Case Study of Post-fire Fuel Analysis and Habitat Structures, and Pre-fire Reconstruction in Bad Bleiberg, Southern Austria.

Presented by

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ABSTRACT

In the course of the "Austrian Forest Fire Research Initiative" (AFFRI) a first forest-fuel analysis in Austria was conducted. Fuel types, which contribute to the fire behaviour, were identified. The fuel load in forests, especially vegetation, litter and downed woody material, play a supportive role in the spread and behaviour of wildfires. At the same time, these ecosystem resources and structures are important components of the habitat suitability for wildlife. Hence, corresponding habitat types were identified in terms of "Wildlife Ecological Stand Types". Furthermore it was an aim to reconstruct the fuel and habitat structures prior to the wildfire at the study site in 2003. Using forest inventory maps from different time periods, it was possible to reveal the changes in habitat suitability due to the wildfire, exemplary for *Capreolus capreolus* and *Tetrao urogallus*. The use of fuel data for habitat research in wildlife ecology is an opportunity. However, a direct translation of the fuel types to the "Wildlife Ecological Stand Types" was not possible, but encouraged the discussion. In the context of habitat suitability, the estimation of fire susceptibility of forests can open up new vistas in wildlife management and nature conservation.

Key words: disturbance, fuel type, habitat suitability, wildfire, wildlife management.

ZUSAMMENFASSUNG

Im Rahmen der „Austrian Forest Fire Research Initiative“ (AFFRI) wurde in Österreich eine erste Analyse von brennbarer Biomasse im Wald durchgeführt. Die „fuel types“, die das Brandverhalten beeinflussen, wurden bestimmt. Die Menge der brennbaren Biomasse in Wäldern, vor allem Vegetation, Streu und Totholz, spielen eine wesentliche Rolle bei der Ausbreitung und dem Verhalten von Waldbränden. Gleichzeitig sind diese Ökosystem-Ressourcen und Strukturen wichtige Requisiten der Habitateignung für Wildtiere. Dementsprechend wurden daraus „Wildökologische Bestandestypen“ identifiziert. Ausserdem war es ein weiteres Ziel, die gegebenen Biomasse- und Habitateigenschaften vor dem Waldbrand, der 2003 im Untersuchungsgebiet stattfand, zu rekonstruieren. Unter Verwendung von Altersklassenkarten verschiedener Zeitreihen, wurde es ermöglicht die Veränderungen der Habitatausstattung und damit der Eignung beispielhaft für *Capreolus capreolus* und *Tetrao urogallus* darzustellen. Für Habitatstudien in der Wildtierökologie, ist das Verwenden von Daten der brennbaren Biomasse eine Chance. Eine direkte Übersetzung der „fuel types“ in die „Wildökologischen Bestandestypen“ ist nicht gelungen, was aber zur Diskussion angeregt hat. Im Kontext der Habitateignung kann die Abschätzung der Brandanfällingkeit von Wäldern neue Perspektiven für das Wildtiermanagement und den Naturschutz eröffnen.

Schlüsselwörter: Fuel Typ, Habitat Eignung, Störung, Waldbrand, Wildtiermanagement.

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INDEX OF ABBREVIATIONS

AFFRI	**Austrian Forest Fire Research Initiative**
BL	**Blank; the term is used for the area, which was affected by the windthrow, the wildfire and salvage logging. It comprises 32,26 ha and is mostly unstocked, covered with herbs, grass and shrubs.**
CBH	**Crown base height**
DBH	**Diameter at breast height**
FMC	**Forest management class**
MR	**Plots sampled in mature stands**
PiL	**Pinus Austria low 51, fuel type**
PiM	**Pinus Austria moderate 52, fuel type**
PL	**Plots sampled in pole stands**
TH	**Plots sampled in thicket stands**
TL	**Timber litter, fuel type**
TU	**Timber understory, fuel type**
WEST	**Wildlife ecological stand type**
022	**Idle grassland**
093	**Thicket**
101	**Pole stand, poor in ground vegetation**
102	**Pole stand, rich in ground vegetation**
103	**Pole stand, regeneration in gaps**
111	**Mature stand, poor in ground vegetation**
112	**Mature stand, rich in ground vegetation**
121	**Regeneration under a mature stand**
123	**Thicket-like regeneration under a mature stand**
124	**Pole stand like regeneration under a mature stand**
131	**High forest, poor in ground vegetation**
132	**High forest, rich in ground vegetation**

CONVERSION TABLE

Fuel size classes:	**Other units used:**
0,6 cm = 0,24 inch	1 cm = 0,394 inch
2,5 cm = 0,99 inch	1 m = 3,28 feet
7,5 cm = 2,9 inch	1 m^2 = 10,76 $feet^2$
	1 ha = 2,5 acre
	1000 kg = 1,1 US ton

INDEX OF SPECIES

Scientific name	Common name
FLORA	
Acer pseudoplatanus	Sycamore Maple
Alnus viridis	Green Alder
Amelanchier ovalis	Snowy Mespilus
Anemone nemorose	Wood Anemone
Brachypodium pinnatum	Tor Grass
Calamagrostis species	Reedgrass
Carex alba	White Sedge
Dactylis glomerata	Orchard Grass
Dentaria enneaphyllos	Nine-leaved Coral-wort
Deschampsia flexuosa	Waivy Hairgrass
Erica carnea	Spring Heath
Erica tetralix	Cross-leaved Heath
Euphorbia species	Spurge
Fagus sylvatica	European Beech
Gallium species	Bedstraw
Larix decidua	European Larch
Mercurialis perennis	Dog´s Mercury
Picea abies	Norway Spruce
Pinus banksiana	Jack Pine
Pinus mugo	Mountain Pine
Pinus sylvestris	Scots Pine
Polygala chamaebuxus	Shrubby Milkwort
Pteridium aquilinum	Common Bracken
Rubus fruticosus	Blackberry
Rubus idaeus	European Red Raspberry
Sesleria varia	Blue Moor-Grass
Sorbus aucuparia	Mountain Ash
Quercus	Oak
Veronica officinalis	Common Speedwell
Vaccinium myrtillus	Common Bilberry
Vincetoxicum officinale	White Swallo-wort
FAUNA	
Bonasa bonasia	Hazel Grouse
Capreolus capreolus	European Roe Deer
Cervus elaphus	Red Deer
Lepus europaeus	European Hare
Rupicapra rupicapra	Chamois
Tetrao urogallus	Western Capercaillie
Tetrao tetrix	Black Grouse

1 Introduction

This master thesis is part of the “Austrian Forest Fire Research Initiative” (AFFRI), which is funded by the Austrian Science Fund. The study site for this master thesis was chosen as a reference site in one of Austria’s fire hot spots, for a wildfire occurred there in the year 2003.

Wildfires in Austria are actually not present in the consciousness of the Austrian people. In general, most Austrians know little about where wildfires occur, what the possible sources for ignition are, and what effects they can have on the ecosystem.

Due to climate change it is hypothesized that the fire susceptibility of Austrian forests is raising (GOSSOW et FRANK, 2003, p. 8). Therefore it is desirable to make an inventory of the fuel load – comprising litter, downed woody material and vegetation – which plays an evident role in the fire susceptibility of a forest stand and in the behaviour of wildfires. In fact, the analysis of the fuel load decodes ecosystem resources important to habitat suitability for wildlife.

In case of a wildfire outbreak these vegetation structures are changed instantly, altering fuel beds and habitats. In terms of post-fire succession and wildlife ecology it is of interest how the fuel and habitat situation has changed due to the wildfire. Obviously there is a link between habitat structures and fuel.

Observing the fire susceptibility of forest stands is for the benefit of forest management, wildlife management, and nature conservation. A fuel analysis enables the identification of fuel types and an estimation of fire susceptibility. However, is it possible to use these fuel classifications to give a statement about habitat structures or habitat types? Establishing this fuel-habitat link is an aim of this thesis because the existence, the nature and the changeability of habitats could then be managed in the light of fire susceptibility, to a certain degree.

It is hypothesized that the identified fuel types might be applicable to the "Wildlife Ecological Stand Types" at the case study site. Two forest dwellers are chosen exemplarily: (a) *Capreolus capreolus* (European Roe Deer) – as more typical for early successional stages – and (b) *Tetrao urogallus (Western Capercaillie)* as especially adapted to old-growth forests.

This approach can be seen as a first step in the development of using fuel analysis for habitat evaluations.

Hence, the aims for this master thesis are:

1. to analyse the present fuel situation at the study site (6 years after the wildfire);
2. to demonstrate relationships between fuel analysis and the evaluation of habitat structures;
3. to therefore identify the present fuel types and "Wildlife Ecological Stand Types";
4. to reconstruct the fuel and habitat situation on the fire prone area prior to the wildfire.
5. to compare the fuel and habitat situation pre- and post-fire on the fire prone area.
6. to illustrate the wildlife species present at the case study site by looking for a pattern in pellet findings.
7. and finally, to link the findings of the study: fuel-habitat link and pre- and post-fire comparison, to reveal the changes in habitat suitability using the examples of *Capreolus capreolus* and *Tetrao urogallus*.

2 Background

2.1 Wildfires in Austria

Compared to wildfires in the Mediterranean, Northern America or Australia, wildfires in Austria occur on a much smaller scale with an average extension of under 1 ha, yet they are numerous. In the period of 1958 to 2007 an annual average of about 56 wildfires (GOSSOW et al., 2008, p. 3) were documented in Austria. However, in the years 2003 and 2007 – the so-called wildfire-years, 140 wildfires (number of occurrences incomplete) were registered each (VACIK, 2010, p.1 f). Under appropriate weather conditions, certain fuel compositions allow the ignition of wildfires nearly everywhere (GOSSOW et al., 2008, p. 3). RUDOLF-MIKLAU (2009, p. 28) states that 95% of wildfires in Austria result from human activity. Natural ignition sources are drought and lightnings, with wind contributing to fire spread. With that, alpine coniferous forests on south oriented steep slopes are especially fire susceptible (GOSSOW, 2004, s.p.). Figure 1 shows the distribution of forest fires in Austria in the year 2003. That year, Europe was struck by a heat wave and a lot of fires were ignited by lightning. (GOSSOW et al., 2008, p. 3)

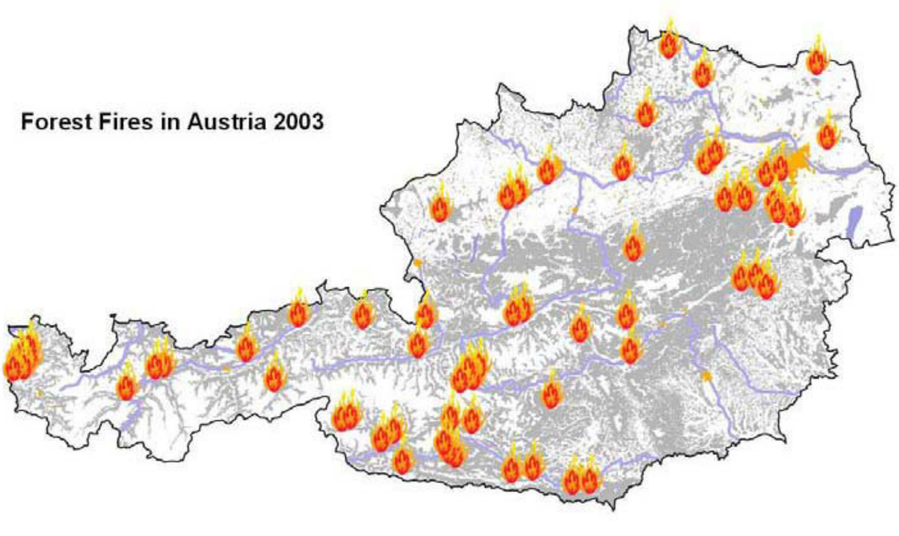


Figure 1: Distribution of forest fires in Austria in 2003 (GOSSOW et al., 2008, p. 1).

Looking back 50 years, the occurrence of wildfires in Austria used to peak in March and April, which are rated as winter or spring-fires. Since the 80[ies], there is a trend towards summer-fires. The statistical average of 2002 to 2009 is 16 fires per month in April, 13 in July and 10 in August.(GOSSOW et al., 2008, p. 3 f and VACIK, 2010, p.1 f)

2.2 Definition: Habitat Structures and Fuel

As this thesis focuses on the change in habitat structures due to a wildfire, the term “habitat” – often not used uniformly – needs to be defined at first.

