Abstract: Nutzwertanalyse (NUWA) is a psychometric instrument for finding the test compromise in the multiple use planning of forestry, when the multiple objectives cannot be expressed in the same physical or monetary unit. It insures a systematic assessment of the consequences of proposed alternatives and thoroughly documents the decision process. The method leads to a ranking of alternatives based upon weighting of the objectives and evaluation of the contribution of each alternative to these objectives. The use of the method is illustrated with hypothetical data.

INTRODUCTION

In management planning of multiple use forestry the situation for the planner is as follows:

Many possible alternatives must be compared in the light of a great number of more or less consistent or conflicting objectives (aims, goals) between which functional relations cannot be specified.

In the process of comparing and assessing the consequences of the alternatives, it is unavoidable that the subjective preferences of the decision-maker and planner and of institutions play a vital role.

Consequently, psychometric methods have to be introduced to obtain solutions corresponding to objectives which cannot be expressed in physical or monetary units.

To overcome these difficulties neither intuition nor, mathematical models are of much help. In NUTZWERTANALYSE (NUWA) an instrument is at hand with which finding the best compromise can be made easier and more rational. The decision process will at the same time gain in clarity, and it will be reproducible in all its steps.
OUTLINE OF THE NUTZWERTANALYSE METHOD

The technique of NUWA consists of the following steps (see Abb. 1):

**Step 1:** The objectives (aims, goals) relevant to the situation are defined and arranged hierarchically according to means-objectives relations. At the end of the "chains of objectives" will be found "aims criteria" (Zielkriterien) $K_j$ sufficiently precise to serve as the basis of analysis and evaluation.

**Step 2:** The weights $g_j$ (Gewichte der Zielkriterien), i.e., the importance each objective shall assume in the process of evaluation, are given by the deciding authority according to its preferences.

**Step 3:** The consequences of each project alternative (alternative action) $A_i$ with respect to each "aim/criterion" $K_j$ are described in a matrix (Zieletragsmatrix). The elements $E_{ij}$ of this matrix can be formulated in words or numbers.

**Step 4:** By "measuring" the consequences of the alternatives, each element $E_{ij}$ is transformed into an element $W_{ij}$ of the "value-matrix" (Zielwertmatrix). The scales (nominal, ordinal, or cardinal) by which the consequences are measured depend on the form and the precision of their description.

By these four steps the evaluation of an alternative has been divided up into $m$ part evaluations, $m$ being the number of criteria (objectives) to be taken into account.

**Step 5:** For each alternative $A_i$ the NUTZWERT $N_i$ is found by combining the weighted "values," according to a set of decision rules, which are consistent with the type of measurement scale used. The result (Nutzwertmatrix) gives ranking of the alternatives analyzed.

So NUWA may be briefly described as a method, with which a number of project alternatives are analyzed and assessed, with respect to a multidimensional system of objectives, by ranking the alternatives according to the preferences of the decisionmakers.

The following considerations in using NUTZWERTANALYSE may help to clear up some of the more difficult aspects:

**System of General Objectives**

The first requirement for using NUWA is to formulate a complete system of well-defined and carefully arranged objectives. In Abb. 2 you will find a "System of General Objectives in Forestry" which I presented in Oslo at the XVIth IUFRO Congress. These objectives are to maximize, minimize, conserve, promote etc., the criteria listed in Abb. 2. This system is only a first try and I hope a start for further joint efforts. Meanwhile in our country a guide for forest regional planning has been published that contains this system in a slightly different form.
Logische Struktur der Nutzwertanalyse
in Anlehnung an ZANGEMEISTER

ZIELSYSTEM

Objectives
K1
K2
Km

Zielkriterien
Weights

Zielertragsmatrix (Eij)
Abb. der Alternativen im Zielsystem durch Zielerträge

Zielwertmatrix (Wi)
Abb. d. Alternativen im Wertesystem durch multidimensionale Präferenzordn.

Nutzwertmatrix (Ni)
Synthese der Zielwerte nach einer Entscheidungsregel

Alternativen
A1 A2 A3 An

Consequences of Alternatives
E11 E21 E31 En1

Values of Alternatives
W1 W2 W3 Wn

Rank of Alternatives
N1 N2 N3 Nn

STEP 1

STEP 2

STEP 3

STEP 4

STEP 5
Heights of Objectives

An example for step 2—the "weighting" of the objectives—is given in Abb. 3. Using the presented system of objectives, the weighting is simulated for the state forests of Hessia, using the method of "pairwise comparison." You find the preliminary weights calculated in percentage numbers in column (3) of the table. After a transformation by means of an interdependence factor, the final general weights are given in column (6) of the table. (These numbers correspond to the weights $g_j$ (Abb. 1). A detailed description of the method is given in another paper by the author (Henne 1976). Other methods are described in Zangenmeister.

