td>
<td>4.8</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Profit (Mil.won/ha)

<table>
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<th></th>
<th>Base line</th>
<th>Minimize SR</th>
<th>Minimize sed</th>
<th>Maximize yield</th>
<th>Maximize income</th>
</tr>
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<tbody>
<tr>
<td>Profit</td>
<td>50.31</td>
<td>59.88</td>
<td>56.67</td>
<td>43.01</td>
<td>67.40</td>
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</table>
### Optimized land use scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Surface Runoff (mm)</th>
<th>Sediment (ton/ha)</th>
<th>Crop Yield (ton/ha)</th>
<th>GMP (Million won/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base line scenario</td>
<td>553.92</td>
<td>10.7</td>
<td>1.6</td>
<td>50.31</td>
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<tr>
<td>Minimum SR scenario</td>
<td><strong>545.15</strong></td>
<td>11.74</td>
<td>1.8</td>
<td>59.88</td>
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<td><strong>10.19</strong></td>
<td>1.7</td>
<td>56.67</td>
</tr>
<tr>
<td>Maximum crop yield scenario</td>
<td>552.88</td>
<td>14.94</td>
<td><strong>4.8</strong></td>
<td>43.01</td>
</tr>
<tr>
<td>Maximum income Scenario</td>
<td>563.11</td>
<td>14.87</td>
<td>1.6</td>
<td><strong>67.4</strong></td>
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</tbody>
</table>

### Optimized land use scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Surface Runoff (%)</th>
<th>Sediment (%)</th>
<th>Crop Yield (%)</th>
<th>GMP (%)</th>
</tr>
</thead>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>9.7</td>
<td>12.5</td>
<td>19.0</td>
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<tr>
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<td>-4.8</td>
<td>6.2</td>
<td>12.6</td>
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<td>Maximum crop yield scenario</td>
<td>-0.2</td>
<td>39.6</td>
<td><strong>200.0</strong></td>
<td>-14.5</td>
</tr>
<tr>
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<td>1.7</td>
<td>39.0</td>
<td>0.0</td>
<td>34.0</td>
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</tbody>
</table>
Conclusion

- Land use systems that produce Reduced surface runoff, Reduced sediment and Maximize yield were identified.
- Land use system which produce maximum yield and maximum income also produce higher Sediment and Surface Runoff.
- Land use system which produce minimize for surface runoff and sediment produce lower economic yield and lower income.
- Further reduction of sediment and surface runoff are possible from the recommended land use by applying effective filter width in the field of particular sub-basin.

<table>
<thead>
<tr>
<th>Optimized land use scenarios</th>
<th>Surface runoff (mm)</th>
<th>Sediment (ton/ha)</th>
<th>Crop yield (ton/ha)</th>
<th>GMP (Million won/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base line scenario</td>
<td>1.6%</td>
<td>5%</td>
<td>-67%</td>
<td>-25%</td>
</tr>
<tr>
<td>Minimum surface runoff scenario</td>
<td>545.15</td>
<td>15%</td>
<td>-63%</td>
<td>-11%</td>
</tr>
<tr>
<td><strong>Minimum sediment scenario</strong></td>
<td>0.6%</td>
<td><strong>10.19</strong></td>
<td>-65%</td>
<td>-16%</td>
</tr>
<tr>
<td>Maximum crop yield scenario</td>
<td>1.4%</td>
<td>47%</td>
<td><strong>4.80</strong></td>
<td>-36%</td>
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<tr>
<td><strong>Maximum income Scenario</strong></td>
<td>3.3%</td>
<td>46%</td>
<td>-67%</td>
<td><strong>67.4</strong></td>
</tr>
</tbody>
</table>
“Thank You,“

Phd student,
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