Beginning with the home range or the precise location (SMITH et SMITH, 2000, p.16) where an organism lives or at least is thought to do so, WHITTAKER et al. (1973, p. 328) include “the range of environments or communities over which a species occurs” as its habitat.

Referring to the review paper of HALL et al. (1997), a very thorough definition is given including the species needs and its relation to the physical and biological characteristics of an area. Furthermore it says that habitat is “the resources and conditions present in an area that produce occupancy – including survival and reproduction – by a given organism” (HALL et al., 1997, p.175).

After having read these definitions of the term “habitat”, images of different habitats might appear in ones mind – differing most apparently because of their visual nature. Which in turn are, to a major part, the result of vegetation structures or vegetation societies. Yet note that habitat includes all resources needed by a species to allow survival (HALL et al., 1997, p.175).

Of course, the conditions such as climate, geology, slope degree or aspect, influence the resources available like food, shelter, vegetation, nutrients, amount of downed woody material and vice versa. The conditions and resources just mentioned are only examples, and it depends on the scale, the knowledge and on the aims of research which ones are considered relevant.

Certainly the main demands of terrestrial animal species are adequate food resources, hiding shelter, thermal cover and a minimum space, offering these resources and structures.

The term “habitat structure”, in the context of this paper, describes the physical presence and composition of living and dead herbaceous and woody vegetation. Also referred to as “fuel” in the subject of fire ecology.

Fuel can, more or less, be ignited easily and is comprised of herbaceous and woody plants, shrubs, trees, snags, large branches, stumps, dead logs, leaves, needles, living and dead vegetation (FULLER, 1991, p. 70).

Referring to GORTE (2009, p. 2 ff), the four characteristics of fuel, significantly influencing the behaviour of a wildfire and its effects on the ecosystem are:

- The **fuel moisture content** is the weighed amount of water expressed as a percent of the oven dried biomass. A moisture content of less than 100% means that the biomass contains more cellulose than water (e.g.: dead vegetation). A moisture content of more than 200% means that the biomass contains more than twice as much water than cellulose (e.g.: moss at a very humid site). Dead biomass typically has a moisture content of 10-100%, depending on the weather conditions in the preceding days and weeks. Considering the fact that fuel can only be ignited with a moisture content of under 20-30%, the moisture content is declared as the most important fuel property. It controls flammability by consuming energy (moisture is evaporated) to the point of ignition.
- The **fuel size (diameter)**: The time it takes for a fuel to loose about two-thirds of its moisture content is used to describe fuels in terms of a time lag of ignition. The time is given in hours and corresponds to the size of fuel. Fine fuels are smaller than 0,6 cm, like litter, grass, needles and fine twigs. They are found in the tree crowns and on the surface and dry out in about one hour: 1- hour time lag fuels. The second size class comprises fuels between 0,6-2,5 cm, the 10-hour

time lag fuels, like small branches and cones. The 100-hour time lag fuels are 2,5-7,5 cm in diameter and the 1000-hour time lag fuels are bigger than 7,5 cm. Concerning the spread of fires, the smaller sized fuels are most important as they ignite first and burn very fast. Yet the fire intensities are low because the fuel mass is low and quickly consumed. Contrary, the large fuels burn at high intensities and affect the ecosystem in many ways.

- The **fuel distribution** (horizontally and vertically): The horizontal distribution describes the continuity of fuels on the surface. A fire break like a street or mineral soil interrupts the fuel continuity and makes the fire die out. Also important is the compactness of the fuelbed. Fuels packed together too close cannot sustain a fire, for the oxygen supply is insufficient. The vertical distribution describes the fuel continuity from the surface into the tree crowns. So called ladder fuels ease the spread of surface fires into the crowns, creating a crown fire. However often wind is needed to start and sustain a crown fire.
- The **fuel quantity** (dry biomass per ha) is also called fuel load and varies extremely in different ecosystems. In forests, the healthy mature trees are usually excluded, so only litter, downed woody material, and undergrowth are considered as fuel load – because they mainly contribute to the spread of fires.

Inventorying fuel in a forest stand also determines habitat structures. Postulating that, wildlife researchers precisely know what kind of habitat is necessary for a given species to live and breed, the impact of a habitat structure change can be estimated by conducting a fuel inventory.

2.3 Fire Ecology

Having presented the situation concerning wildfires in Austria (chapter 2.1), the effects of wildfires will be explained, focusing on present-day habitat structures.

To start with, imagine a stand-replacing wildfire turning a mature forest stand into a clearing. In terms of succession, this means: back to the start. Plants such as herbs and grass start growing nearly immediately after the burn, being followed by shrubs and later trees. It takes many years or even decades for the forest to grow back to the former level and even then, the effects of the fire are still noticeable (FULLER, 1991, p.86).

A wildfire changes the biotic and abiotic ecosystem resources directly and indirectly. As an example: A direct effect of fire itself is the death of vegetation in contrast to the indirect effect that certain wildlife species are absent because no browse is provided until the vegetation starts regrowing.

“The biotic effects of fire include changes in vegetation and subsequent impacts on wildlife. Abiotic effects include changes in soil properties, nutrient cycling, water quality and air quality.” (KENNARD, 2008, s.p.)

This briefing of fire effects on ecosystems shows that there are several properties, which all together characterize the impact of the disturbance – the severity of a fire depends on the fire intensity. The responses of an ecosystem to a fire are directly related to the intensity of a fire (KENNARD, 2008, s.p.).

The fire intensity describes “the heat transfer which causes the adjacent fuels to be heated and burn, thereby releasing more heat and propagating the fire.” (JOHNSON, 1992, p.39)

It is essential at what rate a fire releases heat. The fireline intensity describes that rate per unit time and unit length (FULLER, 1991, p. 40).

Fireline intensity can vary extremely, for it is directly proportional to the rate of spread – mainly influenced by weather and topography. Low to moderate fireline intensities develop from average flame lengths less than 120 cm. Such fires can be controlled using hand tools. Contrary, very intense fires with average flame lengths exceeding 240 cm cannot be attacked directly (ARNO et al., 2002, p. 46).

The behaviour of a wildfire depends on the fuel characteristics such as fuel size and the weather conditions namely wind, recent precipitation, recent and current relative humidity (GORTE, 2009, p. 2). As an example, surface fires, which only burn the ground vegetation at a high rate of speed can start burning the duff layer when speed is reduced, causing severe impacts on the soil. Surface fires can develop into a crown fire when the intensity is high enough (the canopy is preheated) ,and ladder fuels are present. A crown fire is determined to be a stand-replacing fire, in contrast to a surface-fire, which only clears the surface layer of a stand. The behaviour of fires can be predicted, by the main output parameters: Rate of spread, describing how fast the flame front moves and flame length, which indicates fire intensity (ROTHERMEL, 1972, s.p.).

Getting an idea about the multiple properties affecting fire intensity and its ecosystem effects, the complexity of this matter becomes obvious. The mere presence and accessibility of habitat structures such as food, shelter, snags, downed woody material, exposed mineral soil etc. – in short, the mosaic of ecosystem resources – are changed instantly by fire.

Thinking of wildlife, the livelihood of one or several species can disappear, but also the contrary is possible: it could be renewed or created by a wildfire (ARNO et al., 2002, p. 61) – of course this also applies to other disturbances, for instance windthrows or clear cuttings. Following from that, numerous questions arise, such as: How is wildlife affected by a sudden change in habitat structures? How does wildlife cope with such a disturbance? Is everything lost or is there a benefit? How does the spectrum of wildlife species change in the burned area and its surroundings?

There is not much literature on those topics, most likely because it is very difficult to point out the effects of a wildfire on wildlife. In most cases there is no wildlife related data displaying the situation prior to the fire, so studies often only document the status quo after the disturbance. All of these questions have a common ground: They imply habitat dynamics. Therefore, the situations before and after the disturbance need to be compared to derive the impact on wildlife.

3 Study Site

In order to describe the study site and its location, geology and soil, climate, vegetation, wildlife, disturbances and fire history are introduced in the following chapters. Talking about habitat it is essential to know about these conditions.

3.1 Location

The study site is located near the town of Bad Bleiberg (46°38'0"N, 13°40'00"E), which belongs to the district Villach-Land in the federal state of Carinthia – southern Austria. The town of Bad Bleiberg lies 920 m above sea level in the valley between the Dobratsch mountain (2166 m) and the Erzberg mountain (1514 m). The map of Austria shows the location of Bad Bleiberg and the eastern section of the study site with the blank (figure 2).

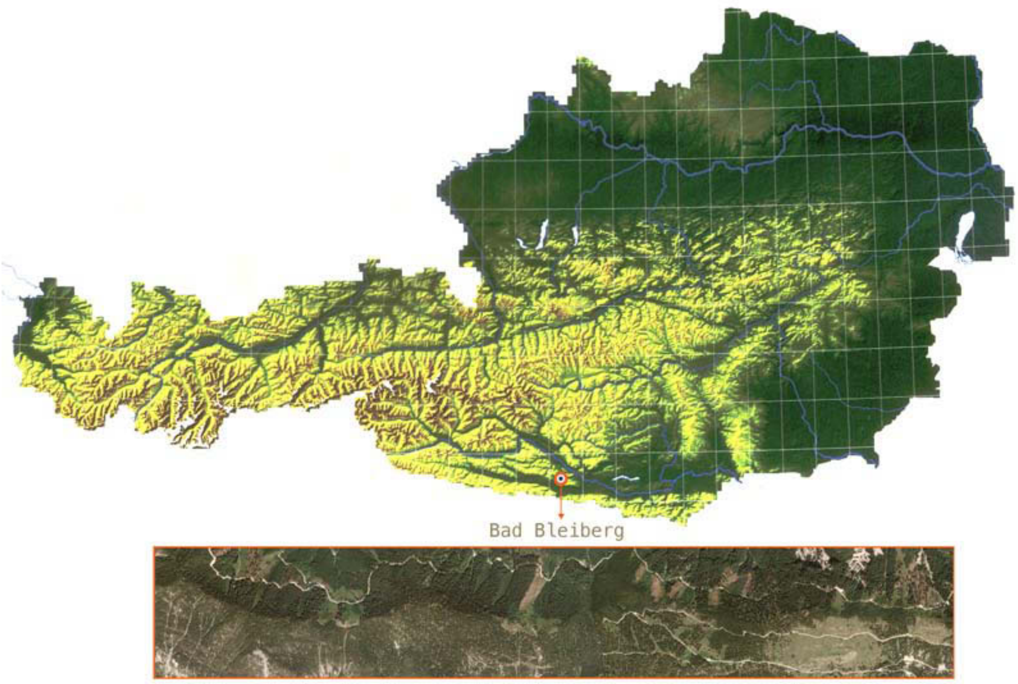


Figure 2: a) Digital elevation model of Austria showing the town of Bad Bleiberg (©Bundesamt für Eich- und Vermessungswesen, 2007, p. 18, modified). b) The aerial photo shows the study site (© Amt der Kärntner Landesregierung, Abteilung 20/Landesplanung – KAGIS, 2006, s.p.).

Since the 14th century, the mining of lead and zinc have played an essential role in the history of Bad Bleiberg. Nevertheless, the “Mining Union” shut down its operation in 1994. In former times, the town had more citizens than Villach, the capital of the district. Today Bad Bleiberg counts 2752 inhabitants and is quite well known as spa town, due to its hot springs.

In 1998, the “Mining Union” finally sold the forest stands of the surrounding slopes. The south-oriented area on the slopes of the Erzberg, north of the town are of interest for this study (figure 2b).

3.2 Geology and Soil

The study site is located between the river Drau and the river Gail in the Gailtal Alps, which belongs to the ridge of the Eastern Alps, the southern part of which is limited by the Periadriatic Seam. Limestone, dolomite, marl, argillaceous shale and sandstone from Permian origin compose the subsoil of the study site. Therefore, mainly alkaline conditions dominate the chemical constitution of the soil. (GEOLOGISCHE BUNDESANSTALT, 2002, p. 29)

Soil conditions are dominated by rendzina and patches of unweathered parental rock, partly covered with brown earth (AMT DER KÄRNTNER LANDESREGIERUNG, 2010, s.p.).

The influence of ground water on soil varies extremely. A few patches are very fresh, especially at the base of slopes and in basins, however dry conditions certainly prevail.

