

3.8 Nature Protection Function

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The preservation of the biological diversity (biodiversity) is, since the world conference in Rio de Janeiro in 1992, recognized to be one of the most important issues of our time. In this context forests are of great importance. With their large area, longevity, and structural diversity, Swiss forests comprise approximately 20,000 animal species and 500 vascular species' habitats (LANDOLT 1991; MEYER and DEBROT 1989). In addition to this are uncounted fungus, algae, bacteria, lichens, and moss species.

Since January 1, 1993 the new Federal Law on Forests has been in effect throughout Switzerland. The purpose of the new law is, among other things, "to protect the forest as an ecosystem near to nature". The term "ecosystem near to nature" is not further defined by the legislature. However, the meaning of "protect", for the purpose of nature protection, is indicated within several law articles pertaining to prohibition of deforestation; possibilities to limit accessibility to people and even limit large events in the forest; possibilities to designate forest reserves in order to preserve the species diversity of fauna and flora; protection against environmentally dangerous substances; regulation of the wildlife population; financial aid for expensive silvicultural operations conducted to protect nature; contributions to measures which protect and support forest reserves.

Conservation in Switzerland is at present primarily directed towards the preservation of endangered species and habitats (species and biotope protection). Most of the studies and inventories (forest conservation inventories) deal with a selection of "high quality" sites. Today, open forests that have low timber volume and some mature timber, forests that have not been managed for a while, forests rich in oak, and larger forests that are not accessible and are barely disturbed are accepted as "forest forms that deserve to be protected and supported" (BUWAL 1996). Here, two criteria are very important: threatened and rarity. The control of full reserves and partial reserves in order to protect valuable and endangered objects are the subject of special national inventories (e.g., flood plain forests, sphagnum bogs); however, extensive ecological evaluations over larger forested areas are missing for the most part.

An integrated conservation cannot be limited to threatened species and species-rich patches that are left over. The large-scale biodiversity of a region is mainly determined by the area used for agriculture and forestry, and for settlements. The area proportion used in the canton of Aargau amounts to 98% (WEBER *et al.* 1993). Therefore, at the national level the NFI is used, apart from other tasks, to recognize problems as well as to control the results of measures beneficial to forest conservation outside of the biotope protection in a stricter sense. The biotope protection "in a stricter sense" refers to the protection of special sites and special forests by designating parks or nature reserves and certain silvicultural operations. In addition to this, "regular" areas are managed to balance ecological impacts. The tools to balance ecological impacts for managed forests include for example: using natural regeneration and tree species adapted to the site; increasing older timber (longer rotation period) and dead timber; protecting and cultivating certain tree species; avoiding monoculture; and improving stand structure. The NFI is the national control instrument for such general nature protection measures and indicators.

For a comprehensive monitoring program that controls biological diversity, and for its development, the NFI would have to be expanded further. But even with its design today, it is an important instrument for the **long-term monitoring of the ecological sustainability in the utilized forest**, especially in the managed forest. For this, all forest stands have to be studied, even the ones with low ecological values, since due to natural development or specific tending operations they could turn into higher valued biotopes over time (VOLK and HAAS 1990).

Since the diversity of animals and plants (biodiversity) is, even today, neither exactly defined nor measurable, the so-called "indicators", "key criteria", or "measures" are used to evaluate forest stands. For the most part these are important habitat parameters for certain

animal groups, such as birds, insects, or small mammals. DUELLI (1995) writes: “The efforts to reduce the whole complexity of biodiversity to single indicators is an unsolvable task: One tries to measure diversity with one single value. However, as soon as we want to preserve and support biodiversity according to the [Earth Summit] convention in Rio de Janeiro for reasons of state, it is necessary to measure and evaluate”.

Indicators and biotope value models can thus never provide an integral answer about the state of nature. The evaluation of species diversity is inevitably always oriented on the limited knowledge and value concept of humans. We speak consequently of nature protection function: A part of society that makes demands on the forest, and in return the forest ideally provides the appropriate effects. The indicators that the NFI selected are therefore oriented as much as possible toward the current expectations of nature conservancy organizations. The association of the indicators with biotope values and ecotone value models is an attempt to combine the individual aspects into one single “measurable quantity”. The goal here is primarily to provide overall information about the spatial distribution and temporal development of the potential forest effects as a habitat for fauna and flora. The ecological value analysis in the forest and on the edge of the forest is one method used to evaluate the success of the forest management that is relevant to nature.

3.8.1 Methods for the Ecological Evaluation of Forest Stands and Forest Edges in the NFI

At the present time there exists neither for lowland forests nor for forests in mountainous regions, procedures for the ecological value analysis that are feasible, universally valid, and verifiable, and which can also be applied to NFI conditions without any additional development. Hence, during the field survey of the second NFI, initial versions of such procedures were developed that were intended to provide the background and experience for the application of future inventories. They were also to allow for an initial assessment of the actual ecological value of stands and forest edges.

3.8.1.1 Background

The evaluation of the state and the development of the forest, with respect to the biodiversity, took place in the second NFI and was primarily based on individual indicators (see also Table 1).

Table 1. Ecological attributes in the second NFI and their significance as an indicator.

NFI2 attribute	Type of data	Indicator for or valuable for:	Type of indicator
Coordinates x,y,z	Area data	Region and elevation: supply of solar radiation, climate, altitudinal vegetation zones; important for all species	Biotope (site)
Aspect, relief, landslides, erosion	Area data	Supply of solar radiation, nutrient supply, changes of site, open area, important for all species	Biotope (site)
Special sites and water bodies	Area data	Dry and wetlands; habitat for specialist, rare plants and animals, amphibians	Biotope (site)
Geomorphologic objects, small relief	Area data	Special sites for plants; habitat particularly for reptiles or amphibian (e.g., salamanders, toads)	Biotope (site)
Dry stone walls and heaps of stones	Area data	Habitat for animals like reptiles (lizards, snakes)	Biotope (site)
Sunny patches without vegetation	Area data	Habitat for insects (e.g., <i>Bombus terrestris</i>)	Biotope (site)
Heaps of branches and wood	Area data	Habitat for small mammals, birds, insects, reptiles	Biotope (stand)
Stumps and dead timber on the ground	Area data	Habitat for insects (larvae), fungi, moss, lichens	Biotope (stand)
Type of gaps	Area data	Forest site with higher supply of solar radiation; habitat for special plants, insects, game	Biotope (stand)
Standing dead timber	Area data	Habitat for insects, fungi	Biotope (stand)
Disturbances	Area data	Dumping ground, old/new forest drainage, buildings in the forest	Influence