Evaluation Scheme

In forest management planning certain types of planning situations constantly recur, e.g., planning the treatment of a stand to be harvested and regenerated (see the following simulation). In such a case an evaluation scheme (Abb. 5) for use in all similar situations can be prepared, in which step 3 and 4 of the NUWA logic are combined and systematized: the possible consequences of alternatives are put in increasing order and a corresponding scale is put above the resulting matrix (in Abb. 5 a cardinal scale is used). With respect to only four "objectives" can the consequences of the alternatives be measured in numerical units: wood production in cubic meters, gross receipts, costs in marks, and amount of labor in hours. In all other cases only qualitative descriptions can be given—for the time being. The vagueness of these descriptions and even some blanks show the field of research yet to be cultivated before intuition can be efficiently replaced by rational thinking in complex planning situations.

Simulation of a NUWA

One of the most important tasks in medium and long-term multiple use management planning of unevenaged forests is to decide

When and how to cut a mature stand,

How and with what species to regenerate the cleared area.

In Abb. 4 a planning situation of this kind involving five silvicultural alternatives ($A_1 - A_5$) is analyzed. You will find the following information:

In column 1 the objectives, drawn from the System of General Objectives in Forestry presented in Abb. 2

In column 2 the general weights of these objectives, drawn from column 6 in Abb.

In column 3 a transformation of the general weights to account for local conditions, and in column 4 the corresponding normalized value of these adjusted weights.
### Nutzwertanalyse

**Weighting of Objectives**

Using the method of "pairwise comparison" (KOELLE)

<table>
<thead>
<tr>
<th>Abb.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 111  | Site productivity | 0 | 0 | +1 | +1 | +2 | +2 | +3 | +3 | +4 | +4 | +4 | +4 | +5 |
| 112  | (Stand) stability | 0 | 0 | 0  | +1 | +2 | +2 | +3 | +4 | +4 | +4 | +5 |
| 113  | Flexibility       | 1 | 0 | 0  | 0  | +1 | +2 | +2 | +3 | +4 | +4 | +4 | +5 |
| 141  | Ecological benefits | 1 | 0 | 0  | 1  | +2 | +2 | +3 | +3 | +4 | +4 | +4 | +5 |
| 142  | Recreation        | 0 | 0 | 0  | 0  | 0  | +2 | +2 | +3 | +4 | +4 | +4 | +5 |
| 143  | Landscape         | 0 | 0 | 0  | 0  | 0  | 0  | +1 | +2 | +2 | +3 | +4 | +5 |
| 121  | Wood production   | 0 | 0 | 0  | 0  | 0  | 0  | 0  | +2 | +2 | +3 | +4 | +5 |
| 131  | Gross revenue     | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | +1 | +2 | +4 | +5 |
| 152  | Work conditions   | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | +2 | +3 | +4 | +5 |
| 151  | Jobs              | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | +2 | +4 | +5 |
| 132  | Costs             | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | +2 | +4 |
| 122  | Other forest products | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 144  | Game preservation | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

| Sum line | 0 | 1,016 | 12,0 | 11,7 |
| Col. 1 + (13 - 1) x 5 | +32 | 92 | 11,8 | 12,0 |
| Preliminary general weight (Col. 2 / 0,780) | +31 | 91 | 11,7 | 1,295 |
| Interdependence factor | +24 | 84 | 10,8 | 1,31 |
| Final general weights (Col. 3 x Col. 4) | +28 | 88 | 11,3 | 0,918 |
| Normalized general weights (Col. 5 / 1,023) | 21 | 81 | 10,4 | 0,935 |
| Final general weights (Col. 6 / Col. 4) | 9 | 69 | 8,8 | 0,984 |

*Note: The table format is not well-defined in the image, but the data suggests a pairwise comparison method is being used to weight objectives. The values represent the relative importance of each objective compared to others.*
### Nutzwertanalyse

#### Regeneration of a Beech Stand (130 years)

<table>
<thead>
<tr>
<th>Objectives</th>
<th>General weights</th>
<th>Last weights</th>
<th>Normalised local weights (Col. 3 · 0.278)</th>
<th>Value of Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site productivity</td>
<td>117</td>
<td>117</td>
<td>120</td>
<td>9</td>
</tr>
<tr>
<td>Stand stability</td>
<td>14.9</td>
<td>14.9</td>
<td>15.2</td>
<td>5</td>
</tr>
<tr>
<td>Flexibility</td>
<td>11.9</td>
<td>11.9</td>
<td>12.2</td>
<td>10</td>
</tr>
<tr>
<td>Water protection</td>
<td>1.0</td>
<td>-</td>
<td>1.0</td>
<td>5</td>
</tr>
<tr>
<td>Soil protection</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Effects on climate</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>3</td>
</tr>
<tr>
<td>Eff. on air pollution</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>3</td>
</tr>
<tr>
<td>Protection against noise</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Biotope for animals &amp; plants</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>8</td>
</tr>
<tr>
<td>Recreation</td>
<td>9.5</td>
<td>12.0</td>
<td>12.3</td>
<td>7</td>
</tr>
<tr>
<td>Landscape</td>
<td>8.5</td>
<td>10.0</td>
<td>10.2</td>
<td>7</td>
</tr>
<tr>
<td>Wood production</td>
<td>7.7</td>
<td>7.9</td>
<td>7.9</td>
<td>8</td>
</tr>
<tr>
<td>Financial results</td>
<td>6.1</td>
<td>6.1</td>
<td>6.2</td>
<td>4</td>
</tr>
<tr>
<td>Work conditions</td>
<td>7.0</td>
<td>7.0</td>
<td>7.2</td>
<td>9</td>
</tr>
<tr>
<td>Jobs</td>
<td>5.3</td>
<td>5.3</td>
<td>5.4</td>
<td>4</td>
</tr>
<tr>
<td>Costs</td>
<td>4.7</td>
<td>4.7</td>
<td>4.8</td>
<td>10</td>
</tr>
<tr>
<td>Other forest products</td>
<td>2.2</td>
<td>2.2</td>
<td>2.3</td>
<td>3</td>
</tr>
<tr>
<td>Game preservation</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>5</td>
</tr>
<tr>
<td>Nutzwert</td>
<td>726</td>
<td>760</td>
<td>508</td>
<td>479</td>
</tr>
<tr>
<td>Rank</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
### Nutzwertanalyse