3.3 Climate

The climate data of the study site is provided by the weather station in Bad Bleiberg, which is located on a south-oriented slope at an elevation of 907m above sea level.

The records of the Central Institute for Meteorology and Geodynamics (German: Zentralanstalt für Meterologie und Geodynamik, ZAMG) are used to calculate the climate data. Monthly and annual means of data relevant to the climate are recorded in a dataset from the year 1971 to 2000. Beginning with the year 1994, annual sets of data are available.

Comparing the means of the year 2003 with the long-term means from the first data set and the calculated means from the annuals, offers profound insights on possible changes. In the year 2003, a heat wave struck Europe, it was the hottest and driest year since weather data recording in most of Europe. In the following, all means refer to the long-term dataset from 1971 to 2000. The year 2003 – it was the year of the wildfire and the great heat wave in Europe – and its difference to the longterm means is additionally shown in table 1. The yearly mean is shown as well as the months february and march to give an overview of the conditions prior to the wildfire.

Table 1: The climate data from Bad Bleiberg shows the longterm means of the years 1971-2000 and 1994-2008 in comparison to the means of 2003 (ZAMG, 2002, s. p. and ZAMG, 2004-2010, s.p.).

Climate Data from Bad Bleiberg							
			Year	Mean	Mean	Difference	Difference
	Unit		**2003**	**1994-2008**	**1971-2000**	**03 to 94-2008**	**03 to 71-2000**
Mean Temperature	°C	Year	6,9	6,59	6	0,31	0,9
		FEB	-5,6	0,02	-2,1	-5,62	-3,5
		MAR	3,2	2,56	1,7	0,64	1,5
Mean Relative Humidity	%	Year	73	77,03	75,8	-4,03	-2,8
		FEB	71	75,07	75,5	-4,07	-4,5
		MAR	61	72,14	71,9	-11,14	-10,9
Mean Precipitation	mm	Year	1216	1240,14	1290	-24,14	-74
		FEB	12	35,00	52,4	-23,00	-40,4
		MAR	2	57,57	82	-55,57	-80
Amount of Precipitation >=1mm	days	Year	101	112,29	11,5	-11,29	89,5
		FEB	4	5,00	6,2	-1,00	-2,2
		MAR	1	7,43	1,8	-6,43	-0,8
Amount of Precipitation >=10mm	days	Year	37	42,71	43,9	-5,71	-6,9
		FEB	0	1,07	7,8	-1,07	-7,8
		MAR	0	1,79	2,7	-1,79	-2,7
Snowfall	days	Year	25	22,86	2,4	2,14	22,6
		FEB	6	4,00	0,3	2,00	5,7
		MAR	1	3,29	0,3	-2,29	0,7
Strong Breeze	Beaufort 6	Year	1	1,64		-0,64	
		FEB	0	0,00		0,00	
		MAR	0	0,36		-0,36	
Windspeed	m/s	Year	3,3	2,89	2	0,41	1,3
		FEB	3,6	3,04	2,1	0,56	1,5
		MAR	4,2	3,77	2,5	0,43	1,7

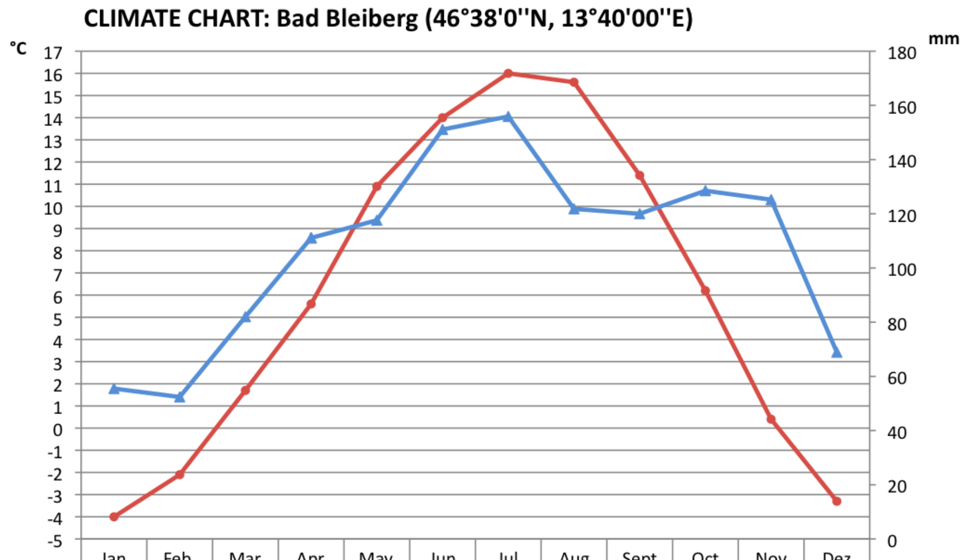
3.3.1 Temperature

The Data in the following section originates from the ZAMG-Website (2002).

The climate can be categorized as continental with typically cold winters and relatively hot summers (figure 3). The coldest months are December, January and February with a mean daily temperature of -3,1°C. The hottest months are June, July and August with a mean daily temperature of 15,2°C. The annual long-term mean temperature is 6°C but absolute daily measurements can vary from extremes of -22,5°C in winter to 34°C in summer.

3.3.2 Precipitation and Snowfall

According to the characteristics of continental climate, the precipitation peaks in summer with 154 mm on average, due to thundershowers. In winter the average precipitation is only 59 mm. On average the annual rainfall is 1290 mm.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dez
Temp [°C]	-4	-2,1	1,7	5,6	10,9	14	16	15,6	11,4	6,2	0,4	-3,3
Percip. [mm]	55,5	52,4	82	111,1	117,6	151,1	155,9	121,8	120	128,5	125,2	68,9

Figure 3: Climate chart for Bad Bleiberg, using the long-term means of the ZAMG (1971- 2000).

The climate chart (figure 3) illustrates the mean temperatures and precipitation. The snow cover can last from October to April with a mean snow cover of 39 cm in mid-winter and an accumulated snow cover of 190,6 cm.

3.3.3 Wind

The main wind directions are north-east and north-west followed by west and east. Especially in spring south-east wind can occur and south-west wind is slightly stronger than during the rest of the year. March usually is the windiest month. In general, the wind is not very strong, but it has increased from a yearly mean of 2 m/s (data from 1971-2000) to 2,92 m/s (data from 2003).

3.4 Vegetation

In Austria the forest ecosystems are categorized, on the basis of geology under similar climate conditions, termed “ecoregions” (German: “Wuchsgebiete”). The study site belongs to the “Ecoregion 6.1 Southern Alps” (German: Wuchsgebiet 6.1. Südliche Randalpen).

The forest stands at the study site can be described as mainly of coniferous. The percentage of tree species in the forest area is composed of: *Picea abies* (Norway Spruce, 59%)*, Pinus sylvestris* (Scots Pine, 11%)*, Larix decidua* (European Larch, 14%)*,* other conifers *(3%), Fagus sylvatica* (Common Beech, 10%)*,* other deciduous trees (2%)*.* The proportion is about 88% conifers and 12% deciduous trees. (ÖBF, 2005, p. 51)

There is another classification typical in Austrian forestry describing forest stand types based on the ground vegetation – it is known as HUFNAGL-Types. Ernst HUFNAGL was a forester himself and created the classification as a practical indicator for site class determination. Referring to HUFNAGL (1970) the stand types are classified as mainly *Erica carnea-type* and *Seslerium* in mature sparse *Pinus sylvestris* stands, indicating low quality classes in terms of timber production (ÖBF, 1999, p. 24). The *Schattenkräuter-type*, representing the shade-loving herbs, is found patch-wise indicating best water, nutrient and air conditions in the soil – the best conditions for timber production. The HUFNAG-TYPES can also be used as indicators for soil moisture conditions and to identify fire susceptible plant communities. These aspects are most pertinent to this thesis.

3.5 Wildlife

According to the local hunter's association, several game species are found in the area: *Capreolus capreolus* (European Roe Deer)*, Rupicapra rupicapra* (Chamois)*, Lepus* (European Hare or Alpine Hare, not specified)*, Tetrao urogallus* (Western Capercaillie)*, Tetrao tetrix* (Black Grouse)*, Cervus elaphus* (Red Deer), are present (listed in descending order of abundance). (MARKTGEMEINDEAMT BAD BLEIBERG, 2010, s. p.)

Capreolus capreolus is found all over the study site, as well as *Lepus*. *Rupicapra rupicapra* is mostly found in the very steep and rocky areas in the west of the blank, as well as on the blank itself, especially during winter. Then, also *Cervus elaphus* can be observed on and around the blank. Actually this species is found in the very east of the blank or on the backside of the mountain, which leads into the Ebenwald-valley and on the opposite side of the Bad Bleiberg-valley, on the north-oriented slopes of the Dobratsch mountain. Here, the species *Capreolus capreolus* and *Tetrao tetrix* are also present and wildlife movements can be presumed. Now back to the slopes of the Erzberg, which is the actual study site. *Tetrao urogallus* is present mainly east and west of the blank. Moving to the very west of the blank, mainly *Tetrao tetrix* can be observed. (ANGERER, 2010, s. p.)

As the term wildlife includes a great variety of species, which cannot all be taken into account, this thesis is confined on game species.

3.6 Natural Hazards and Forest Management

Wildfires are certainly not the most important natural hazards in Austrian forestry. Windthrows, avalanches or insect pests such as bark beetle infestation are far more common. The aim of the following chapters is to provide a general overview of the study site from the perspective of disturbance ecology.

“ A disturbance is a relatively discrete event in time that disrupts communities or populations, changes substrates and resource availability, and creates new opportunities for new individuals or colonies.” (SMITH et SMITH., 2000, p. 293)

The scale of disturbances ranges from breakage of branches, over the death of a single tree to stand-replacing events (SPLECHTNA et GRATZER, 2005, p. 58).

Ecologically, wildfires are treated as disturbances, although they differ from the above mentioned, in that wildfires consume biomass and convert it to organic and mineral products (BOND et KEELEY, 2005, p. 387).

The authors even compare this consumption-conversion-effect of wildfires on ecosystems to the effect of herbivory.

An outline of the kind of coarse-scale disturbances, which occurred in Bad Bleiberg since 1998, will be given in order to underline the motion of potential habitats. Along with wildfires, other disturbances discussed here are windthrows and clear cuttings.

The forests of Bad Bleiberg are characterized as generally overaged (ÖBF, 1999, p. 110), hence, several harvesting activities have been done and are planned. Further on, clear-cutting is done in strips with an average size of 4,5 ha. These clearcut strips can be seen as kind of disturbance, as patches are created. In the area, which later was burned, about 2 ha were cut clear in two patches. On a small scale, the practice is to create small circular patches (20 m diameter) to enhance natural regeneration – termed femel felling.

In November 2002, a windthrow affected 20 ha of mainly old sparse *Picea abies* dominated stands and created 2 big blanks and a few smaller ones. It was estimated that 200 m^3/ha wood were blown down (HONSIG-ERLENBURG et MORITZ, 2004, p.17). During winter, the blowdowns were left on the site. In spring 2003, the site was cleared during a salvage logging operation.

3.7 Fire History

Firstly, it needs to be pointed out that Austria has not been the place to do research on fire ecosystems (GOSSOW et al., 2008, p.1). So, the fire history of the study site mainly deals with one major event and a few small wildfires in the community of Bad Bleiberg. Secondly, the fire discussed, started (March 2003) in the blowdowns – so it is necessary to keep in mind the overlapping of two ecological disturbances.

3.7.1 The Wildfire in 2003

On the Erzberg mountain in the woods of Bad Bleiberg (at an elevation of 1500 m), a wildfire occurred in the morning of March 18th 2003. Lumberjacks were clearing and salvage logging the site of the windthrow in November

2002. Research on the cause for the fire revealed two stories (a, b) with one consensus – carelessness. (a) A small fire was ignited by a lumberjack in order to burn brushwood. (b) After cleaning the oily chainsaw with a tissue, a lumberjack burned that tissue in order to keep the forest clean. The burning tissue was blown away by a gust of wind and ignited some downed woody material. Unfortunately the steep slope, the upward wind, the dry weather conditions and the fuel load made the fire uncontrollable and it spread quickly. (ANGERER, 2010, s.p.)

The fire spread west (parallel to the slope) and north (uphill) ,and finally crowned. In the afternoon it extended to a size of 10 ha in a mature *Picea abies* dominated stand. The following morning, the fire reached an extension of about 20 ha, and 25 ha on the third day. (ROSSBACHER, 2003, s.p.)

The fire service operation was massive, with daily up to 170 fire fighters involved, 29 fire engines, 6 helicopters, 3 Pilatus Porter aeroplanes, 1500 metres of pipelines, 6 tanks (HONSIG-ERLENBURG et MORITZ, 2004, p. 20), the rescue service, the police, and the military with 50 pioneers in total (ROSSBACHER, 2003, s. p.). Repeatedly, the embers caught fire, so the operation team tried to keep the soil wet and dig out the glowing rootstocks. On the 5th day, the fire was declared to be under control. Not until 18 days after the wildfire outbreak, it was considered extinguished, having burnt an area of about 25 ha (HONSIG-ERLENBURG et MORITZ, 2004, p.17). The wildfire consumed about 1300 m^3 wood – from the windthrow area and standing trees of the neighbouring stands (ANGERER, 2010, s.p.). After salvage logging the total blank (including the partially overlapping fire prone area and the windthrow area) has an extension of 32,26 ha – it is referred to as blank or BL in this thesis (figure 4).

Figure 4: The blank in 2003 with a size of 32,26 ha (© Amt der Kärntner Landesregierung, Abteilung 20/Landesplanung – KAGIS, (2003), modified).

The aerial photo (figure 4) shows the blank in the year of the wildfire. The blank was recolonized by grass and herbaceous vegetation instantly and afforestation measures stared the following year. The other unstocked patch, in the west of the blank, is part of the windthrow-area. The small patches, appearing whitish on the aerial photo are gravel resulting from former mining operations.

3.7.2 Other Wildfires

There have been several other wildfires in the forestry district Villach Land – within which the study site lies, as well. 104 wildfires have been registered since 1974, with a total burnt area of about 280 ha (HONSIG-ERLENBURG et MORITZ, 2004, p. 7). Table 2 shows type and cause of the wildfires as percentage of all wildfires in that district.

Table 2: Wildfires in the forestry district Villach-Land since 1974 (HONSIG-ERLENBURG et MORITZ, 2004, p. 7).

Type of fire	% of total fires
Surface fire	54
Crown fire	14
Surface and crown fire	17
n.s.	14

Cause of fire	% of total fires
Lightning	13
Railway	3
Carelessness	36
Arson	4
n.s.	44

Focusing on the community of Bad Bleiberg, several wildfires occurred in the past (table 3), unfortunately most of them are not well documented. Hopefully, documentation will improve on future wildfires, since the AFFRI has created a wildfire database, which has also gathered information about past wildfires.

Table 3: All documented wildfires in the community of Bad Bleiberg. The description includes: Location, time, size, cause and reference (see citation for reference).

Location	**Time**	**Size**	**Cause**	**Citation**
Spitzeck	60ties, 70ties, 80ties	n.s.	No precise information available. The last fire was probably caused by construction works on the expressway.	ANGERER, 2010
Kreuth	17.03.03	20 m^2	Carelessness	AFFRI, 2010
Erzberg	18.03.-04.04.03	25000 m^2	Carelessness	AFFRI, 2010
Dobratsch	16.08.03	40 m^2	Probably lightning	AFFRI, 2010
Feldkofel	24-28.07.06	n.s.	Lightning	AFFRI, 2010
Kadtuschen	25.07.06	10 m^2	n.s.	AFFRI, 2010
Sattlernock	26.05.07	n.s.	Lightning	ANGERER, 2010
Erzberg	22.11.09	10000 m^2	n.s.	ANGERER, 2010

4 Material and Methods

This section starts with explaining how the link from fuel data to habitat information is established. With that, a fuel concept and a habitat concept are introduced, which are used to describe the current situations and finally reveal the changes due to the wildfire. After the theoretical input it is clarified, which data is needed to analyse the fuel situation and how sampling and analyses are done. In addition, it is illustrated how the wildlife sampling is linked to the structural information of potential habitats.

4.1 Comparison: Habitats Pre- and Post-fire

“When building a fuel model, the task is more one of describing vegetation as a fuel complex rather than precisely measuring its biomass, although the two are related.” (BURGAN et ROTHERMEL, 1984, p. 8)

With that, the fuel data can also be used to describe habitat structures, as already suggested by GOSSOW (1996, p. 431 f): Mammals appear structure and stratum oriented in their habitat demands and use and also “Habitat evaluation procedures (HEP) are preferably based on optimal structural parameters,” multiplied with limiting factors.

Hence, the sampling of fuel at the study site and the identification of fuel types makes it possible to estimate how habitat structures have changed following a wildfire and how they might change in consequence of a future wildfire. In notes: A wildfire changes habitat structures and subsequently succession, depending on fire intensity. The newly established habitat structures create new fuelbeds, which influence future fire behaviour.

In order to find out how potential habitats have changed due to the wildfire, the data has to be made comparable. For the fuel data, this happens via fuel types referring to the classification of SCOTT et BURGAN (2005, see appendix IV). Data for the habitat evaluation is categorized via WEST (REIMOSER, 1986, s. p. and REIMOSER et al. 2003, p. 109-117, see appendix V). These two concepts are introduced in the following two chapters (4.1.1 and 4.1.2).

The forest management classes (FMCs) comprising the developmental stage and age of a stand are the basis for the fuel data sampling and also the basis for the categorization of the WESTs. Each sampled plot is identified as fuel type and separately as WEST. After that, the plot information is summed up in the FMCs. Following that, the FMCs are expressed as shares of fuel types and shares of WESTs.

The fuel type and WEST characterisation of the FMCs is then used as input for the forest inventory map, provided by the Austrian Federal Forests Company (German: "Österreichische Bundesforste AG", ÖBf). Using the map of 2004 the current fuel type and WEST situation is revealed. The map of 1998 reveals the situations prior to the wildfire (and the windthrow).

For the actual identification of habitat-change, not the whole study site is compared, but only the blank, which has a size of approximately 32 ha.

4.1.1 Concept: Fuel Types

Fuel types describe the fuelbed as an association of fuel elements (NWCG, s.a., s.p.) and serve to predict the fire behaviour and severity. For this purpose, mathematical models have been developed by ROTHERMEL (1972).

"A fuel model is a set of fuelbed inputs needed by a particular fire behaviour or fire effects model." (SCOTT et BURGAN, 2005, p. 1)

With the fuel data sampling at the study site, these inputs are quantified and then formulated into fuel types, given by SCOTT et BURGAN (2005), and into newly developed fuel types for Austria, given by ARPACI et al. (2010 a), an AFFRI member. The general fire-carrying fuel determines the fuel type. An estimation of fire behaviour of each fuel type is included.

The current fuel types for each plot and the study area are identified by Alexander ARPACI. In addition these fuel types are used to reconstruct the fuel situation before the wildfire and windthrow occurred.

4.1.2 Concept: Wildlife Ecological Stand Type

The concept of the "Wildlife Ecological Stand Type" (WEST) (German: Wildökologischer Bestandestyp, WÖBT) by REIMOSER (1986) describes the vegetation structures of forest stand types in Austria, from which the suitability for wildlife can be concluded. The focus is set on assessing the suitability of a stand in supplying food, thermal cover, hiding shelter and mobility (REIMOSER, 1986, p.164).

The developmental stages of forest stands are the basis of this habitat evaluation, which is beneficial to forest management. Further, the vegetation structure types are classified following species, height, density and degree of ground vegetation cover. Main features to identify the WEST:

- total ground vegetation cover not higher than 1,3 m;
- woody ground vegetation cover not higher than 1,3 m;
- canopy cover;
- stocking density;
- average height of the dominating woody vegetation (including regeneration);
- accessibility of a stand (pruning).

(PARTL, 2001, p.19)

The three main WEST categories "Non Forest Types", "Forest Types" and "Special Types" are divided into several subcategories. As the first one describes different types of grassland, the last describes forest streets, swamps, etc. The "Forest Types" are most relevant for this study, describing varieties of regeneration, thicket stands, pole stands and mature stands (all WESTs are listed in appendix V). (REIMOSER, 1986, p. 166 ff)

In the following, the framework, which the WEST concept is based on, is summarized referring to REIMOSER (2006, p. 39 f).

The structure of wildlife populations and population dynamics are strongly interacting with the habitat structures and succession. Both, wildlife and habitat, need to be considered in order to understand the ecological relationships. So, what does the presence of wildlife in an area depend on? The main habitat properties, influencing habitat quality – which is expressed in the colonisation of an area by certain species – are: Climate, relief features, shelter possibilities, food supply, area size and disturbances. Of course also these properties are highly correlative and with that, the habitat quality is not constant but alternates, for instance daily, annually, depending on the season and specific requirements of the species. Yet, the habitat quality not only depends on the interaction of the habitat properties and the wildlife requirements in an area, but also on their relationship to the attractiveness of surrounding areas (relativity of the habitat quality). The attractiveness of a habitat can singularly be changed by the modification of the surrounding. The smaller the observed area size, the greater the relativity of the habitat quality.

The main habitat properties (REIMOSER, 2006, p. 41-46) are explained now.

Shelter from climate, wind, rain, cold and heat is called thermal cover. It is determined to be found in stand types with a well balanced microclimate. But also wildlife itself can create a favourable microclimate by rearranging habitat structures. Hiding shelter, often in stands with rich ground vegetation, protects from being seen by enemies, competitors and humans. Lodge (functions as "living room") is used for resting, communication, moving freely and observing, in non-browsing periods.

The relief features such as aspect, slope degree, hollows and tips mainly influence climate and mobility. Especially when there are a lot of disturbances by humans or predators, the necessity to be able to move without constraints is given. Steep slopes, rocky areas, unstable snow covers and very dense stands might decrease mobility. The effects of disturbances are different, depending on day time, the season, how long it lasts, how frequent it is, and what kind of disturbance it is. The general availability of food is not necessarily the amount of food, which is effectively accessible, but the access at all seasons or day- and night times. Restrictions due to a great investment of energy, competition, disturbances, snow or topography exist.

The WESTs were originally developed for *Capreolus capreolus*, but can be applied to other wildlife species as well (c.f. SCHATZ, 1992, for *Tetrao* *urogallus*). Modifications may be useful especially for vegetation heights in respect of wildlife size or for very special habitat resource needs. (REIMOSER, 2010, s.p.)

In this study, each plot is identified as WEST using the sampled fuel data. It shall be shown, in how far this data can be used to do a WEST classification. Therefore the habitat suitability of the blank will be ascertained for *Capreolus capreolus* following the "original" WESTs and for *Tetrao urogallus* using slightly modified WESTs.

4.2 Fuel Sampling

4.2.1 Study Site

The area in which the 24 study plots are sampled comprises about 570 ha and is situated between 960 m and 1370 m above sea level. The area in which the transects for the pellet sampling lies has an extension of about 130 ha. The blank, on which the comparison of the pre- and post-fire fuel types and WESTs is done measures approximately 32 ha, at an elevation between 1200-1500 m.

4.2.2 Plot Design

The method for fuel data sampling in Austrian forests was designed by ARPACI et al. (2010, s.p.), AFFRI-member from the Institute of Silviculture at the University of Natural Resources and Life Sciences in Vienna (BOKU). The plot design is based on BROWN et al. (1982). To adopt fuel sampling to Austrian forests, several modifications have been made. A plot consists of:

- 1 macroplot, which is 25 m x 25 m;
- 8 subplots, which each have a diameter of 2 m and 1 m, 2 subplots are selected, which contain a square of 50 cm x 50 cm;
- 4 transects measuring 25 m each, which are the diagonals of the macroplot, starting in its centre.

The sketch of the sampling plot (illustrated in figure 5) shows the macroplot represented by the square. The circles show the 1 m and 2 m diameter subplots. For collecting the fuel samples, there are squares, in 2 subplots, which are selected randomly. The transects are the diagonals of the macroplot. The direction of the macroplot is oriented to the north.

These elements of a plot are defined as sampling units in which different fuel data is collected at different scales. Merging these sampling units allows to produce a detailed characterisation of the forest structures.

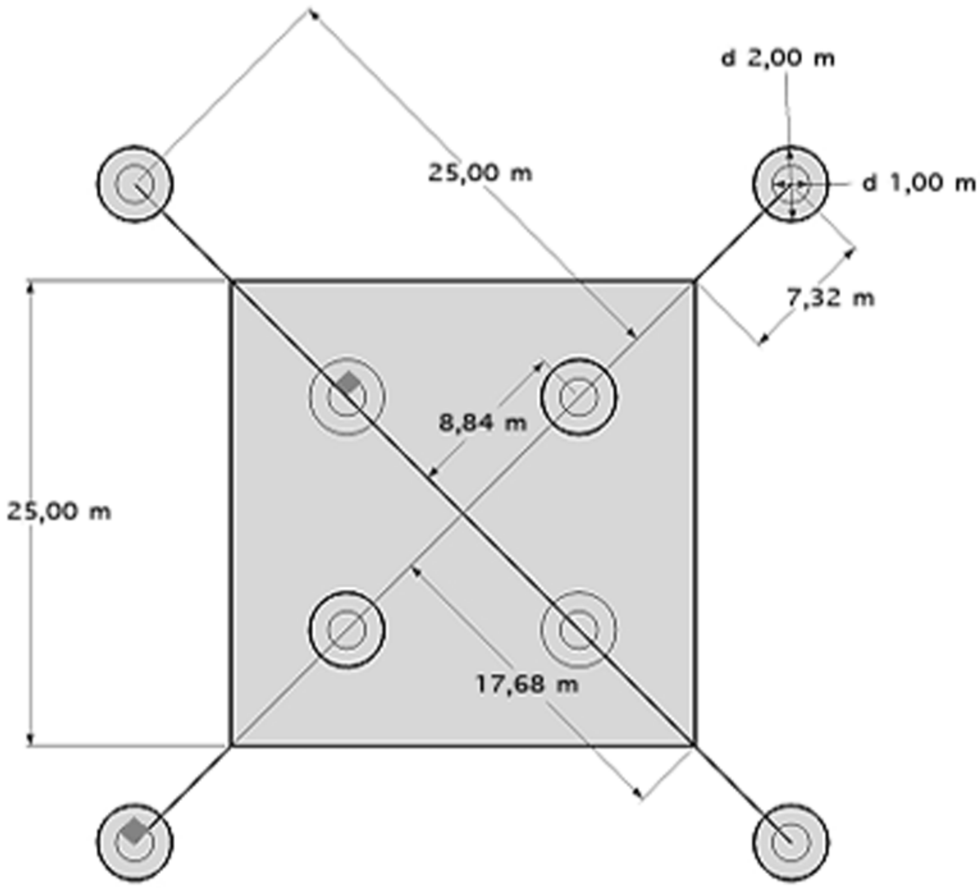


Figure 5: Sketch of the sampling plot (ARPACI et al., 2010, s.p.).

4.2.3 Forest Management Class

In order to sample the characteristic features of the site, 24 plots (P1-P24) were established in relation to the forest management classes (FMCs). This was done to ease data analyses by referring to a commonly known forest classification. Yet, this classification of the forest stands does not correspond to the usual 20-year age classes – it was simplified. The principle of classification is based on the developmental stage of the timber vegetation, which was estimated by the age of a stand and average DBH (diameter at breast height):

- thicket stands: maximum 40 years old with an average DBH of 10-15 cm;
- pole stands: between 40 and 80 years old with an average DBH of 15-20 cm;
- mature stands: older than 80 years with an average DBH of more than 20 cm;
- the blank includes the burned area and parts of the windthrow, it is mostly unstocked and mainly covered with herbs, grass and shrubs.

The shares of these three forest management classes are as follows: 6 plots in thicket stands (TH), 10 plots in pole stands (PL), 7 plots in mature stands (MR) and 1 plot on the blank (BL).

The exact plot locations have been randomly identified in advance and mapped out with GPS data.

4.2.4 Macroplot

The centre of the square macroplot (basic measure: 25 m x 25 m) was located by geographic coordinates. 4 photos in each direction were taken, and elevation, aspect and slope degree were recorded.

Before laying out the plot, the slope degree had to be measured and all lengths of the plot had to be adjusted in order to avoid distortion.

The projected area on a horizontal plane becomes smaller on steeper slopes. The slope correction factor allows to reference the fuel loading to the horizontal area. (HARVEY et al., 1997, p. 14)

The slope correction factor is calculated as follows (BROWN et al., 1982, p. 16):

$$c = \sqrt{1 + \left(\frac{percent\ slope\ of\ sampling\ plane}{100} \right)^2}$$

Table 4 shows the increase in plot measures.

Table 4: Slope correction factor for steepness.

Slope [%]	Slope correction factor	Adjusted side length of macroplot [m]*
30	1,04	26,00
50	1,12	28,00
70	1,22	30,5

* The basic side length of the macroplot is 25 m. Multiplication of the basic side length by the slope correction factor.

Furthermore, the steepness of a slope is a very important factor for fire spread. Especially in combination with wind, fire can move uphill very fast.

After establishing the macroplot, the cover of trees, shrubs, grass, soil and stones was estimated. Note that the cover estimation was done for two layers: The canopy cover of mature trees as one layer and shrubs, grass, soil and stones as 2nd layer. This gives an overview of the structure of the plot in respect of fuel density, fuel brakes, the fuel ladders and with that fire spread possibilities.

Each tree located in the macroplot taller than 2 m and bigger than 10 cm DBH was included in the sampling of mature tree species, height, DBH, crown class, vitality and CBH (crown base height). The age was estimated by coring 2 to 4 representative individuals of each macroplot to recheck the FMC estimation and to assess the site index. These properties partially determine the fire susceptibility of a stand.

4.2.5 Transects

The 4 transects have a length of 25 m each and run from the centre of the macroplot through its corners. Now, imagine a plane starting from the ground and rising up two meters in height, every piece of downed woody material intersecting this plane is examined (planar intersect method referring to BROWN, 1974). According to specific rules, data about downed woody material was collected here. In accordance to the concept of the fuel hour classes, downed woody material smaller than 0,6 cm (1-hour time-lag fuels) and between 0,6-2,5 cm (10-hour time-lag fuels) was collected in the distance of 5 to 7 m from the centre. Downed woody material sized between 2,5 cm and 7,5 cm (100-hour time -lag fuels) was collected in the distance of 5 to 10 m. Downed woody material bigger than 7,5 cm (1000-hour time-lag fuel) was collected in a distance of 5 to 25 m. This last category had to be examined more thoroughly to identify the species, the diameter and the degree of decomposition – relevant for the fuel load calculations of downed woody material (chapter 4.3.1). The flammability of downed poles is very low, especially with increasing degree of decomposition. Yet in case of ignition these poles can contribute to very high fire intensities. The sampling on the transects focuses on two main fuel characteristics: horizontal and vertical fuel distribution and fuel size (see chapter 2, "Definition: Habitat Structures and Fuel").

4.2.6 Subplots

A subplot is defined as a circle with 2 m in diameter, containing a circle of 1 m in diameter. 4 subplots lie within the macroplot, the other 4 outside. Each subplot has its centre on a transect – in the middle of which and at the end. Data collected here includes the cover of woody vegetation dead/alive, herbaceous vegetation dead/alive, soil and stones. The homogeneity or continuity of the fuel structures is detected on a finer scale on the subplots, which is important to know, when estimating the spread of ground fires. The relation of living and dead woody and herbaceous vegetation was estimated as input for the dynamic fuel models by SCOTT et BURGAN (2002).

The time needed for a fire to make a living plant consumable by the flames is considered in the fire spread calculations.

Regeneration, that is, all trees smaller than 2 m and with a DBH smaller than 10 cm, was sampled by species, height and stem diameter. Seedlings were also sampled in the subplots, but only within a diameter of 1 m. Regeneration plays a key role in the development of a crown fire as it can act as ladder fuel, further on, the natural regeneration-potential of the forest stand can be estimated.

All herbaceous species present were listed for the diversity index and five measurements of the vegetation heights are taken, in order to determine the fuelbed depth. Similar to regeneration, high herbaceous vegetation can be considered as ladder fuel. Especially as thin branches are ignited faster than thicker ones of same mass (LEX, 1996, p. 161). Above all there are certain species, which are susceptible to fires (KÖNIG, 1996, p. 47): On soils, far from ground water, grasses like *Carex* (Sedge) and *Calamagrostis* (Reedgrass) species*, Deschampsia flexuosa* (Wavy Hairgrass)*, Dactylis glomerata* (Orchard grass) and shrubs such as *Rubus fruticosus* (Blackberry) *and Rubus idaeus* (European Red Raspberry). On soils, well connected to ground water *Pteridium aquilinum* (Common Bracken) among others can be rich fuel in dry spring and midsummer stages.

As herbaceous species reliably indicate soil moisture conditions, a plus of information for fire modelling is gained.

2 subplots were selected randomly, at which each 0,25 m^2 of the vegetation was clipped off and collected in separate bags according to the fuel-hour classes – fresh and dry weight were measured to calculate the fuel load and the moisture content, which determines flammability. The fresh weight was measured on the day of sampling, whereas the dry weight was determined in the laboratory (oven dried 24 h at 100°C). After the vegetation has been removed, the litter depth was measured to determine the fuelbed depth. Litter was also collected in bags and weighted fresh and dry. Fuel particles bigger than 0,6 cm need to be sorted out and collected separately depending on fuel size and fuel particle.

In consequence all fuel particles and sizes were sampled individually. This makes the information about fresh and dry weight of each fuel size class and fuel particle class more accurate. After the fuel collection the duff depth was measured, also for fuel depth determination. A duff sample (0,035 m^2) was collected at every 3rd plot and fresh and dry weight were measured. Litter and duff are sampled separately as the compactness of duff is mostly higher. Litter often burns independently from the duff layer (BROWN et al., 1982, p. 3), because of rich oxygen supply. A burning duff layer changes fire behaviour and very much influences the post fire succession. Depending on the heat of the fire, nutrients stored in the raw soil under the duff layer are burned or chemically transformed – resulting in totally new soil and nutrient conditions.

4.2.7 Time frame

The data for the fuel analysis in Bad Bleiberg was collected from mid July to the beginning of August 2009. A team of 2 people managed to sample 1 to 4 plots per day, depending on location, topography, vegetation, amount of fuel and weather conditions.

4.3 Fuel Analysis

After sampling, a data base containing the fuel data was created. Several parameters were calculated for the fuel analysis to determine the fuel types. The formulas for the calculations of the forest characteristics and the fuel load are presented in the following.

4.3.1 Calculations

Forest characteristics describing a stand – as used in forest inventory maps – can help to interpret the fuel conditions before and after a wildfire. The following characteristics have been estimated using the sampled data. The data was calculated for each plot separately and for the FMCs.

Forest characteristics:

mean age

$$mean\ age = \frac{1}{n} * \sum_{i=i}^{n} a_i$$

n...number of trees

a...estimated age of trees

number of trees per ha

$$N/ha = \frac{number\ of\ trees}{plotsize\ [ha]}$$

tree basal area (G) per ha

calculated with the circle area formula and the mean DBH

$$G[m^2/ha] = \sum_{i=1}^{n} \frac{\pi\ d_i^2}{4} * \ plotsize[ha]$$

d...diameter at breast height [m]

percentage of tree species

as a relation of the tree basal area (G) per ha

$$species\ relation\ [\%] = \frac{G_x}{\sum_{i=1}^{n} G_i} * 100$$

G_x...basal area of one species

G_i...basal area of all species

Lorey-height (hl)

is a tree height weighted according to the share of the basal area of a certain DBH class (KRAMER et AKÇA, 2008, p. 117).

$$hl = \frac{(h1+h2+h3+h4+h5)}{5}$$

h1...h5...is the mean height of classes with the same basal area

mean height of species

$$mean\ height\ [m] = \frac{1}{n} * \sum_{i=1}^{n} h_i$$

n...number of trees

h...height of trees

mean DBH of species

$$mean\ DBH\ [cm] = \frac{1}{n} * \sum_{i=1}^{n} d_i$$

n...number of trees

d...DBH of trees

H/D relation of tree height and DBH in percent

$$H/D relation\ [\%] = \sum_{i=1}^{n} \frac{h_i}{d_i} * 100$$

h...height of trees

d...DBH of trees

standing volume

calculated with form factors and formulas after POLLANSCHÜTZ (1974, s.p.) for *Picea abies*, *Larix decidua* and *Pinus sylvestris* and with the form factors for *Acer pseudoplatanus* after SCHIELER (1988, s.p.).