NFI2 attribute	Type of data	Indicator for or valuable for:	Type of indicator
Heavy utilization	Area data	Extensive anthropogenic damages of the forest vegetation and/or trees	Influence
Type and intensity of grazing	Area data	Influencing the ground flora	Influence
Number of years since last treatment	Timber harvest	Influenced by the timber harvest	Influence
Amount of timber yield	Timber harvest	Influence through timber harvest; supply of solar radiation	Influence
Tools for timber harvest	Timber harvest	Influence through timber harvest (horse, cable crane, heavy machines)	Influence
Forest transportation system	Accessibility	Disturbance through road construction and road usage	Influence
Age of stand	Stand data	Old timber stands: valuable as habitat for insects and birds	Biotope (stand)
Stand edge, forest edge	Stand data	Transitional biotope: habitat for insects (caterpillar), birds, shade-intolerant plants, game, reptiles	Biotope (stand)
Closure of ground vegetation	Stand data	Browsing supply for game, indicator for supply of light; habitat for insects (e.g., wild bees)	Biotope (stand)
Stage of forest development (DBH _{dom})	Stand data	Young growth, old timber, etc.: habitat for game, insects, birds (e.g., hole nester), small mammals	Biotope (stand)
Crown closure of the stand	Stand data	Supply of solar radiation, coverage: flora, insects, birds, game	Biotope (stand)
Closure of shrub layer	Stand data	Vertical structure (birds) and cover (game)	Biotope (stand)
Stand structure (vertical layers)	Stand data	Vertical structure: birds, small mammals	Biotope (stand)
Forest type	Stand data	Coppice with standards, coppice forest, chestnut plantations (Selve), selection-type forests, etc.: valuable habitat for insects, birds	Biotope (stand)
Number of ligneous species	Stand data	Wide species conservation	Species
Type and closure of berries	Stand data	Habitat and food for small mammals, birds (e.g., wood grouse), insects, game	Biotope, species
Tree and shrub species	Tree data	Ligneous species diversity, ligneous species ecological valuable for insects, birds, small mammals (oaks, soft wood, etc.)	Biotope, species
Proportion of dead branches >20%	Tree data	Habitat for insects	Biotope (stand)
Tree damages	Tree data	Habitat for fungi, insects, birds, small mammals	Biotope (stand)
Trees with cavity	Tree data	Habitat for birds, small mammals and bats	Biotope (stand)
Stem diameter	Tree data	Old timber: important, for example, as tree cavity for black woodpecker (small mammals, bats, hole nester), insects	Biotope (stand)
Type of regeneration	Young growth	Closeness to nature for the forest regeneration	Influence
Protection of regeneration	Young growth	Obstacle for game, species perpetuation (e.g., silver fir, yew, etc.)	Influence
Aspect of the forest edge	Forest edge	Supply of solar radiation	Biotope (site)
Proportion of the individual ligneous species	Forest edge	Species diversity for tree and shrub species	Biotope, species
Structure of forest edge	Forest edge	Depth and incline of the transitional biotope	Biotope (stand)
Width of shelter belt	Forest edge	Width of the border biotope, light entry	Biotope (stand)
Width of shrub belt at forest edge	Forest edge	Width of the border biotope, habitat for birds, insects, small mammals, reptiles, game	Biotope (stand)
Width of herb border at forest edge	Forest edge	Width of the undisturbed herbal vegetation; flora, insects	Biotope (stand)
Density of forest edge	Forest edge	Supply of solar radiation, cover for game	Biotope (stand)
Shape of forest edge	Forest edge	Interlink and surface of forest/field; habitat diversity	Biotope (stand)
Limits of forest edge	Forest edge	Disturbance of the biotope forest edge	Influence
Surroundings of forest edge	Forest edge	Network of biotopes, disturbance of the border biotope	Influence
Condition of forest edge	Forest edge	Influence on the ecological quality and development of the forest edge	Influence

The assessment of species diversity indicators was, due to the costs, very limited: Ligneous species on the terrestrial grid in the second NFI (6412 sample plots) as well as a detailed survey of the entire vegetation on the 4.0 x 4.0 km grid (approximately 730 sample plots). The main focus was in the second NFI on the so-called habitat and influence indicator (BRÄNDLI and ULMER 1999), especially on those for which concrete ideas about the nominal condition with respect to conservation existed (Schweizerischer Bund für Naturschutz (SBN) 1989; Schweizerischer Bund für Naturschutz (SBN) 1992; VON BÜREN *et al.* 1995).

The goal of several research projects in the 1980's was to describe biodiversity in forests with standardized methods and a minimum of cost. Especially in the Federal Republic of Germany, different forest biotope evaluation methods were developed (AMMER and UTSCHIK 1982; AMMER and UTSCHIK 1983; AMMER and UTSCHIK 1986; AMMER and UTSCHIK 1988; BECHET 1976; DIETERLE 1988; GÖHRINGER 1988; HAAS 1989; KAULE 1991; SCHIRMER 1991; VOLK 1993; VOLK and HAAS 1990). Similar approaches in Switzerland can be found by GUNTERN (1988) and STOFFEL (1992). All evaluation methods have the following ideas in common: Assessment of qualitative indicator attributes (closeness to nature, diversity, rarity, threatened, abundance), evaluation or weighting, transformation, aggregation, quantification, and presentation as a total value, which was often considered as the biotope value/rating.

3.8.1.2 Procedures

For the development of the models in the NFI, the literature in Switzerland and the surrounding countries was examined for applicable evaluation models for forest stands and forest edges. The main focus here was the search for criteria (e.g., closeness to nature), the weights of the parameters with respect to each other, and the classification recommendations for the model values. The different approaches were studied in respect to the parts they have in common. Based on this, the parameters were selected from the existing data catalog of the second NFI. Parameters were only evaluated if their ecological value for certain animal groups (birds, insects, and small mammals) was qualitatively or quantitatively known and if they had already been used in models described in literature. Of special importance were the habitat requirements of two indicator species: black woodpecker and wood grouse. The forest, as a habitat for plants, was only indirectly considered by using indicators for light and temperature. The models presented here in the NFI should not obscure the fact that currently only few verified, universally valid and feasible indicators for the ecological value analysis are available for mountain forests as well as for forests in lowlands.

