Nutzwertanalyse

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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 (Zielertragsmatrix). 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.

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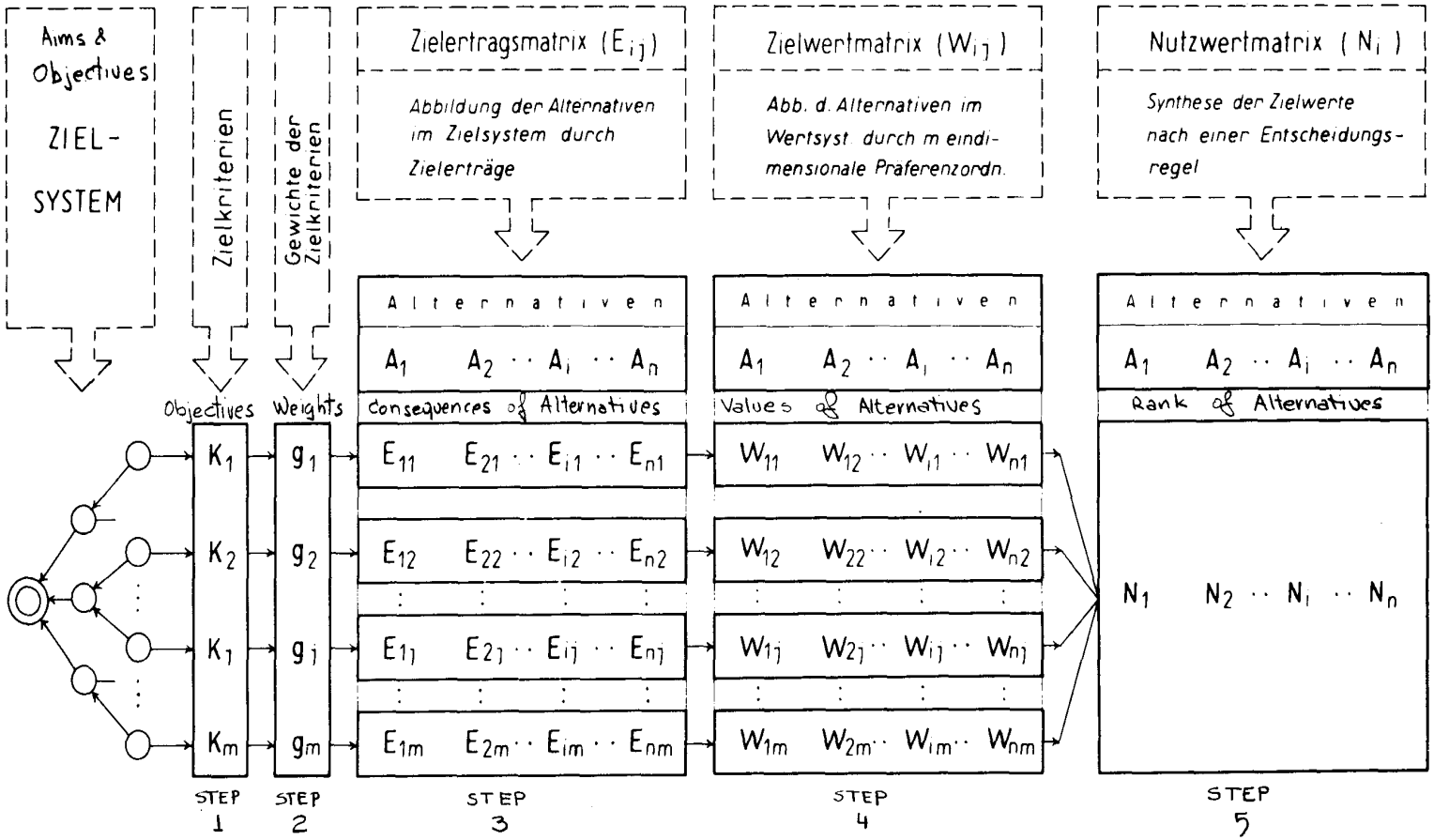
Nutzwertanalyse

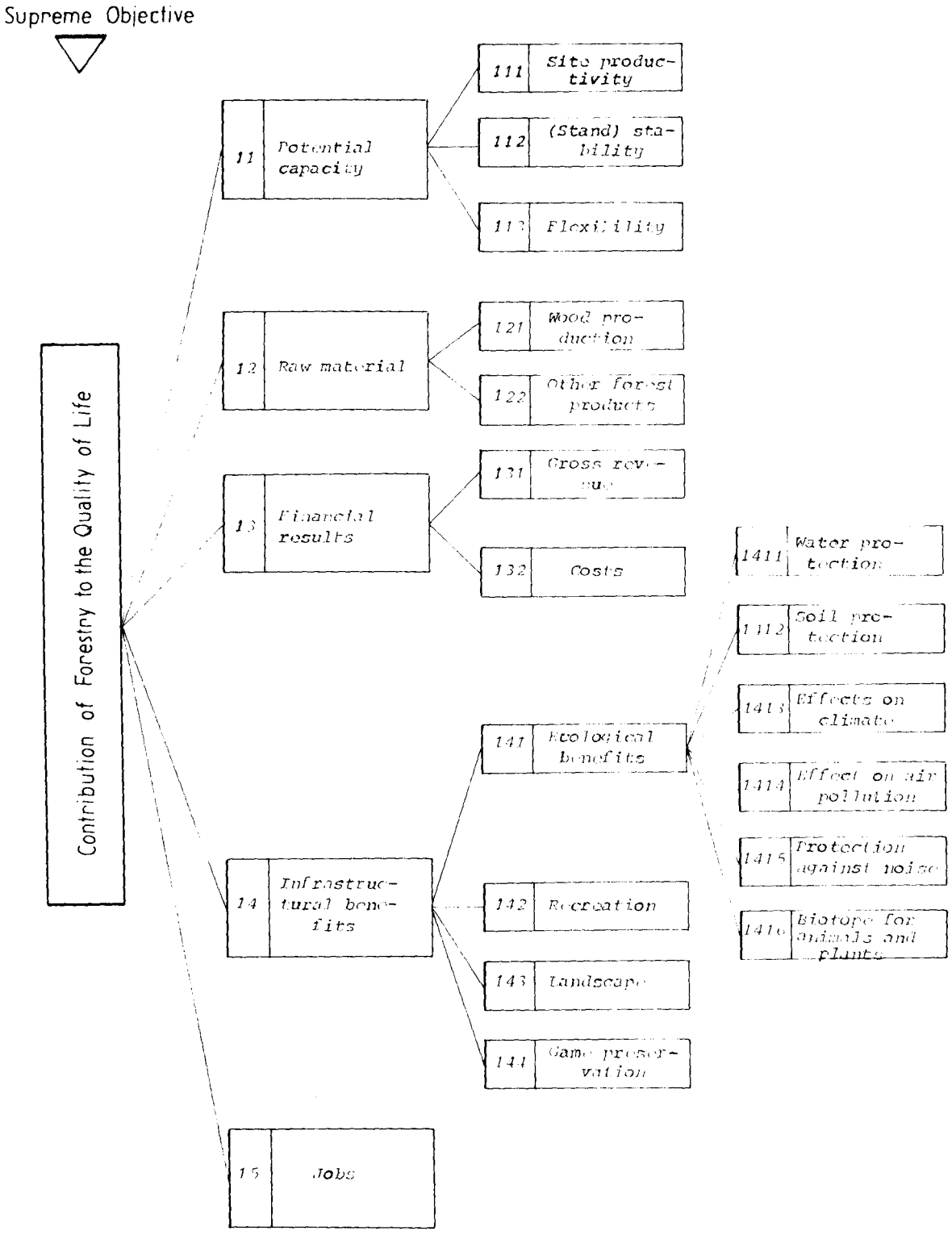
Logische Struktur der Nutzwertanalyse

in Anlehnung an ZANGEMEISTER

Abb. 1



FEA - GIESSEN **Nutzwertanalyse**	System of General Objectives in Forestry	Abb. 2



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 can be measured in numerical units: woos 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.

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Weighting of Objectives

Using the method of "pairwise comparison" (KOELLE)

Abb. 3

Is the objectivebelow more or less important*) than the objective here

*) Scale reaching from +5 = very much more import. 0 = equally important to −5 = very much less important

		Site productivity	(Stand) stability	Flexibility	Ecological benefits	Recreation	Landscape	Wood production	Gross revenue	Work conditions	Jobs	Costs	Other forest products	Game preservation	Sum line	Col. 1+(13−1) x 5	Preliminary general Weight (Col. 2 ÷ 0,780)	Interdependence factor	Final general Weights Col. 3 x Col. 4	Normalyzed general weights Col. 5 ÷ 1,023
		111	112	113	141	142	143	121	131	152	151	132	122	144	①	②	③	④	⑤	⑥
111	Site productivity	—	0	+1	+1	+2	+2	+3	+3	+3	+4	+4	+4	+5	+ 32	92	11,8	1,016	12,0	11,7
112	(Stand) stability	0	—	0	+1	+2	+2	+3	+3	+3	+4	+4	+4	+5	+ 31	91	11,7	1,295	15,2	14,9
113	Flexibility	−1	0	—	0	+1	+1	+2	+2	+3	+3	+4	+4	+5	+ 24	84	10,8	1,131	12,2	11,9
141	Ecological benefits	−1	1	0	—	+2	+2	+3	+3	+3	+4	+4	+4	+5	+ 28	88	11,3	0,918	10,4	10,2
142	Recreation	−2	−2	−1	−2	—	+2	+2	+3	+4	+4	+4	+4	+5	+ 21	81	10,4	0,935	9,7	9,5
143	Landscape	−2	−2	−1	−2	−2	—	+1	+1	+2	+2	+3	+4	+5	+ 9	69	8,8	0,984	8,7	8,5
121	Wood production	−3	−3	−2	−3	−2	−1	—	+2	+2	+3	+3	+4	+5	+ 5	65	8,3	0,951	7,9	7,7
131	Gross revenue	−3	−3	−2	−3	−3	−1	−2	—	0	+1	+2	+4	+5	− 5	55	7,1	0,869	6,2	6,1
152	Work conditions	−3	−3	−3	−3	−4	−2	−2	0	—	+2	+3	+4	+5	− 6	54	6,9	1,049	7,2	7,0
151	Jobs	−4	−4	−3	−4	−4	−2	−3	−1	−2	—	+2	+4	+5	−16	44	5,6	0,967	5,4	5,3
132	Costs	−4	−4	−4	−4	−4	−3	−3	−2	−3	−2	—	+4	+5	−24	36	4,6	1,049	4,8	4,7
122	Other forest products	−4	−4	−4	−4	−4	−4	−4	−4	−4	−4	−4	—	+2	−42	18	2,3	1,000	2,3	2,2
144	Game preservation	−5	−5	−5	−5	−5	−5	−5	−5	−5	−5	−5	−2	—	−57	3	0,4	0,836	0,3	0,3
		−32	−31	−24	−28	−21	−9	−5	+5	+6	+16	+24	+42	+57	0	780	100,0	13,000	102,3	100,0

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Example of a Nutzwertanalyse
Regeneration of a Beech Stand (130 years)

Abb. 4

1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Objectives		weights			Value of Alternatives							Teilnutzwerte (Col. 6 .... 10x Col. 4)				
		General weights Abb. 3 Col. 6	Local weights	Normalised local weights (Col. 3 : 0,978)		Leaving the beech stand for another 40 years, then Dougl.f.	Nat. regen. of beech, compl. by planting Larch + Norway spr.	Clear cutting, planting of Norway spruce	Clea - cutting, planting of Douglas fir	Clear cutg., pl. of Dougl. fir along road gradual reg. by select. cutting						
						A 1	A 2	A 3	A 4	A 5		A 1	A 2	A 3	A 4	A 5
111	Site productivity	11,7	11,7	12,0		9	10	7	6	8		108	120	84	72	96
112	(Stand) stability	14,9	14,9	15,2		5	9	4	2	5		76	137	61	30	76
113	Flexibility	11,9	11,9	12,2		10	8	2	1	3		122	98	24	12	37
1411	Water protection		–													
1412	Soil protection		–													
1413	Effects on climate	10,2	1,0	1,0		5	5	5	5	5		5	5	5	5	5
1414	Eff. on air pollution		–													
1415	Protection against noise		2,0	2,0		3	6	5	4	7		6	12	10	8	14
1416	Biotope for animals o. plants		1,0	1,0		8	10	3	1	6		8	10	3	1	6
142	Recreation	9,5	12,0	12,3		7	10	5	4	7		86	123	62	49	86
143	Landscape	8,5	10,0	10,2		7	10	6	5	8		71	102	61	51	82
121	Wood production	7,7	7,7	7,9		8	5	10	7	8		63	40	79	55	63
13	Financial results	6,1	6,1	6,2		6	3	10	8	8		37	19	62	50	50
152	Work conditions	7,0	7,0	7,2		9	4	9	9	8		65	29	65	65	58
151	Jobs	5,3	5,3	5,4		4	6	10	9	7		22	32	54	49	38
132	Costs	4,7	4,7	4,8		10	6	3	4	5		48	29	14	19	24
122	Other forest products	2,2	2,2	2,3		3	1	10	5	9		7	2	23	12	21
144	Game preservation	0,3	0,3	0,3		5	5	3	3	8		2	2	1	1	2
		100	97,8	100		Nutzwert						726	760	608	479	658
						Rank						2	1	4	5	3

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Evaluation Scheme
Methods of Regeneration and Choice of Species

Abb. 5

Value of alternatives → 0 1 2 3 4 5 6 7 8 9 10

Nr.	Objectives ↓	Zielertrage				
111	Site productivity	Biological activity of soil: strongly negative influence	slightly negative influence	not influenced	slightly favourable influence	strongly favourable influence
112	Stand stability	very low	low	medium	high	very high
113	Flexibility	conversion possible only in long intervals and technically difficult and/or costly	conversion possible during life-time of stand, few options in the next generation			conversion easy, several alternatives, many options in the next generation
121	Wood production	mean annual volume increment (m^3): 0 - 3,5	3,5 - 7	7 - 10,5	10,5 - 14	14 - 17,5
122	Other forest products	net revenue: negligible	low	medium	high	very high
131	Gross revenue	mean annual gross revenue, DM per ha, price basis 1976: 0 - 240	240 - 480	480 - 720	720 - 960	960 - 1200
132	Costs	mean annual direct costs, DM per ha, prices and wages 1976: 50 - 80	80 - 110	110 - 140	140 - 170	170 - 200
1411	Water protection	effects: very unfavourable	unfavourable	none	favourable	very unfavourable
1412	Soil protection	intensity and depth of root penetration: very low	low	medium	high	very high
1413	Effects on climate	effects on local climate: very unfavourable	unfavourable	neutral	favourable	very favourable
1414	Effect on air pollution	limited to certain seasons, missing during regeneration phase	limited to certain seasons, reduced in regeneration phase	medium	high during most of the year, only shortly interrupted during regeneration phase	very high in all age phases and during most of the year
1415	Protection against noise					
1416	Biotope for animals and plants	number of species: very low	low	average	high	very high
142	Recreation	open for activities during lesser part of rotation, no shelter by old trees in regeneration phase, snow cover higher and longer, no sunlight in winter				open for activities during greater parts of rotation, shelter by old trees even during regeneration phase, seasonal change between shadow and sunlight
143	Landscape	monotony with regard to tree species, age, stand structure etc., prevailing of "unaccustomed" species, no transparency of stands				harmonious change of tree species, age classes, stand structure, silvicultural intensity, prevailing of well known species, transparency of stands
144	Game preservation	as habitat for game on the average: hardly qualified	less qualified	normally qualified	well qualified	highly qualified
151	Jobs	mean annual volume of work, hours per ha: 2 - 5	5 - 9	9 - 12,5	12,5 - 15,5	15,5 - 18
152	Work conditions					

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

Henne, A. 1976. Ziele, Zielgewichte und Nutzwertanalyse in der mittelfristigen forstlichen Planung. Allg. Forszeitschr. 32.

Zangemeister, C. Nutzwertanalyse in der Systemtechnik. Wittemannsche Buchhandlung, Munchen, Gesim.

See for additional reference:

Gundermann, E. 1972. Untersuchungen sur Erfassung, Wertung and Ordnung der Erholungsfunktion von Waldbestanden im bayerischen Hochgebirge. Forschungsberichte der Forstl. Versuchsanstalt, Munchen.

Henne, A. 1972. De Sozialfunktionen des Waldes in der mittelfristigen forslichen Planung. Allg. Forstzeitschr. 24.

Jacob, H. 1973. Zur Messung der Erlebnisqualitat von Erholungswaldbestanden. Beiheft 9 zu Landschaft and Stadt, Ulmer Verlag.