	Form factors						
Tree species	**b1**	**b2**	**b3**	**b4**	**b5**	**b6**	**b7**
Picea abies	0,46818	-0,01392	-28,21300	0,37474	-0,28875	28,2790	0,000
Larix decidua	0,60944	-0,04557	-18,66310	-0,24874	0,12659	36,9783	-14,204
Pinus sylvestris	0,43595	-0,01491	5,21091	0,00000	0,02870	0,0000	0,000
Acer pseudoplatanus	0,50101	-0,03521	-8,07176	0,00000	0,35210	0,0000	0,000

Formula

$$V_{SmR} = pi/(4*1000)*(b1*d^2*h+b2*d^2*h*\ln^2 d+b3*d^2+b4*d*h+b5*h+b6*d+b7)$$

V_{SmR} ... standing volume *h..height [dm]*

d..DBH [dm] *b1..b7...form factors*

stocking degree (BG)

as a relation of the calculated standing volume and the figures of the yield table.

$$BG = \frac{V / ha}{YT}$$

V… standing volume

YT...values from the yield table

site index

estimated from the yield table (MARSCHALL, 1992, s.p.) by using species, age and Lorey-height.

Fuel load calculations:

Moisture content (MC)

of the collected fuels referring to PYNE et al. (1996, p.107):

$$MC\ [\%] = \frac{(m_f - m_{od})}{m_{od}} * 100$$

m_f...*fresh weight*

m_{od}...*oven dry weight*

fuel load

Fuel size and fuel particle from the subplot sampling were linked to each plot as fuel load, dry biomass per ha, corrected by the slope correction factor (see chapter 4.2.4.) (HARVEY, 1997, p. 14).

$$dry\ kg/ha = \frac{dry\ fuel[kg]}{plotsize[ha]} * c$$

c...slope correction factor

downed woody material load

the number of intersections of downed woody material from the transects was calculated into kg/ha following BROWN (1974, p. 15 ff):

<0,6 cm - 7,5 cm material: $t/ac = \frac{11,64 * n * d^2 * s * a * c}{N * l}$

t/ac...US tons per acre

11,64...constant

n...number of intersections

d^2*...squared average-quadratic-mean diameters [inch] for nonslash ground fuels. The composite value was used for these calculations: 0,0151 for fuel size class <0,6 cm, 0,289 for fuel size class 0,6-2,5 cm and 2,76 for fuel size class 2,5-7,5 cm.*

s...approximate value for the specific gravity of conifers: 0,48 for the fuel size classes <0,6 cm and 0,6-2,5 cm and 0,4 for the fuel size class 2,5-7,5 cm.

a...the fuel angle correction factor for nonslash fuels: 1,13.

c...average slope correction factor.

N...number of sample points.

l...length [feet] of sampling plane.

>7,5 cm material: $t/ac = \frac{11,64 * \sum d^2 * s * a * c}{Nl}$

Differentiate rotten and sound fuels >7,5 cm.

t/ac...US tons per acre

11,64...constant

$\sum d^2$*...the sum of all squared diameters [inch] for rotten and sound fuels.*

s...approximate value for the specific gravity of conifers: 0,4 for sound fuels, 0,3 for rotten fuels.

a...the fuel angle correction factor for nonslash fuels: 1.

c...average slope correction factor.

N...number of sample points.

l...length [feet] of sampling plane.

4.3.2 Maps, Aerial Photos and Historic Documents

Using maps, aerial photos and data from the forest inventory of different time periods, the study site is analysed in regard of its development before and after the wildfire. Knowledge of the forest characteristics before the wildfire releases information about the fire behaviour, and habitat structures.

The aerial photos from the years 1994, 2003 and 2006 were provided by the KAGIS (Federal Geographic Information System, Carinthia). The data of the forest inventory of 1998 and 2004 was provided by the Austrian Federal Forests Company (German: "Österreichische Bundesforste AG", ÖBf).

4.4 Game Species Sampling

The general question of how the wildfire in 2003 directly affected the wildlife in Bad Bleiberg cannot be answered. The comparison of the forest stands before and after the wildfire (explained in chapter 4.1) reveals the changes in habitat structures, which obviously influence the presence of wildlife. Consequentially, it was checked which species (focus on game species) are present at all on the blank and its neighbouring stands – this area comprises about 130 ha. The presence was confirmed by finding pellets.

At this stage, the game species sampling and its scope is restricted to only illustrating the species presence, without being able to state the impact of the wildfire on the habitat quality. The value is revealed only after a further wildfire takes place in the area and a repeated game species sampling focusing on successional developments, for example, are done. Nevertheless, that exceeds the capacity of this study and the limitation of illustration was accepted. The method of the wildlife sampling is therefore purely qualitative, as explained below.

4.4.1 Transects

Transects were laid from east to west and vice versa, crossing the whole blank ideally parallel to the slope and entering the neighbouring forest stands, crossing all FMCs. The four transects, named T1, T2, T3 and T4, were each between 900-2200 m long and followed with a metering wheel to exactly locate all findings, focusing on pellets.

4.4.2 Time Frame

The data collection for the habitat evaluation lasted 3 days and was done in March and April 2010. The early springtime was chosen on purpose – a time window between melted snow cover and not yet growing ground vegetation, in which the pellets are detected easier.

Note that the pellets found in spring are mainly evidence of wildlife presence in their winter and early spring habitat.

4.5 Illustration of the Method

In order to get the general idea of the methods used in this study, figure 6 illustrates what is undergone step by step, which data is generated and how it is processed to finally answer the questions, how the fuel and habitat situation have changed.

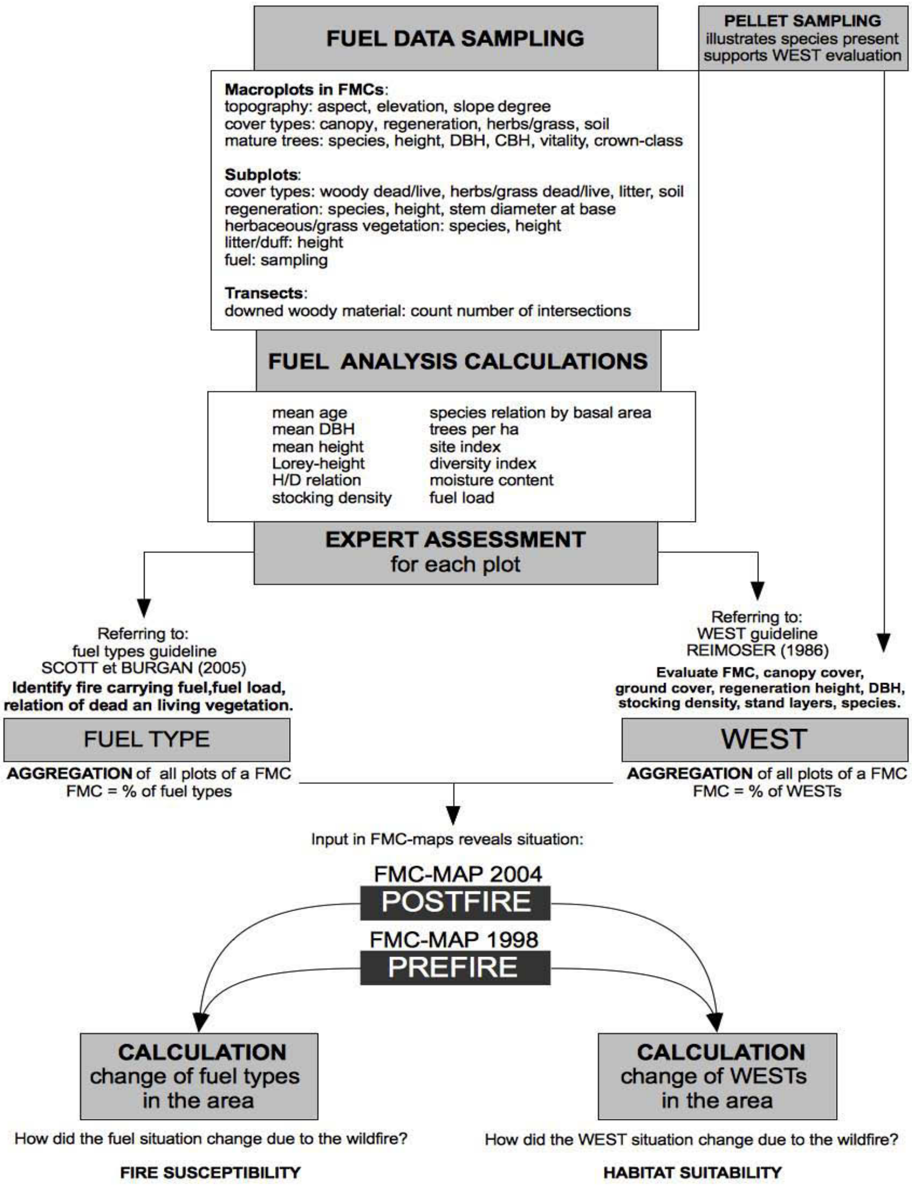


Figure 6: Process of fuel analysis and of identifying the change in habitat structures after the wildfire.

5 Results

This chapter is structured beginning with analysing the current fuel situation in order to identify the fuel types. Secondly, the habitat aspects are introduced by laying down the results of the pellet sampling and identifying the “Wildlife Ecological Stand Types” (WESTs). Finally the current fuel types and WESTs are compared with the fuel types and WESTs prior to the wildfire.

5.1 Fuel Analysis

The results of the fuel analysis will be presented by giving information about the setting of the sample plots, categorized in forest management classes (FMCs). Thereafter, the fuel loads in the FMCs are stated and summarized. Note that the results for the blank are not included at this point, because no mean values could be calculated, as only 1 plot was sampled (consult appendix III for the sampled data).

5.1.1 Topography

As defined by the method for the fuel sampling, the slopes on which the plots were established, were mainly south-oriented and a few were south-west-oriented. The plots were quite evenly distributed between 964 m and 1367 m above sea level, with an average plot location of 1106 m above sea level. The slope was rather steep in general, at an average of 25°. The plots sampled in thicket stands (TH) had an average of 16°, the ones in pole stands (PL) of 25° and the plots in mature stands (MR) of 33°.

5.1.2 Cover

The estimated canopy cover in all FMCs is about 63% on average ($\bar{x}$, table 5). The grass cover is estimated highest in MR, as the stands are very sparse. There are one or two outliers in each FMC with an average grass cover of only 14% – it is suggested that this is due to rocky slopes from former mining operations.

In contrast, there is at least one plot in every FMC with a nearly continuous grass cover due to poor stocking density and an open canopy cover.

The macroplot cover estimation only gives an overview, so it is very helpful to look at the subplot cover estimations for more details. Summing up the vegetation covers (wood and herbs/grass dead and alive), there is an average cover of 51% in PL-plots to 77% in TH-plots. TH-plots have the most woody material dead and alive (12%) and MR-plots have the highest average herbs/grass dead/alive cover (67%). The relation of dead vegetation to living vegetation generally is very low. In plots of PL, there are a lot more litter (33%) and soil patches (16%) on the subplots, compared to the other FMCs. Table 5 shows the results in detail.

Table 5: Cover types on macroplots and subplots in the FMCs.

Average of macroplot cover	**TH**	**PL**	**MR**	**$\bar{x}$**
Canopy [%]	62	66	62	63
Regeneration [%]	15	3	4	7
Herbs/Grass [%]	58	59	75	63
Soil [%]	27	38	21	30
Average of subplot cover				
Woody Alive [%]	11	5	5	7
Woody Dead [%]	1	0	0	0
Herbs/Grass Alive [%]	51	43	55	50
Herbs/Grass Dead [%]	14	3	12	8
Litter [%]	23	33	18	25
Soil [%]	0	16	10	10
Number of sampled plots	6	10	7	23

5.1.3 Standing Trees

5.1.3.1 Thicket Stands

The shares of tree species by basal area in the macroplots classified as TH are 59% for *Pinus sylvestris* and 39% for *Picea abies*. The remaining 2% are are made up of *Acer pseudoplatanus, Larix decidua* and others.

Some plots in the TH were found under the canopy of MR. With that the average height (12 m) and DBH (17 cm) are not characteristic for a classical thicket stage.

The average number of mature trees per ha is 756 (459 *Pinus sylvestris*, 278 *Picea abies*, 17 *Larix decidua*, 2 *Acer pseudoplatanus*), with a standing volume of 124 m^3/ha. Regeneration of *Pinus sylvestris* is very sparse with only about 10% of the total regeneration (about 22300 saplings per ha). 90% of the regeneration is *Picea abies*. Figure 7 shows the average numbers of regeneration individuals (<2 m) and mature trees in TH.

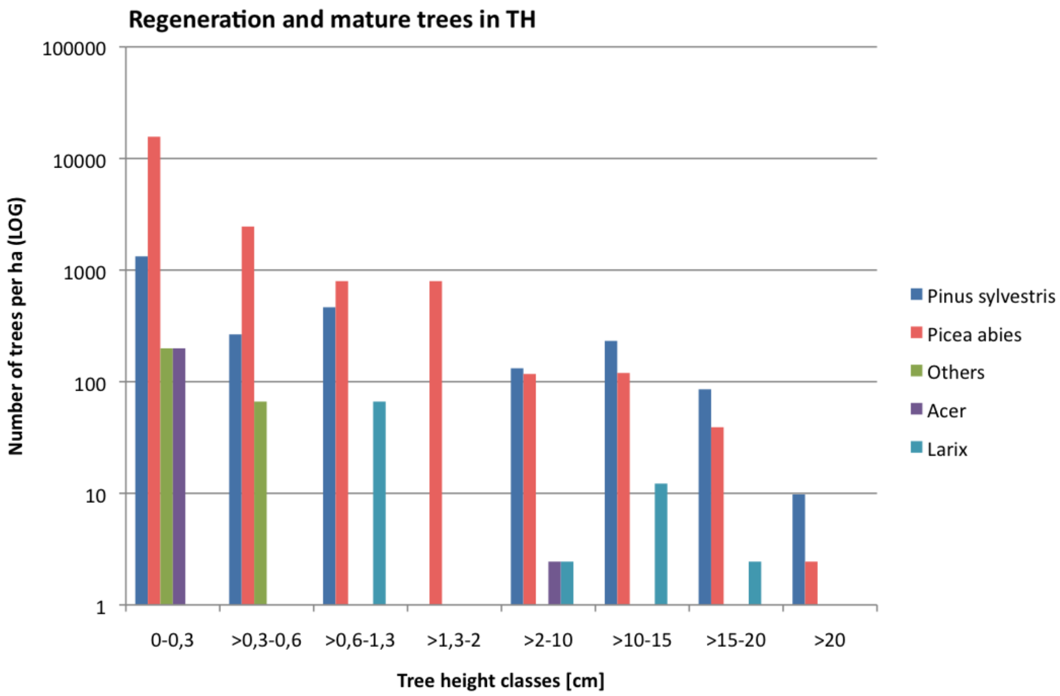


Figure 7: Number of living trees in TH, classified by height [m].

In addition to living trees, also snags were counted. On the plots classified as TH, six snags were found, which corresponds to 2,4 snags per ha.

Along with the DBH, the CBH was measured. Only 13% of the trees in the macroplots have branches touching the ground. Most trees (79%) have a very high CBH – the lowest branches of a tree are higher than 2 m. So, in total 21% of the trees have low hanging branches, which contribute to propagating fire ("fire ladders").

Along with the analysis of the tree-related measurements, the site index was determined. In TH the best timber production conditions are site index 6 for *Pinus sylvestris* and site index 14 for *Picea abies*.

5.1.3.2 Pole Stands

The relation of tree species in PL is 82% for *Pinus sylvestris* and 18% for *Picea abies*. The average height of both species is 13 m with an average DBH of 19 cm. On average PL count 785 stems per ha (629 *Pinus sylvestris*, 149 *Picea abies,* 7 others like *Fagus sylvatica* and *Quercus*). The standing volume is estimated with 184 m^3/ha.

As regeneration, 29100 saplings per ha are estimated. About 30% of the regeneration originates from *Pinus sylvestris* and 14% from *Sorbus aucuparia*, *Alnus viridis* and 3% others. *Picea abies* holds the major share of regeneration with 53%. Figure 8 shows that the taller trees are *Pinus sylvestris* or *Picea abies.* Regeneration is more diverse compared to the other FMCs, represented by more than 7 species.

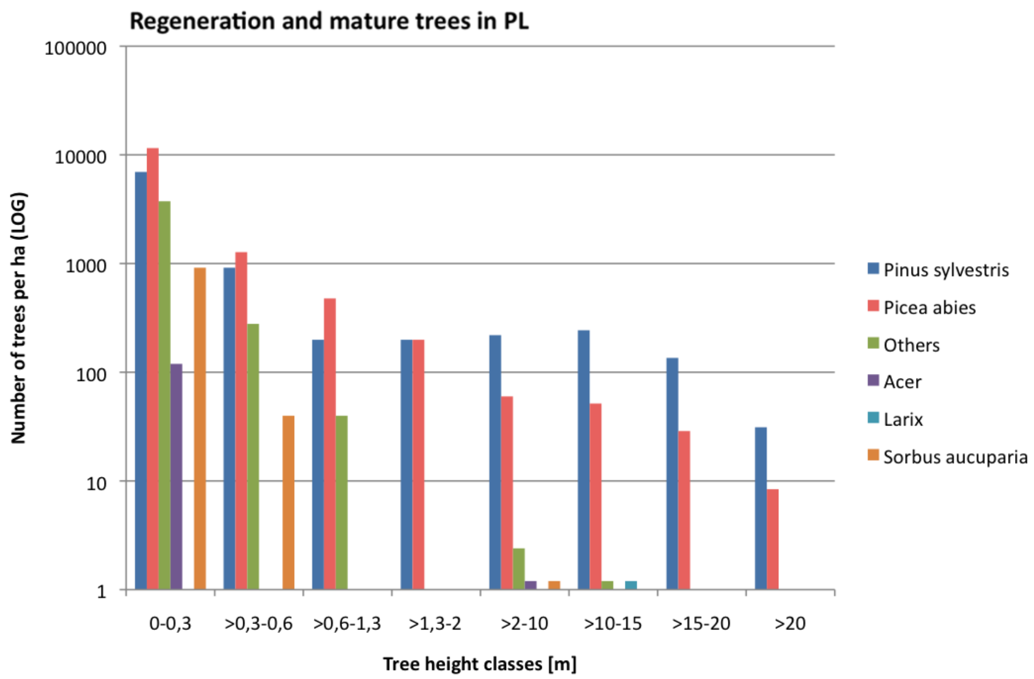


Figure 8: Number of living trees in PL, classified by height [m].

In PL snags count 5,3 per ha and 29% of the trees have the critical CBH under 2 m. Trees with branches actually touching the ground make up 6%.

The site index of PL is rather poor: 2 for *Pinus sylvestris* and 4 for *Picea abies*.

5.1.3.3 Mature Stands

The relation of tree species in MR is 79% for *Pinus sylvestris* and 21% for *Picea abies*. The average height is only 14 m with a DBH of 28 cm. On average, there are 391 stems per ha in MR, from which about one fourth is of *Picea abies*. The remaining stems are 295 for *Pinus sylvestris* per ha and 2 other species per ha. The standing volume is estimated with 188 m^3/ha.

In this stand type 11700 saplings per ha are estimated. Figure 9 shows that the regeneration is nearly equally distributed between *Pinus sylvestris* (3180) and *Picea abies* (3030). About 14% of the regeneration is made up of other species such as, *Fraxinus excelsior, Alnus viridis, Sorbus aucuparia* and *Acer pseudoplatanus*. *Amelancier ovalis* is very prominently represented with estimated 4500 saplings per ha, but since this species is not used for timber production it is not taken into account at this point.

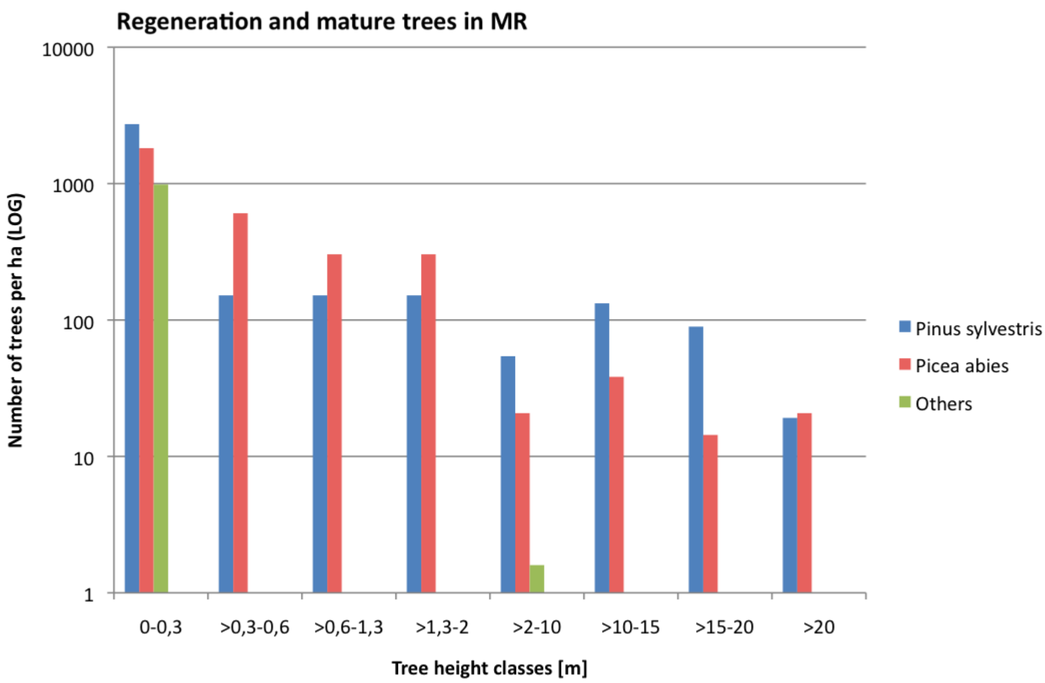


Figure 9: Number of living trees in MR, classified by height [m].

In MR the number of snags is only 1,4 per ha.

The CBH situation is similar to PL: 6% of the trees have branches touching the ground. Yet, only 66% of the trees have very high branches so, 34% of the trees have their crown base in the fire critical zone.

In MR the site index is similar to PL, however the production conditions for *Picea abies* are lower than 4.

5.1.4 Ground Vegetation

Herbaceous and grass species were sampled in the subplots. Each species was classified, yet density was not taken into account.

The average vegetation height was calculated for each plot. The vegetation height variation was quite high. On plots in TH, the average vegetation height is 17 cm. In PL it is only 14 cm, because some subplots were covered with moss only. In MR the vegetation heights reached up to 45 cm, the average height is 21 cm.

In total, 79 different species were counted: 63 in TH and 60 in PL and 65 in MR. On average 21 different species occur in TH, 24 in PL and 17 in MR.

To gain more information about the diversity of food resources, a diversity index was calculated by number of species per area. Diversity is less when the index moves towards 0 and is higher when it moves towards, or even exceeds 1 (HOBOHM, 2000, p. 17).

In the case of Bad Bleiberg, the studied plots of TH have a diversity index of 0,4 – 63 different herbs and grass species were sampled. In TH the most frequently sampled species are: *Polygala chamaebuxus* (Shrubby Milkwort) and *Erica carnea* (Spring Heath), *Brachypodium pinnatum* (Tor Grass), *Carex alba* (White Sedge), *Pteridium aquilinum* (Common Bracken) and *Vaccinium myrtillus* (Common Bilberry).

In PL 60 herbs and grass species were sampled, however, the diversity index is only 0,2. The most frequently sampled species in PL are: *Polygala chamaebuxus* (Shrubby Milkwort), *Euphorbia* species (Spurge), *Erica carnea*

(Spring Heath), *Calamagrostis* species (Reedgrass) and *Carex alba* (White Sedge).

In MR 65 herbs and grass species were sampled, the diversity index is 0,4. The most frequently sampled species in MR are: *Erica carnea* (Spring Heath), *Polygala chamaebuxus* (Shrubby Milkwort), *Gallium* species (Bedstraw), *Vincetoxicum officinale* (White Swallo-wort), *Euphorbia* species (Spurge) and *Veronica officinalis* (Common Speedwell).

Vegetation types referring to HUFNAGL (1970) were identified. Indicator species determine the stand type. In several cases, intermediate vegetation stand types were found. Figure 10 illustrates the main HUFNAGL-Types of the sampled plots.