Based on literature, three partial models for the criteria "closeness to nature", "species diversity," and "structural diversity" were designed. Subsequently, an NFI survey team that was experienced in ecological matters ocularly rated these criteria on their stands and forest edges on a discrete scale during the usual data survey of the second NFI. They supplemented their survey with a final overall assessment of the biotope and ecotone value (field opinion). In the eastern and southern areas of Switzerland, a total of 351 forest stands, 79 having a forest edge, were ecologically assessed. After gathering the data, the models for the criteria and the overall assessment were optimized in the sense that they correlated, as best as possible, with the ocular ratings (BRÄNDLI *et al.* 1996). The weight for the attributes and the individual indicators was the subject of the model optimization in particular.

In the following, the models were also tested on NFI sample plots in the cantons of Aargau, Zurich, Vaud, Valais, and Grisons (field tests). The second NFI had neither sufficient funds nor time to validate the models with respect to the actual observed species diversity of the avifauna for example. If possible, these types of additional studies and model optimizations should be conducted while preparing a third NFI.

3.8.1.3 Application

The NFI models are directed to the **ecological dynamical aspects of the managed forest**; those attributes that (possibly) are substantially influenced by the type of forest management. Site parameters (elevation, aspect, area distribution, special sites, plant communities, etc.), which can either barely or not at all be influenced by the manager over a short period of time, were not intentionally used for the ecological evaluation models of the forest stands and forest edges. But the NFI site parameters were used as indicators for the ecological potential of the corresponding site. This strict separation of site potential and the real ecological diversity of the stands is the prerequisite to derive the improvement potential for stands (required action) and to control the success of the measures (VON BÜREN *et al.* 1995). Apart from an “optimal model” for the biotope value that includes all relevant parameters of the second NFI, a “minimum model” was developed as well, so that comparisons with the first NFI were possible even though it contained considerably less ecological data.

3.8.2 Biotope Value of the Forest Stand

The biotope value is derived based on the three criteria “closeness to nature”, “ligneous species diversity”, and “structural diversity”. Criteria such as “rarity” and “threatened” could not be integrated, since the second NFI was not optimized with respect to the appropriate parameters. Each one of the three criteria that were used is a variable composed of several parameters (attributes) whose outcomes could take on different values. The criteria themselves receive different weights in the final model:

biotope value = $a \cdot (\text{closeness to nature}) + b \cdot (\text{ligneous species diversity}) + c \cdot (\text{structural diversity})$
a, b, c: constants

3.8.2.1 Closeness to Nature of the Forest Stocking

Spruce plantations in areas of broadleaf mixed forests are not adapted to the site. Such forests are regarded as going against nature (unnatural) and ecologically of inferior quality. In the Plateau, the species spectrum is one-third lower in mostly pure spruce stands than the species spectrum in oak forests at the same elevation level (MÜLLER 1991). The replacement of the broadleaf forest by coniferous forests in general, results additionally in a steep decline of species and a strong decrease of the population density of soil organism (HEYDEMANN 1982).

Furthermore, broadleaf forests in lowlands allow, at least at the beginning of the vegetation period, more light and warmth to enter the stand and to reach the forest ground than coniferous forests. As a consequence, the living conditions and the turnover in the soil and in the lower vegetation layer are improved – an important prerequisite for many herbaceous plants and grasses. Spruce monocultures in broadleaf forest areas create long-term problems for the soil and the soil organism (Schweizerischer Bund für Naturschutz (SBN) 1989). Large proportions of conifers or spruce in a broadleaf forest area are thus regarded as indicators for a reduced diversity of fauna and flora.

The evaluation of the “closeness to nature” for the coniferous proportion is based on the model data for the potential natural vegetation (PNV, see Chapter 3.1) according to BRZEZIECKI *et al.* (1993) and on the current stocking as defined by the NFI (trees over 12 cm DBH). The relevant quantities for the evaluation of the current mixture of tree species in the natural area of the broadleaf forest are the current basal area proportion of conifers overall as well as the basal area proportion of spruce and fir (Table 2), similar to KIENAST *et al.* (1994) and differentiated by forest communities. The communities 1 to 46, according to ELLENBERG and KLÖTZLI (1972), are classified as broadleaf areas. Exotic species such as northern red oak are rare in Switzerland and were not considered in the model.

In broadleaf forest areas, stands that contain less than 10% or 25% conifers are considered “close to nature”. The natural proportion of silver fir in individual broadleaf communities is

taken into account here. “Moderately far from the natural state” are broadleaf forests with a coniferous proportion of up to 75 %; “far from the natural state” are those with a coniferous proportion of above 75%. If the proportion of spruce trees alone is above 75%, the stand is considered in the NFI to be “very far from the natural state”.

Since the model for the PNV does not account for some specific edaphic site factors, such as karren fields, some local misclassifications are possible. This is especially true for higher elevations in the western parts of the Jura (region around the Col du Marchairuz), where the prevalent forests are not mixed broadleaf forest as in the model, but are very often mixed fir forests (Dryopterido-Abietetum). Consequently, the proportions of mixed broadleaf forests “very far from the natural state” are overestimated in these regions.

The small size of the NFI sample plots makes conclusive interpretations impossible, such as whether a stand possesses all of the important natural tree species like silver fir or mountain ash (*Sorbus aucuparia* L.) in mountain forests. Stockings in areas of coniferous forests (i.e., on NFI sample plots with the modeled communities 47 to 71 according to ELLENBERG and KLÖTZLI, 1972) cannot be evaluated as a result and are rated in the biotope value model with respect to the closeness to nature (BWNATURN) by the same value 4 as natural mixed broadleaf forests. In contrast to that, mixed broadleaf forests that are “very far from the natural state” receive the minimal value of 1 (Table 2).

Table 2. NFI model for the closeness to nature of the forest stocking (BWNATURN): Code, definition of code, derivation based on the thresholds for the proportion of conifers and spruce as well as rating of the attribute.

Code	Definition of the code (class)	Derivation based on the thresholds for the conifer and spruce proportion	Rating (weight)
1	Mixed broadleaf forest that is very far from the natural state	>75% spruce ¹⁾	1
2	Mixed broadleaf forest that is far from the natural state	>75% conifer ²⁾ , <75% spruce	2
3	Mixed broadleaf forest that is moderately far from the natural state	10%/25%–75% conifer ³⁾	3
4	Mixed broadleaf forest that is close to nature	<10%/25% conifer ⁴⁾	4
5	Conifer forest community	E+K No. 47–71	4

E+K No.: Number of the forest community according to ELLENBERG and KLÖTZLI (1972)

- 1) E+K No. 1–46
- 2) E+K No. 1–46, excluding fir for E+K No. 20 and 46
- 3) 10–75% conifer for E+K No. 1–7; 9–11; 13–17; 21–44
25–75% conifer for E+K No. 8, 12, 18, 19
25–75% conifer (excluding fir) for E+K No. 20, 46
- 4) <10% conifer for E+K No. 1–7; 9–11; 13–17; 21–44
<25% conifer for E+K No. 8, 12, 18, 19
<25% conifer (excluding fir) for E+K No. 20, 46

3.8.2.2 Diversity of Ligneous Species in the Upper Layer

Mixed stands with a large number of ligneous species usually contain more animal and plant species, as well as having a larger overall number of individuals than single-species stands, as has been shown for birds. A diverse avifauna, in turn, can be an indicator for rich species diversity of a biotope. This is true since birds live off other animals and plants and are thus relatively high in the food pyramid.

In particular for the species protection of fauna, the occurrence of pioneers or softwoods such as willow, birch, alder, native poplar, Scotch pine, or the occurrence of special tree species such as oak, chestnut, sweet cherry, wild fruits, and sorbus species are important as habitats and

food sources (see also for example VON BÜREN *et al.* 1995). For example, of all native ligneous species, oak has the largest species spectrum of lignicolous beetles (BROGGI and WILLI 1993).

The diversity of ligneous species is based in the NFI on the dominant individuals that shape the biotope; that is trees which belong to the upper stand layer and have a DBH of at least 12 cm. The diversity among ligneous species (BWARTEN) is calculated as a function of the number of tree species per sample plot (500 m²) and the occurrence of special species (minimum of one individual in the upper layer). The values for ligneous species diversity can range between 1 and 7 (Table 3). In the result volume publication for the second NFI, ligneous species diversity is interpreted as follows: 1–2 = “low”, 3–4 = “medium”, 5–7 = “high”. (BRÄNDLI and ULMER 1999).

Table 3. Derivation and weights for the ligneous species diversity in the NFI model (BWARTEN).

Number of tree species	Weight
0 or 1 species	1
2 species	2
3 species	3
4 species	4
5 and more species	5
Occurrence of special species ¹⁾	Weight
No	0
Yes	2

¹⁾ Birch, willow, alder, native poplar, native oak, sorbus species, wild cherry, wild apple and pear trees, Scotch pine, sweet chestnut

3.8.2.3 Structural Diversity of the Stand

In forests with a good vertical and horizontal structure, the supply of heat, light, or water is considerably higher than in poorly structured ones. These factors influence the density and diversity of the (herbaceous) vegetation, which is an important source of food for herbivores and, therefore, indirectly for carnivores. According to USHER and ERZ (1994), it is at least partially possible to use the considerably more simple assessment of structural attributes instead of the number of animal species that are directly counted. Diverse structured forests increase the chance of a better habitat and site network for individual animal and plant species. Highly structured forests also offer more protection, cover, and/or overview (eyrie trees).

The diversity of the avifauna is regarded as being a good indicator of the general ecological diversity, since birds, depending on the species, feed on plants (fruits, seeds) and/or animals (insects, soil organisms). The special habitat requirements of breeding birds that live in the forest (MÜLLER 1991), especially the mountain cock and the black woodpecker (RIECKEN 1992), was given the highest priority in the selection of the NFI structural parameter. In addition, certain habitat requirements of other species such as insects, small mammals, wildlife, amphibian, and reptiles were taken into account (see Table 1). The weight of these attributes (see Table 4) was based on expert opinion and on the literature.

During the field validation (see procedures), the parameters (attributes, variables) and their categories (classes) were checked with respect to their plausibility and some of the weights were slightly changed (EST, STRUK, BHDGT50). In particular, the parameters “crown closure” ($R^2=0.23$), “stages of development” ($R^2=0.12$), and “stand structure” ($R^2=0.09$) had a significant statistical relationship with the ocular assessment of the structural diversity. These three “key parameters” were already assessed in the first NFI and formed the minimum model (BWSTRU1M) for the analyses of the development. BWSTRU1 is a more comprehensive comparison model and BWSTRUKT is the optimal model for the second NFI. Even though BWSTRUKT is much more detailed, the coefficient of multiple determination R^2 with 0.44 is hardly larger than for the model BWSTRU1M ($R^2=0.36$). The parameters for the three structural models are explained in Table 4.

Table 4. Parameter and weight of the attributes used in the NFI model for the structural diversity of stands.

Parameter (attribute)	Abbreviated name	Categories (classes)	Weight
Crown closure	SCHLUSSG	Crowded	1
		Normal	3
		Loose	3
		Open	6
		Sparse	6
		Grouped/crowded	5
		Grouped/normal	5
		Complete	4
Stages of development	EST	Young growth and thicket	2
		Pole wood	1
		Young timber	2
		Medium timber	3
		Old timber	6
		Mixed	4
Stand structure	STRUK	One-layered	1
		Multi-layered	3
		Multistorey	5
		Cluster structure	5
Basal area proportion of trees with a DBH >50 cm	BHDGT50	0%	0
		1–24%	2
		25–49%	3
		50–100%	5
Damage proportion of the stand (excluding needle/leaf loss of unknown cause)	BSTSGRAD	No damage detected	0
		Slight damage	1
		Moderate damage	2
		Heavy damage	3
		Very heavy damage, dead	4
Forest edge	WARA	Not existing	0
		Existing	5
Stand edge	BESTGREN	Not existing	0
		Existing	2
Type of gap	LUECKEN	No larger gaps in the stand	0
		Cutover or windfall areas	3
		Forest meadow without ligneous species	5
		Forest meadow with ligneous species	4
		Blocks, scree area	2
		Erosion and landslide areas	2
		Rock areas	2
		Avalanche ride, forest aisle	2
Coverage of shrub layer	STRADG	Less than 1%	0
		1–9%	1
		10–25%	2
		26–50%	3
		51–75%	4
		76–100%	5
Coverage of berry bushes	BEERDG	Less than 1%	0
		1–9%	1
		10–25%	3
		26–50%	5
		51–75%	3
		76–100%	2
Stumps, lying dead timber	STOECKE	Not existing	0
		Existing	2
Standing dead trees	DUERRSTA	Not existing	0
		Existing	3
Heaps of branches	AHAUFEN	Not existing	0
		Existing	2

$$\text{BWSTRUKT} = \text{EST} + \text{SCHLUSSG} + \text{STRUK} + \text{BHDGT50} + \text{BSTSGRAD} + \text{WARA} + \\ \text{BESTGREN} + \text{LUECKEN} + \text{STRADG} + \text{BEERDG} + \text{STOECKE} + \\ \text{DUERRSTA} + \text{AHAUFEN}$$

$$\text{BWSTRU1} = \text{EST} + \text{SCHLUSSG} + \text{STRUK} + \text{BHDGT50} + \text{BSTSGRAD}$$

$$\text{BWSTRU1M} = \text{EST} + \text{SCHLUSSG} + \text{STRUK}$$

EST:	Stage of development
SCHLUSSG:	Crown closure
STRUK:	Stand structure
BHDGT50:	Basal area proportion of tree with a DBH >50 cm
BSTSGRAD:	Damage proportion of the stand
WARA:	Forest edge
BESTGREN:	Stand edge
LUECKEN	Type of gap
STRADG:	Coverage of shrub layer
BEERDG:	Coverage of berry bushes
STOECKE:	Stumps, lying dead trees
DUERRSTA:	Standing dead trees
AHAUFEN:	Heaps of branches

Based on the comparison to the field assessments, which take into account the nature conservation demands, the structural diversity of the stand BWSTRUKT can be interpreted as follows:

Up to 14	Very homogeneous
15–20	Homogeneous
21–25	Heterogeneous
Over 26	Very heterogeneous

The theoretical values for BWSTRUKT range from 3 to 56. The values actually determined in the second NFI range between 4 and 41 (mean 20), where 41 corresponds to a very high structural diversity. In the result volume publication of the second NFI, the following classes were formed:

Up to 15	Low	16 to 24	Medium	Over 24	High
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3.8.2.4 Biotope value of the Stand

The biotope value of the stand is based in the NFI on the criteria “closeness to nature”, “ligneous species diversity”, and “structural diversity”. These three criteria were *standardized* during the derivation of the biotope value by dividing their observed values by the maximum achievable values. By comparing several different empirical “biotope value models” with the subjective general assessment from the field tests, those models where the *structural diversity was weighted twice* obtained the highest correlation.

The model BIOLFI2 is optimized for the extensive attribute catalog of the second NFI and considers most of the relevant structural attributes known from the literature. It is particularly suited to recognize regions with high structural diversity. The model BIOLFI1 and BIOLFI1M include only attributes that were already assessed in the first NFI. These models were used to illustrate the change between 1983/85 and 1993/95. The correlations of all three models to the field assessments are all the same. The choice of model for the analysis depends ultimately on which attributes are relevant for the comparison to other studies. If there are no preferences in this respect, the simplest model should be chosen that is easiest for others to comprehend. In the result volume publication of the second NFI, the simplest model BIOLFI1M was used for comparison with the first NFI (BRÄNDLI and ULMER 1999).

$$\text{BIOLFI2} = \text{BWNATURN}/4 + \text{BWARTEN}/7 + 2 \cdot \text{BWSTRUKT}/56$$

$$\text{BIOLFI1} = \text{BWNATURN}/4 + \text{BWARTEN}/7 + 2 \cdot \text{BWSTRU1}/27$$

$$\text{BIOLFI1M} = \text{BWNATURN}/4 + \text{BWARTEN}/7 + 2 \cdot \text{BWSTRU1M}/18$$

For the interpretation of the model values, the following thresholds were determined based on the ocular field validations, which took into account the conservation demands:

Biotope value	BIOLFI2	BIOLFI1	BIOLFI1M
Low	Up to 1,30	Up to 1,40	Up to 1,40
Tends to be low	1,31–1,85	1,41–1,85	1,41–2,00
Tends to be high	1,86–2,40	1,86–2,35	2,01–2,60
High	2,41–4,00	2,36–4,00	2,61–4,00

The values that were observed for BIOLFI2 in the second NFI range between 0,54 and 3,21 for a total of 6,330 stands (mean 1,91). In the result volume publication the following classes were formed:

Up to 1,60	= Low
1,61–2,00	= Medium
Over 2,0	= High

It is important to note that the transition from “low” to “high” is not distinct (Figure 1). The data from the field assessment in 1995 indicate that the dividing value is between 1.75 and 2.0 at approximately 1.85. In the second NFI the biotope values for 60% of all the stands exceeded this threshold.

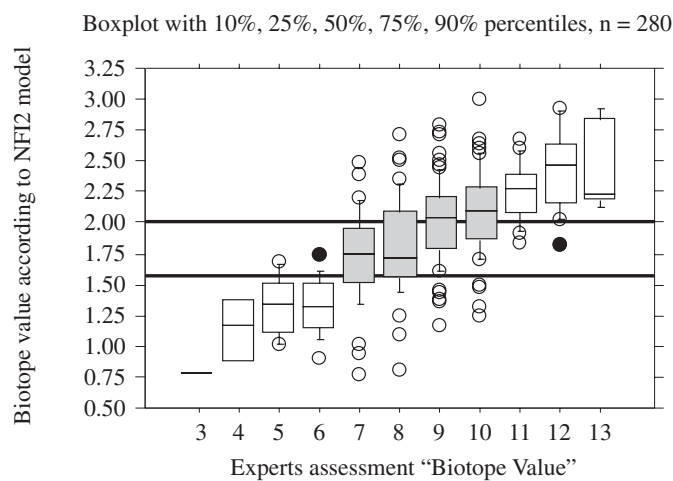


Figure 1. Relationship between the calculated model values and the ocular assessments for the “biotope value.” The ocular assessment corresponds to the total of the three partial assessments “closeness to nature,” “species diversity,” and “structural diversity” with possible values ranging between 3 and 15.

3.8.3 Ecotone Value of the Forest Edge

Forest edges are boundary or edge biotopes and are referred to as ecotones. This means that they are transitional zones between different biotopes. The forest edges offer habitat for plants and animals that live within open fields and the forest and, in addition, for organisms that are specialized in living in transitional habitats. For some species that have been displaced from intensively used cultural landscapes and are therefore endangered, it is possible that the ecologically valuable forest edges present a last refuge and chance of survival (VON BÜREN *et al.* 1995).

Intact forest edges play an important role in the network of habitats. This was the reason that in the second NFI all forest edges which were in the proximity to the sample plots were recorded for the first time. These 1,048 forest edges were assessed in detail along a 50 meter assessment line. The goal was to representatively record the diversity of the forest edges in Switzerland (BRÄNDLI *et al.* 1995). The NFI methods for the forest edge survey were developed by the author and are described in the manual for field survey (STIERLIN *et al.* 1994). The NFI procedure was developed to analyze the forest edges qualitatively and to detect changes. The length of the forest edge cannot be determined with this method.

The actual ecotone value refers at the forest edge cross section (Figure 2) to the zone elements “herb border”, “shrub belt”, and “shelter belt”, as well as to the “structure” in general, and refers along the forest edge (Figure 3) to the element “shape”, “density”, and “ligneous species”. The surroundings (open land), as well as the forest stands bordering to the inside, are not forest edge elements in the narrower sense.

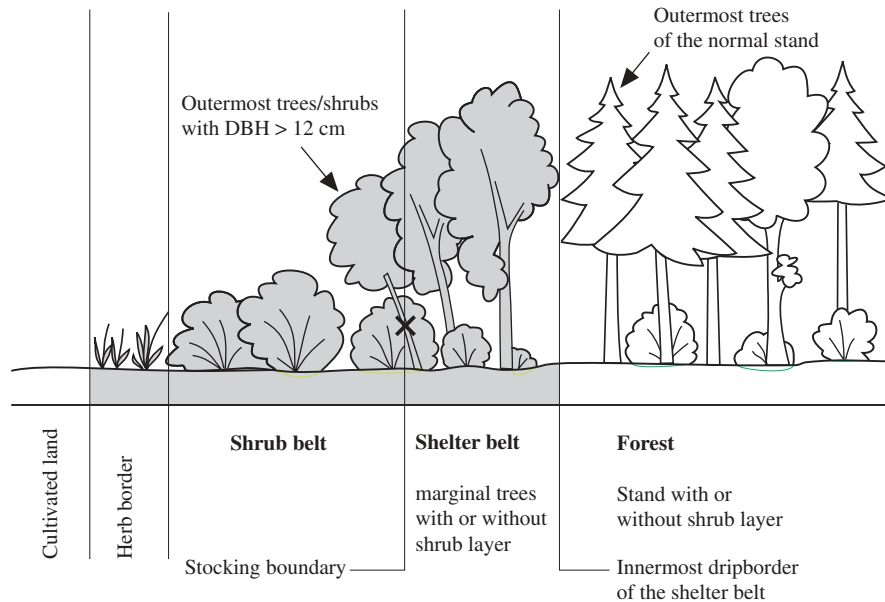


Figure 2. Forest edge in a cross-sectional view.

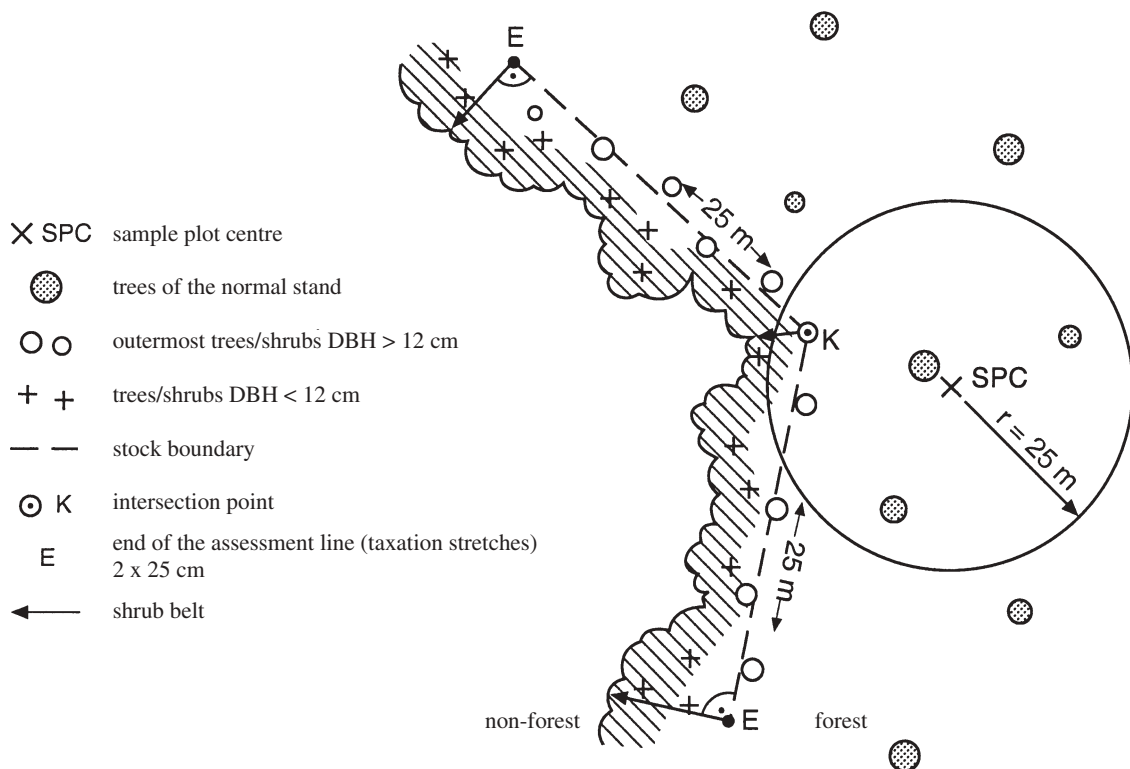


Figure 3. Situation with a forest edge – assessment line and sample plot.

Similar to the biotope value of the stand, the ecotone value was developed based on examples from literature (see for example, HONDONG *et al.* 1993; KRUG 1992; KRÜSI and SCHÜTZ 1994; VON BÜREN *et al.* 1995) as an integral model quantity for the ecological values of the edge biotope. Furthermore, the ecotone value was checked by experts in the field with respect to its plausibility and was developed further when necessary. The model is based solely on indicators that are related directly to the forest edge, influenced by forest and agricultural operations, and able to reveal ecologically relevant developments. The important ecological forest edge aspects that include “site” (aspect, elevation, soil, etc.), “surrounding”, and “biotope value of the stand” are not integrated. They are separately discussed and are particularly important for the derivation of the potential improvement of forest edges that have low ecotone values.

The ecotone value model is based on two criteria: “ligneous species diversity” and “structural diversity”. The criterion “closeness to nature” was not introduced or studied, since the necessary background about the forest edge communities was not available, and because most of the forest edges in the middle of Europe have been created by humans and are thus only “semi-natural” biotopes. Furthermore, the evaluation of the criterion “closeness to nature” in the cultural landscape is not considered very meaningful according to COCH and HONDONG (1995). Parameters such as dead trees, heaps of branches, or older timber along the forest edge were not specifically assessed. They were part of the biotope values in the bordering stand, which included the forest edge as well.

The assignment of model values for ligneous species diversity, structural diversity, and ecotone values to the relative classes “low”, “medium”, and “high” was oriented with the notion of conservation and was based on expert opinions in field tests in several regions of Switzerland (see Chapter 3.8.2.1). The NFI indicator model for the forest edge evaluations is suitable for spatial and temporal comparisons, but does not allow an absolute judgement with respect to the ecological value of individual forest edges.

3.8.3.1 Ligneous Species Diversity along the Forest Edge

The ligneous species diversity (WRARTEN) encompasses the three aspects “number of ligneous species” (WRANZART), “proportion of briers” (WRDORN), and “proportion of softwood and special species” (WRWEICH). The “number of ligneous species” takes the preservation of species into account here.

During the assessment of the ligneous species at the forest edges, approximately 100 different native and non-native species were differentiated (see page 71, STIERLIN *et al.* 1994). Of the 1,048 assessment lines that were 50 meters in length, between 1 and 28 different ligneous species were observed. Even though the statements, with respect to the ecological importance of individual ligneous species, are in part contradictory in the literature, it was attempted to take into account the occurrence of valuable species (WRDORN, WRWEICH) as well. “Briers”, for example, are regarded as potential breeding biotopes for birds and are used by numerous insects as a food source. The “softwood and special species” are primarily valuable food sources for insects, birds, and small mammals. Commonly used, but undifferentiated, general attributes like “coniferous proportion” were not taken into the model; instead, the coniferous proportion was taken into account separately by tree species and by site of the bordering stand for the derivation of the criterion “closeness to nature” in the model “biotope value” (see 3.8.2.2).

WRARTEN = WRANZART + WRDORN + WRWEICH

WRANZART: Number of tree and shrub species according to the species survey at the forest edge

WRDORN: Total proportion of briers: $\sum(A_i)$

WRWEICH: Total of the softwood/special species proportion: $\sum(A_k)$

A_i : Coded proportion A of the ligneous species i_n ; $n=1-7$

A_k : Coded proportion A of the ligneous species k_m ; $m=1-27$

- A: Coded proportion of a forest edge area occupied by a ligneous species:
 0 = Missing
 1 = Very rare or all individuals smaller than 1.3 meters
 2 = Sparse, less than 1% of the forest edge area
 3 = 1–5% of the forest edge area
 4 = 6–25% of the forest edge area
 5 = 26–50% of the forest edge area
 6 = 51–75% of the forest edge area
 7 = 76–100% of the forest edge area
- i: The 7 ligneous species: *Berberis vulgaris*, *Crataegus* sp., *Hippophaë rhamnoides*, *Prunus mahaleb*, *Prunus spinosa*, *Rhamnus cathartica*, *Rosa canina*
- k: The 27 ligneous species (groups): *Alnus glutinosa*, *A. incana*, *Betula pendula*, *B. pubescens*, *Castanea sativa*, *Corylus avellana*, *Hedera helix*, *Malus sylvestris*, *Pinus sylvestris*, *Populus alba*, *P. canescens*, *P. nigra*, *P. tremula*, *Prunus avium*, *P. padus*, *Pyrus communis*, *Quercus cerris*, *Q. petraea*, *Q. pubescens*, *Q. robur*, *Rubus fruticosus*, *R. idaeus*, *Salix* sp., *Sorbus aria*, *S. aucuparia*, *S. domestica*, *S. torminalis*

The mean value for all 1,048 NFI sample plots with a forest edge indicated that the criterion ligneous species diversity (WRARTEN) was almost equally determined by the number of species (WRANZART) and the occurrence of special species (WRDORN, WRREICH):

	Mean	Maximum
WRARTEN	22.1	57
WRANZART	11.5	28
WRDORN	3.1	11
WRWEICH	9.4	28

Based on the validation of the model values by experts in the field, the values for WRARTEN, which are relative to the conservation requirements, can be interpreted as follows:

Ligneous species diversity

Up to 11	Low
12–20	Tends to be low
21–29	Medium
30–38	Tends to be high
Over 38	High

The values determined for the ligneous species diversity in the second NFI range between 1 and 57. On the same basis as above, three classes were derived for the result volume publication of the second NFI:

Up to 15	Low
16–25	Average
Over 25	High

3.8.3.2 Structural Diversity at the Forest Edge

The parameter selection and weighting for the model “structural diversity” is based on the data catalog from the second NFI, the field tests in 1995, and accounts given in the literature of their ecological relevance. Site parameters (e.g., aspect) and site-specific attributes (proportion of broadleaf) were not considered in the structure model. Other attributes of the second NFI (thick or dead trees, heaps of branches, heaps of rocks, etc.) were assessed on the sample plot and cannot be directly related to the forest edge area. They were used for the biotope value of the stand. Zoological attributes such as anthills, droppings, etc. were not assessed in the second NFI.

Table 5. Parameter and weight of the attributes used in the NFI model for the structural diversity at the forest edge.

Parameter (attribute)	Abbreviated name	Categories (classes)	Weight
Structure of forest edge	AUFBAU	Without shelterbelt, without shrub belt	1
		Without shelterbelt, with shrub belt	2
		Steep shelterbelt, without shrub belt	2
		Wide shelterbelt, without shrub belt	2
		Shrub belt under the shelterbelt	3
		Shrub belt in front of the shelterbelt	4
Width of shelterbelt	MANTELBR	Multistoried shelterbelt with shrub belt	5
		0-2 meters	1
		3-4 meters	2
		5-6 meters	3
		7-8 meters	4
Width of shrub belt	STRABR	over 8 meters	5
		0-1 meters	1
		2 meters	2
		3 meters	3
		4-5 meters	4
Width of herb border	KRAUTBR	over 5 meters	5
		Less than 0,5 meter (not existing)	1
		0,5-1,0 meter	2
		1,1-2,0 meters	3
		2,1-5,0 meters	5
Shape of forest edge	VERLAUF	over 5,0 meters	7
		Straight	1
		Undulating	2
		Indented	3
		Deeply indented	4
Density of forest edge	DICHTE	Patchy	5
		open; 0-24% closed	1
		sparse (or with gaps); 26-50% closed	2
		loose; 51-75% closed	3
		dense; 76-100% closed	3

The structure diversity (WRSTRUKT) at the forest edge was calculated from six forest edge parameters based on the weights for the attributes (Table 5). The experience with the field survey for the second NFI showed that the shelter belt width (MANTELBR) was very often difficult to determine and indicated that in three-quarters of all cases, the width was between 2 and 5 meters. The extreme case, namely the absence of a shelter belt, has already been taken into account by the parameter “structure of forest edge” (AUFBAU). Since little is known about the ecological relevance of the shelter belt width, this parameter was disregarded in the minimum structural diversity model (WRSTRUKM). This reduced structure model correlated better with the subjective structure assessment from the field test as well. The parameters for the structure models are explained in Table 5.

$$\text{WRSTRUKT} = \text{AUFBAU} + \text{MANTELBR} + \text{STRABR} + \text{KRAUTBR} + \text{VERLAUF} + \text{DICHTE}$$

$$\text{WRSTRUKM} = \text{AUFBAU} + \text{STRABR} + \text{KRAUTBR} + \text{VERLAUF} + \text{DICHTE}$$

AUFBAU: Structure of forest edge

MANTELBR: Shelter belt width

STRABR: Width of shrub belt

KRAUTBR: Width of herb border

VERLAUF: Shape of forest edge

DICHTE: Density of forest edge

On the 1,048 assessed forest edges, WRSTRUKM had a mean value of 12.4 (maximum 24), and WRSTRUKT had a mean value of 14.5 (maximum 28). Based on the validation of the model values by experts in the field, the values for WRSTRUKT, relative to the conservation requirements, can be interpreted as follows:

Up to 11	Low
12–14	Tends to be low
15–17	Moderate
18–21	Tends to be high
Over 21	High

On the same basis as above, three classes were derived for the result volume publication of the second NFI:

Up to 12	Low
13–15	Moderate
Over 15	High

3.8.3.3 Ecotone Value of the Forest Edge

The ecotone value of the forest edge (OEKOLFI2) is based on the criteria ligneous species diversity and structure diversity. Compared to the expert assessment of the field tests, as for the biotope value, the highest correlations were obtained when the structure diversity was weighted twice as high as the species diversity in the *standardized* model. Based on this, the mean values for the species and structure diversity were multiplied by 3.0, and 3.5 for the following *non-standardized* ecotone models.

$$\text{OEKOLFI2} = \text{WRARTEN} + 3.0 \cdot \text{WRSTRUKT}$$

$$\text{OEKOLFIM} = \text{WRARTEN} + 3.5 \cdot \text{WRSTRUKM}$$

The less complicated ecotone model OEKOLFIM (without considering the shelter belt width) had a slightly higher correlation with the subjective general assessment than OEKOLFI2.

Depending on the problem task, either model can be used.

Within the result volume publication of the second NFI, the model OEKOLFI2 was used. The observed values for this model ranged between 24 and 138 (mean 65.7). The value 138 was the result of the highest number of species and structure diversity achieved. The two to five best forest edges have ecotone values of 116 and 115. Since absolute judgement of the ecotone values are always debatable, the following relative classification in the second NFI is based on the 25% and 75% quartile for all 1,048 studied forest edges.

Up to 55	= Low
56–75	= Average
Over 75	= High

It is interesting to note that these statistical limits match exactly those that were derived earlier from the field assessment (Figure 4).

Applying the evaluation system of KRÜSI and SCHÜTZ (1994), the threshold for “good” forest edges is at an NFI2 ecotone value of approximately 100. This threshold is only reached by 2% of all studied cases. Forest edges can be considered “satisfactory” with an ecotone value of over 70, which corresponds approximately to the lower threshold for “high” forest edge quality according to the second NFI. Approximately 40% of all assessed forest edges reach this value. An “average” ecotone value, in accordance with the second NFI, corresponds to a rating of “unsatisfactory” according to Krüsi and Schütz. A “low” ecotone value definitely corresponds to the rating “poor”.

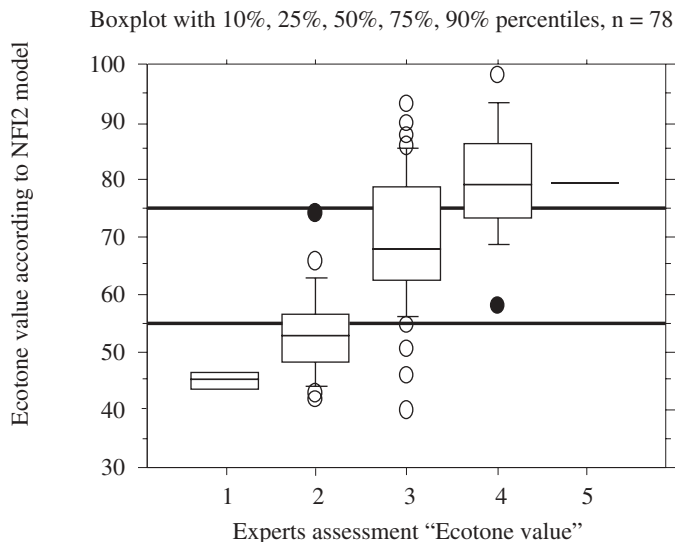


Figure 4. Relationship between the calculated model values and the ocular assessments for the "ecotone value." In the ocular assessment a value of 1 corresponds with the evaluation of "very low" and the value 5 with the evaluation "very high."

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