Environmental Efficiency of Traditional Farming with Consideration of Grassland Biodiversity: Implication for the Ukrainian Carpathians

Irina Solovyeva, Ernst-August Nuppenau

Mountain hay meadows – economic, social and environmental value

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Research focus: Impact of traditional farming on environment

→ provision of environmental public goods such as mountain grassland biodiversity

State of the art:

- Biodiversity declines with increasing land use intensity (Kleijn et al., 2009)
  - Low-intensity traditional farming is effective in biodiversity provision
  - Intensification of agriculture is a threat for existing biodiversity
- Most observed scenarios for traditional farming systems are agricultural intensification (Tasser & Tappeiner, 2002) and land abandonment (Dullinger et al., 2003)
- Land abandonment is usual for disadvantageous areas (MacDonald et al., 2000)
- Land abandonment can lead to biodiversity loss in semi-natural landscapes connected to traditional farming (Fonderflick et al., 2010, Baumann et al., 2011)
Possible benchmarks for positive and negative externalities

Boundary to prevent biodiversity loss due to intensification

Boundary to prevent biodiversity loss due to abandonment

Mountain grassland biodiversity and landscape quality

Intensification

Extensification

Negative externality

Positive externality

Source: own representation based on Huenlenbroeck and Whitby, 1999, p. 27
Study area: the Ukrainian Carpathians

HNV farming concept
(Beaufoy 2007)

- Low-intensity farming
- Presence of semi-natural vegetation
- Presence of landscape mosaic

Features of the study area

- Traditional mostly subsistent farming with extensive farming practices (hand mowing, manure fertilization, cropping of small fields, rotation recognition, etc.)
- Limited opportunities for intensification due to geographical and climatic conditions
- Semi-natural landscapes
- Mountain grasslands converted from forests – habitat of conservation interest (hot-spots of biodiversity)
- Mosaic landscape
- Abandonment of grasslands leads to forest succession and loss of the landscape mosaic

HNV farming is regarded as a holistic system of extensive land use practices which includes the notion of connectivity between farming and nature
Joint production as a concept complementary to the theory of environmental external effects

Source: own representation based on Huelenbroeck and Whitby, 1999, p. 27
Traditional setting of production analysis

Source: Modified from Kuosmanen and Kortelainen, 2004
Environmental performance analysis

Incorporating the environmental externalities provides more complete representation of the production technology.

Modification of commonly used measures of technical efficiency.

\[
\text{Efficiency} = \frac{\text{Output}}{\text{Input}}
\]

Positive environmental externalities

Positive externality can be incorporated as an output (Sipilainen et al., 2008, Areal et al. 2012)

Case study (Sipiläinen et al., 2008):
Efficiency in production of agricultural biodiversity was considered to compare organic and conventional practices.
Environmental performance analysis

Positive environmental externalities

Positive externality can be incorporated as an output (Sipiläinen et al., 2008, Areal et al. 2012)

Case study (Sipiläinen et al., 2008):
Efficiency in production of agricultural biodiversity was considered to compare organic and conventional practices
Specification of the model

Positive environmental externality as a desirable output

Source: Modified from Kuosmanen and Kortelainen, 2004
DEA method
(Data Envelopment Analysis)

- Efficiency within a homogenous set of decision making units (DMU);
- Consideration of multi-input and multi-output production options;
- Usage of LP (linear programming) models solved for the efficiency measure of every DMU:
  - To construct efficiency frontier (reference technology);
  - To calculate the distance to the frontier for the less efficient DMUs.
DEA environmental efficiency

DMU \( k \) \quad \leftrightarrow \quad \text{Set of DMUs}

Output-oriented distance function \quad \leftrightarrow \quad \text{Reference technology represented by the set of constraints}
Data

- **Socio-economic survey**
  - 33 households
  - Kosiv, Verhovina and Nadvirna administrative regions

- **Geo-botanic survey**
Research sites in the Ukrainian Carpathians

- **Nadvirna district**
  - 3 villages
  - 11 households

- **Kosiv district**
  - 5 villages
  - 12 households

- **Verhovina district**
  - 3 villages
  - 10 households
Data

- **Socio-economic survey**
  - 33 households
  - Kosiv, Verhovina and Nadvirna administrative regions
  - Questionnaires: 42 questions covered such topics as land size, details about meadow management, motivation, future plans, selling of products, etc.

- **Geo-botanic survey**
  - 60 Sites
  - Information collected:
    - Site description
    - Percentage of vegetation cover
    - List of plant species
    - Abundance of these species
Specification of inputs and outputs

Set of conventional inputs

Farm

Set of conventional outputs

Environmental output

Source: Modified from Kuosmanen and Kortelainen, 2004
Specification of environmental output

- Literature based
  - Species richness (number of species)
  - Shannon diversity index
  - Presence of rare species
    - The indices are representing the quantitative indicators of a meadow but are not reflecting the quality of species combination

- Suggested aggregated biodiversity index
  - Connection of quantity and quality evaluation – not only the number of species but also their quality matters
Method: Biodiversity indicator

\[
BDI_j = \sum_{i=1}^{5} I_{ij} \times w_i
\]

<table>
<thead>
<tr>
<th>Indicators for evaluation (I(_{ij}))</th>
<th>Weights (w(_i))</th>
<th>Min value</th>
<th>Max value</th>
<th>Scale based scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Number of species</td>
<td>0,5</td>
<td>19</td>
<td>62</td>
<td>Scale 1 to 5</td>
</tr>
<tr>
<td>2 Number of productivity species</td>
<td>0,2</td>
<td>5</td>
<td>20</td>
<td>Scale 1 to 5</td>
</tr>
<tr>
<td>3 Number of rare species</td>
<td>0,15</td>
<td>0</td>
<td>5</td>
<td>Scale 1 to 5</td>
</tr>
<tr>
<td>4 Number of species indicating forest succession</td>
<td>0,1</td>
<td>0</td>
<td>6</td>
<td>Reverse scale with 5 for 0 species and 0 for max.</td>
</tr>
<tr>
<td>5 Vegetation cover</td>
<td>0,05</td>
<td>60%</td>
<td>100%</td>
<td>Scale 1 to 5</td>
</tr>
</tbody>
</table>
Specification of inputs and outputs

Set of conventional inputs

Farm

Set of conventional outputs

Environmental output

Source: Modified from Kuosmanen and Kortelainen, 2004
## Specification of outputs

### Set of conventional outputs

### Volume index

<table>
<thead>
<tr>
<th>Product</th>
<th>Estimation from the questionnaire</th>
<th>Unit</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>Information to the milk amount per cow</td>
<td>liters/ha per year</td>
<td>4370.55</td>
</tr>
<tr>
<td>Meat</td>
<td>Information on the meat sold and the meat consumed</td>
<td>kg/ha per year</td>
<td>63.92</td>
</tr>
<tr>
<td>Cheese</td>
<td>Information on the cheese sold and the cheese consumed</td>
<td>kg/ha per year</td>
<td>20.65</td>
</tr>
<tr>
<td>Potato</td>
<td>Output of potato per ha</td>
<td>kg/ha per year</td>
<td>5156.82</td>
</tr>
<tr>
<td>Hay</td>
<td>Output of hay per ha</td>
<td>kg/ha per year</td>
<td>2575.60</td>
</tr>
</tbody>
</table>
Specification of inputs and outputs

Source: Modified from Kuosmanen and Kortelainen, 2004
### Specification of inputs

**Set of conventional inputs**

<table>
<thead>
<tr>
<th>Input</th>
<th>Estimation</th>
<th>Unit</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td>Time spent for work connected to grasslands</td>
<td>Man-hours/ha per year</td>
<td>946,64</td>
</tr>
<tr>
<td>Capital</td>
<td>Number of machines (mowing machine or truck)</td>
<td>Items</td>
<td>1,15</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>Use of the manure or chemical fertilizers</td>
<td>kg/ha per year</td>
<td>897,86</td>
</tr>
<tr>
<td>Land</td>
<td>Grasslands (hay meadows and pastures)</td>
<td>ha</td>
<td>9,17</td>
</tr>
</tbody>
</table>

**without three largest farmers in the sample**
Specification of inputs: Labour

Who does the work

- Themselves, family: 69.7%
- Hired people: 6.1%
- Both: 24.2%
Specification of inputs: Capital

**Mowing method**

- Hand scyth: 18%
- Mowing machine: 24%
- Both: 58%
Specification of inputs: Capital

Usage of truck for hay transportation

- 39.4% own truck
- 30.3% rented truck
- 30.3% no truck
Specification of inputs: Fertilizers

Fertilization is usually used just for inner meadows

![Types of fertilizers used by the farmers](image)

- Organic: 74.2%
- Chemical: 6.5%
- Mixed: 9.8%
- None: 6.5%
### DEA environmental efficiency

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eff1</td>
<td>Efficiency of production without consideration of environmental output (model with one output)</td>
</tr>
<tr>
<td>EnvEff1</td>
<td>Efficiency of production with consideration of environmental output: both outputs are maximized (model with two outputs)</td>
</tr>
</tbody>
</table>
### DEA environmental efficiency

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<tr>
<td>Eff1</td>
<td>Efficiency of production without consideration of environmental output (one output-four inputs model)</td>
</tr>
<tr>
<td>EnvEff1</td>
<td>Efficiency of production with consideration of environmental output: both outputs are maximized (two outputs-four inputs model)</td>
</tr>
<tr>
<td>Eff2</td>
<td>Efficiency of production with consideration of environmental output: conventional output is maximized</td>
</tr>
<tr>
<td>EnvEff2</td>
<td>Efficiency of production with consideration of environmental output: environmental output is maximized</td>
</tr>
</tbody>
</table>
## Results: Efficiency scores

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Efficiency score ≥1</th>
<th>Efficiency score below 0,50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eff1</td>
<td>Efficiency of production without consideration of environmental output</td>
<td>0,57</td>
<td>0,33</td>
<td>30,10%</td>
<td>48,50%</td>
</tr>
<tr>
<td></td>
<td>(one output-four inputs model)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EnvEff1</td>
<td>Efficiency of production with consideration of environmental output: both outputs are maximized (two outputs-four inputs model)</td>
<td>0,90</td>
<td>0,15</td>
<td>54,50%</td>
<td>0,00%</td>
</tr>
<tr>
<td>Eff2</td>
<td>Efficiency of production with consideration of environmental output: conventional output is maximized</td>
<td>0,76</td>
<td>0,30</td>
<td>54,50%</td>
<td>36,40%</td>
</tr>
<tr>
<td>EnvEff2</td>
<td>Efficiency of production with consideration of environmental output: environmental output is maximized</td>
<td>0,87</td>
<td>0,18</td>
<td>54,50%</td>
<td>9,10%</td>
</tr>
</tbody>
</table>
## Results: Comparison of efficiency rankings

<table>
<thead>
<tr>
<th>Farm</th>
<th>Rank of Eff1</th>
<th>Rank of EnvEff1</th>
<th>Change in rankings</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>30,5</td>
<td>9,5</td>
<td>21</td>
</tr>
<tr>
<td>20</td>
<td>30,5</td>
<td>9,5</td>
<td>21</td>
</tr>
<tr>
<td>1</td>
<td>28,5</td>
<td>9,5</td>
<td>19</td>
</tr>
<tr>
<td>16</td>
<td>26</td>
<td>9,5</td>
<td>16,5</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>9,5</td>
<td>14,5</td>
</tr>
<tr>
<td>33</td>
<td>23</td>
<td>9,5</td>
<td>13,5</td>
</tr>
<tr>
<td>17</td>
<td>21</td>
<td>9,5</td>
<td>11,5</td>
</tr>
<tr>
<td>22</td>
<td>32</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td>21</td>
<td>28,5</td>
<td>19</td>
<td>9,5</td>
</tr>
<tr>
<td>10</td>
<td>33</td>
<td>24</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>14</td>
<td>9,5</td>
<td>4,5</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>31</td>
<td>11</td>
<td>9,5</td>
<td>1,5</td>
</tr>
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<tbody>
<tr>
<td>23</td>
<td>15</td>
<td>30</td>
<td>-15</td>
</tr>
<tr>
<td>24</td>
<td>18,5</td>
<td>33</td>
<td>-14,5</td>
</tr>
<tr>
<td>27</td>
<td>13</td>
<td>27,5</td>
<td>-14,5</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>26</td>
<td>-14</td>
</tr>
<tr>
<td>25</td>
<td>16</td>
<td>27,5</td>
<td>-11,5</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>31</td>
<td>-11</td>
</tr>
<tr>
<td>15</td>
<td>18,5</td>
<td>29</td>
<td>-10,5</td>
</tr>
<tr>
<td>29</td>
<td>10</td>
<td>20</td>
<td>-10</td>
</tr>
<tr>
<td>26</td>
<td>17</td>
<td>25</td>
<td>-8</td>
</tr>
<tr>
<td>28</td>
<td>27</td>
<td>32</td>
<td>-5</td>
</tr>
</tbody>
</table>
Implications

- along with the standard efficiency measures, it is important to consider environmental efficiency in case traditional type of farming is concerned;
- different approaches to analysis of environmental efficiency depending on the objectives of the application of the results;
- there might be differences in distribution based on the different study regions which are characterized by different climate conditions.

→ Challenges:

- to exclude the influence of natural site characteristics from the evaluation;
- extensive data requirements of the DEA-method.
Further questions

- Efficiency analysis and optimising behaviour
- What are the sources of inefficiencies?
- Being rational?
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THANK YOU for your attention!