#### Evaluation Scheme

### Methods of Regeneration and Choice of Species

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Use of Alternatives</th>
<th>Method of Regeneration</th>
<th>Influence on the Environment</th>
<th>Biodiversity</th>
<th>Forest Type</th>
<th>Land Use</th>
<th>Site Suitability</th>
<th>Junior</th>
<th>Middle</th>
<th>Senior</th>
</tr>
</thead>
<tbody>
<tr>
<td>107</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Abb** 5

---

**Legend**:  
- **very low**  
- **low**  
- **medium**  
- **high**  
- **very high**

**Mean Annual Volume Increment (m³)**  
- 0 - 1.5  
- 1.5 - 2  
- 2 - 3  
- 3 - 4  
- 4 - 5  
- 5 - 6  
- 6 - 7  
- 7 - 10  
- 10 - 14  
- 14 - 17  

**Other Forest Products**:  
- negligible  
- low  
- medium  
- high  
- very high

**Dies and Snow**:  
- 0 - 200  
- 200 - 400  
- 400 - 700  
- 700 - 1000  
- 1000 - 1200

**Cultivation**:  
- 50 - 90  
- 90 - 110  
- 110 - 140  
- 140 - 170  
- 170 - 200

**Water Protection**:  
- very unfavourable  
- unfavourable  
- medium  
- favourable  
- very favourable

**Soil Protection**:  
- very low  
- low  
- medium  
- high  
- very high

**Effects on Climate**:  
- very unfavourable  
- unfavourable  
- neutral  
- favourable  
- very favourable

**Protection against Wind**:  
- limited to certain areas  
- medium  
- high during winter or the entire coniferous forest regeneration phase

**Biotope for Animals and Plants**:  
- very low  
- low  
- medium  
- high  
- very high

**Recreation**:  
- open for activities during leisure phase  
- open for activities during recreation phase  
- snow cover higher and longer  
- luxuriant underwood

**Landscape**:  
- harmony with regard to tree species, age, stand structure, etc., preservation of "unintended" species, transparency of stands

**Forest Preservation**:  
- hardly qualified  
- legally qualified  
- normally qualified  
- well qualified  
- highly qualified

**Jobs**:  
- 2 - 5  
- 5 - 8  
- 8 - 12  
- 12 - 14  
- 14 - 18

**Work Conditions**:  
- very low  
- low  
- medium  
- high  
- very high

---

107
In columns 6 ... 10 the value matrix for the five alternatives obtained by applying the given evaluation scheme

In columns 11 ... 16 the "Teilnutzwerte" found by multiplying the values in columns 6 ... 10 with the "local" normalized weights drawn from column 4

At the foot of columns 11 ... 16 the "Nutzwerte" of the alternatives, ranging from 479 to 760, calculated by summing up the corresponding column of Teilnutzwerte

The alternative with the highest numerical value A2 is assigned rank 1. This alternative will yield a mixed stand of deciduous trees and conifers, produced by natural regeneration of the existing beech stands, using a shelterwood method, supplemented by planting larch and spruce.

This solution is the best compromise under the local conditions, the area being part of a nature park on the border of the Rhine-Main-Industrial Region. A look at columns 11 to 16 in the "Teilnutzwerte" (Abb. 4) shows which objectives contribute the most points to the "Nutzwert" of A2.

On the one hand it is the high importance attributed to the objectives of site preservation, stability and flexibility, in which the principle of sustained yield--of all the benefits of forests--is reflected. On the other hand it is the importance of recreation and landscape under the special circumstances of the example.

CONCLUSIONS

In conclusion, I hope I have been able to show not only how much more transparent the decision processes can become by using NUWA, but also how much weight the ecological, hygienic and aesthetic objectives are given in the silviculture and forestry of our country.

LITERATURE CITED


See for additional reference:

