Rice Paddy Ecosystem services for Climate Change using land use and climate change scenarios

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I. Introduction
I. Introduction

Ecosystem Services

• Services provided by paddy fields

  • Provisioning of habitat
  • Water cycling
  • Nutrient cycling
  • Soil formation
  • Biomass production

• Provisioning
  • Food product
  • Raw materials
  • Biochemical and genetic resources
  • Fresh water

• Supporting
  • Climate regulation
  • Pollutant purification
  • Carbon storage
  • Natural disaster buffer
  • Temperature control
  • Prevention of erosion and soil loss

• Regulating
  • Heritage
  • Knowledge system
  • Social relations
  • Recreation and tourism
  • Science and education
  • Inspiration and aesthetic values

Source: Oh et al. (1996); Kim et al. (2013); Yoo and Lee (2013); Jung et al. (2014); Nayak et al. (2019)
I. Introduction

## Land Cover Changes

### • Land cover changes by time

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Agriculture</th>
<th>Forest</th>
<th>Grass</th>
<th>Wetland</th>
<th>Bare soil</th>
<th>Water</th>
<th>Changes</th>
<th>KEI(2019)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1980s</strong></td>
<td>2.09</td>
<td><strong>23.58</strong></td>
<td>66.34</td>
<td>3.75</td>
<td>0.86</td>
<td>1.29</td>
<td>2.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1990s</strong></td>
<td>3.42</td>
<td><strong>21.62</strong></td>
<td>66.25</td>
<td>4.32</td>
<td>0.49</td>
<td>1.68</td>
<td>2.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2000s</strong></td>
<td>6.29</td>
<td><strong>19.34</strong></td>
<td>63.51</td>
<td>7.16</td>
<td>0.33</td>
<td>1.21</td>
<td>2.15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### • Land transformation from agricultural land cover (1989-2009)

<table>
<thead>
<tr>
<th></th>
<th>1989</th>
<th>2009</th>
<th>Forest</th>
<th>Grass</th>
<th>Wetland</th>
<th>Bare soil</th>
<th>Water</th>
<th>Changes</th>
<th>KEI(2019)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>2,752</td>
<td><strong>15,664</strong></td>
<td>3,358</td>
<td>537</td>
<td>303</td>
<td>605</td>
<td>568</td>
<td>-8,124</td>
<td></td>
</tr>
</tbody>
</table>

23,788
II. Method
ES and Models

• Selected ecosystem services
  • Soil carbon storage
  • Fresh water provision

• Integrated Valuation of Ecosystem Services and Trade-offs (InVEST)
  • Carbon Storage model
  • Annual Water Yield model

II. Method

Soil Carbon Storage

- Fixes carbon dioxide in the atmosphere and converts it to biomass of rice, and stores carbon as biomass in soil and above-ground parts including roots
- $C_{(x,y,M)} = M \times (D_a + D_b + D_c + D_d)$
  - $C_{(x,y,M)}$: a given cell($x,y$) with a land cover
  - $D_a$: carbon stored above ground
  - $D_b$: carbon stored below ground
  - $D_c$: carbon stored as soil organic carbon
  - $D_d$: carbon stored as dead organic matter carbon

Source: Kumar et al. 2018
II. Method

Soil Carbon Storage

Raw Data

Input Data

Run the model

EGIS: Ministry of environment Korea, Environmental Geographic Information Service. 2018. egis.me.go.kr

** Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2006)
II. Method

Annual Water Yield

• Annual water yield by excluding evapotranspiration and soil absorption from precipitation

• The amount of water are available depending on the amount of precipitation in the target area and hydro-sluice conditions, etc.

• $Y(x) = \left(1 - \frac{AET(x)}{P(x)}\right) \times P(x)$
  • $Y(x)$: water yield of each cell
  • $AET(x)$: annual actual evapotranspiration
  • $P(x)$: annual precipitation
II. Method

**Annual Water Yield**

### Raw Data
- WorldClim ver2.0
- Global PET database + MODIS NTSG
- Effective depth of soil map (NAS)
- Soil characteristic map (NAS), USDA SPAW
- WAMIS basin map
- EGIS Land cover map

### Spatial Data
- InVEST default
  - Song 2015
  - Redhead et al. 2016
- Sharp et al. 2014
  - Song 2015
- Satellite data
  - Farmmap

### Biophysical Data

#### Input Data
- Precipitation
- Reference evapotranspiration
- Root restricting layer depth
- Plant available water content
- Watershed
- Land Use Land Cover

#### Run the model
- Mean precipitation / pixel
- Mean potential evapotranspiration / pixel / watershed
- Mean actual evapotranspiration / pixel / watershed
- Annual water yield volume (m³) / watershed
- Annual water yield volume of paddy (m³)

#### Inside of the model
- Annual Water Yield
- Method
II. Method

Temporal Comparison

- Raw Data
  - WorldClim ver2.0
  - Global PET database + MODIS NTSG
  - EGIS Land cover map

- Input Data
  - Precipitation
  - Reference evapotranspiration
  - Current Land Use Land Cover
  - Other input data

- Run models
  - Annual Water Yield Model
  - Soil Carbon Storage Model

- Outcome
  - Past Water Yield
  - Past Carbon Storage
  - Current Water Yield
  - Current Carbon Storage

- Method
  - Past: 1980-1999 (20 years)
  - Current: 2000-2020 (20 years)
III. Results
III. Results

Study Area

- Jeonbuk province, South Korea
  - 15.3% of paddy field in Korea
  - 16.2% of rice production in Korea

source: statistics Korea (2012)
### III. Results

#### Jeonbuk rice paddies’ Soil Carbon Storage

<table>
<thead>
<tr>
<th>Carbon Storage (Mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>0.984694</td>
</tr>
<tr>
<td>2.95408</td>
</tr>
<tr>
<td>3.93878</td>
</tr>
<tr>
<td>47.2653</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Past</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3,036,702 ton C / yr</td>
<td>2,733,031 ton C / yr</td>
</tr>
<tr>
<td></td>
<td>100.96 ton C / ha / yr</td>
<td>90.25 ton C / ha / yr</td>
</tr>
</tbody>
</table>

Rice paddies contribution

Soil Carbon Storage
### III. Results

#### Jeonbuk rice paddies’ Annual Water Yield

<table>
<thead>
<tr>
<th>Water Yield (m³)</th>
<th>Past</th>
<th></th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Yield</strong></td>
<td>6,626,775 m³</td>
<td>6,200,436 m³</td>
<td></td>
</tr>
<tr>
<td><strong>per m³ per year</strong></td>
<td>1,349.7 m³/ha/yr</td>
<td>1,282.2 m³/ha/yr</td>
<td></td>
</tr>
</tbody>
</table>
Soil Carbon Storage

• Rice paddies can capture greenhouse gases such as CO2 and can be a potential natural carbon storage.

• CH4 and N2O emission from rice paddies can be reduced through sustainable management scheme

Annual Water Yield

• Water yield in rice paddies decreases mainly due to land cover change

• Climate change may have negative impact on water yield in rice paddies

• Rice paddy conservation is necessary for the sustainable water yield
IV. Conclusion
Paddy fields not only produce rice but also provide various ecosystem services, and these ecosystem services can contribute to climate change mitigation and adaptation.

The rice paddy ecosystem in the whole of Korea and in the Jeonbuk region, the target of the pilot analysis, is continuously decreasing.

As a result of the analysis of ecosystem services for ‘carbon storage’ and ‘Annual water yield’ are decreasing.

It is necessary to preserve the rice fields rather than develop them in consideration of not only future food security but also the various ecosystem services provided by rice fields.
Thank you