The ***Erica-type*** is the predominant HUFNAGL-TYPE at the study site. 22% of TH, 40% of PL and 43% of MR were classified as such.

This stand type indicates dry, permeable rendzina on steep slopes. Water and nutrient supply is bad. Timber production is limited in such stands. (HUFNAGL, 1972, p.19)

A subtype of the *Erica-type* is the ***Seslerietum-type***. This pioneer grass usually always accompanies *Erica carnea*, but here it becomes predominant. The soil and quality conditions are the same as in the *Erica-type*. (HUFNAGL, 1972, p. 20)

In TH there is no *Seslerietum-type*. In PL 20% and in MR 29% of the HUFNAGL-Types are *Seslerietum-types.*

The ***Helleborus niger-Hepatica nobilis-type (SL-type)*** is very similar to the *Erica-type* jet the nutrient supply is better (HUFNAGL, 1970, p. 21).

22% of the TH, 10% of the PL and 14% of the MR are of this type.

The *SL-Erica-type* occurred as intermediate vegetation type. In TH this HUFNAGL-TYPE dominates the stands (66%), in PL it is 30%, and in MR it reaches 14%.

Only very few subplots of the ***"Schattenkräuter"-type (K-type)*** with *Anemone nemorose, Dentaria enneaphyllos* and *Mercurialis perennis* as indicator species, appear in the midst of *Erica carnea* stands.

The hydrophilic ground vegetation grows in the shade or under a dense canopy cover. This stand type is totally contrary to the *Erica-type*. Water, nutrient and air supply are very good, the best growth conditions are given. (HUFNAGL, 1972, p. 24)

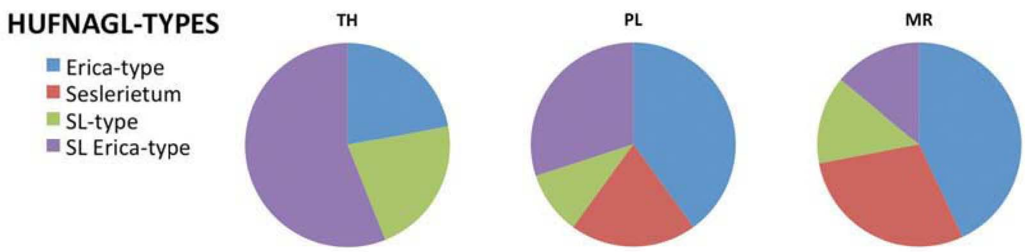


Figure 10: Main HUFNAGL-Types in each FMC.

5.1.5 Fuel Load on Subplots

In terms of amount, on average 4838 kg/ha of dry biomass were collected per macroplot-unit (not distinguishing according to the FMC).

The evaluation of the fuel size on the subplots of the total study site shows that 56,89% of the fuel is sized smaller than 0,6 cm, 36,85% are between 0,6-2,5 cm and only 6,26% are 2,5-7,5 cm big. On subplots no fuels bigger than 7,5 cm were sampled.

The fuel size is linked to the fuel particles, which are 58,28% downed woody material, 17,00% litter, 10,79% vegetation, 10,45% cones and 3,47% bark, lichen and droppings.

Now merging the information about fuel size and fuel particles the evaluation shows that 28,50% of the fuel consists of downed woody material sized between 0,6-2,5 cm, which is the biggest share of the fuel in total. The other big part (26,85%) of the downed woody material is smaller than 0,6 cm. The third biggest amount of fuel is litter smaller than 0,6 cm (16,88%).

Litter is only relevant in the smallest fuel size class, as well as live vegetation. The latter is represented with 10,79% of the overall total. The live vegetation consists of grass, herbs and dwarf shrubs. No live woody vegetation was sampled as fuel on the subplots. Cones make up 10,45%, mainly sized between 0,6-2,5 cm. For detailed information table 6, shows the relations of fuel size and fuel particles of all plots.

Table 6: Detailed composition of fuel particles [%] of the average fuel amount (4838 dry kg/ha) – all plots.

FMC Fuel size [cm]	Downed woody material [%]	Litter [%]	Vegetation alive [%]	Cones [%]	Bark [%]	Lichen [%]	Droppings [%]	∑ [%]
<0,6	26,85	16,88	10,79	1,54	0,81	0,02	-	56,89
0,6-2,5	28,50	0,12	-	6,44	1,75	0,02	0,02	36,85
2,5-7,5	2,93	-	-	2,47	0,86	-	-	6,26
Total	58,28	17,00	10,79	10,45	3,42	0,04	0,02	100,00

As input for fire behaviour models, the fuel data is used with a less detailed resolution. The particles of interest are downed woody material, litter and live vegetation – cones and bark are added to downed woody material and lichen and droppings are added to litter. Table 7 shows the average fuel amounts of all plots regarding those categories.

Table 7: Average fuel amounts [dry kg/ha] of the main fuel particles in the fuel size classes.

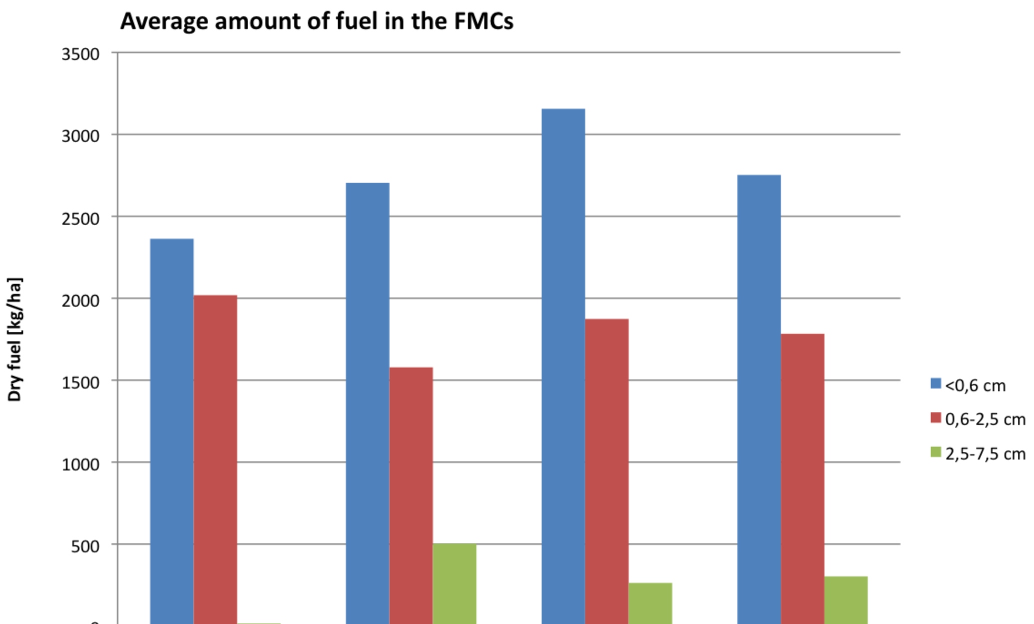
FMC Fuel size [cm]	Downed woody material [dry kg/ha]	Litter [dry kg/ha]	Vegetation alive [dry kg/ha]	∑ [dry kg/ha]
<0,6	1413	817	522	2752
0,6-2,5	1775	8	-	1783
2,5-7,5	303	-	-	303
Total	3491	825	522	4838

Before analysing the fuel particles of the plots according to their FMCs separately, table 8 and figure 11 give an overview of the fuel size distribution in the different FMCs. As only one plot on the blank was sampled it is not included in the following analyses.

The results show, that the share of the smallest fuel size is the highest in all FMCs. The last column ($\bar{x}$) of table 8 represents the average fuel distribution in the fuel size classes of all sampled plots, regardless of FMC.

Table 8: Shares of fuel size classes in the FMCs.

Fuel size [cm]	TH [%]	PL [%]	MR [%]	∑ [%]	$\bar{x}$ [%]
<0,6	16,32	18,68	21,80	56,81	56,89
0,6-2,5	13,95	10,91	12,94	37,79	36,85
2,5-7,5	0,11	3,47	1,82	5,40	6,26
Total	30,38	33,06	36,56	100,00	100,00



	TH [kg/ha]	PL [kg/ha]	MR [kg/ha]	$\bar{x}$ [kg/ha]
<0,6 cm	2362	2704	3156	2752
0,6-2,5 cm	2018	1578	1873	1783
2,5-7,5 cm	15	503	263	303

Figure 11: Average amount of fuel per size class [dry kg/ha], in the FMCs: TH, PL and MR.

5.1.5.1 Thicket Stands

In TH an average fuel amount of 4395 dry kg/ha was collected. The detailed distribution can be seen in table 9, the dry kg/ha amounts are shown in table 10. Starting with the fuel type downed woody material, the analysis shows that this fuel particle is the most important one. Contrary to the other FMCs, downed woody material is bigger here; mainly in the class 0,6-2,5 cm. This class represents 44,74% of all fuel in TH. The other large part of the fuel is smaller than 0,6 cm: litter (19,63%), downed woody material (17,80%), and vegetation (14,31%). Cones, bark and lichen were also collected but are neglectable.

Table 9: Shares of fuel particles in the fuel size classes in TH.

TH Fuel size [cm]	Downed woody material [%]	Litter [%]	Vegetation alive [%]	Cones [%]	Bark [%]	Lichen [%]	∑ [%]
<0,6	17,80	19,63	14,31	0,71	1,29	-	53,74
0,6-2,5	44,74	-	-	0,60	0,52	0,05	45,91
2,5-7,5	-	-	-	-	0,35	-	0,35
Total	62,54	19,63	14,31	1,31	2,16	0,05	100,00

Table 10: Average fuel amounts [dry kg/ha] of the main fuel particles in the fuel size classes in TH.

TH Fuel size [cm]	Downed woody material [dry kg/ha]	Litter [dry kg/ha]	Vegetation alive [dry kg/ha]	∑ [dry kg/ha]
<0,6	870	863	629	2362
0,6-2,5	2016	2	-	2018
2,5-7,5	15	-	-	15
Total	2901	865	629	4395

5.1.5.2 Pole Stands

The average amount of fuel collected in PL is 4785 dry kg/ha. The distribution can be seen in table 11 and 12. 68,59% of the fuel is downed woody material: 35,99% smaller than 0,6 cm, 25,78% between 0,6-2,5 cm and 6,82% between 2,5-7,5 cm. The amount of litter is relatively low with only 14,05%, but note that there is also litter larger than 0,6 cm. In comparison to the other FMCs, the fuel type, vegetation, is extremely low with only 5,46%. Yet, the cones gain importance (9,17%), especially in the second size class, but they can be found in all fuel size classes. The share of bark is comparable to the one in TH, yet the size class is bigger. Neglectable fuel types are lichen and droppings.

Table 11: Shares of fuel particles in the fuel size classes in PL.

PL Fuel size [cm]	Downed woody material [%]	Litter [%]	Vegetation alive [%]	Cones [%]	Bark [%]	Lichen [%]	Drop-pings [%]	∑ [%]
<0,6	35,99	13,77	5,46	1,25	-	0,04	-	56,51
0,6-2,5	25,78	0,28	-	4,74	2,1	0,03	0,05	32,98
2,5-7,5	6,82	-	-	3,18	0,51	-	-	10,51
Total	68,59	14,05	5,46	9,17	2,61	0,07	0,05	100,00

Table 12: Average fuel amounts [dry kg/ha] of the main fuel particles in the fuel size classes in PL.

PL Fuel size [cm]	Downed woody material [dry kg/ha]	Litter [dry kg/ha]	Vegetation alive [dry kg/ha]	∑ [dry kg/ha]
<0,6	1782	661	261	2704
0,6-2,5	1561	17	-	1578
2,5-7,5	503	-	-	503
Total	3846	678	261	4785

5.1.5.3 Mature Stands

The collected fuel in MR is 5292 dry kg/ha. This FMC has the biggest average amount of fuel, as illustrated in table 13 and 14. The share of the smallest fuels is also biggest compared to the other FMCs. The relative amount of litter (18,92%) and vegetation (15,18%) is comparable with the amount found in TH. The cones reach a share of 18,61% in this FMC, and also the bark (5,34%) doubles its weight in comparison to the other FMCs.

Table 13: Shares of fuel particles in the fuel size classes in MR.

MR Fuel size [cm]	Downed woody material [%]	Litter [%]	Vegetation alive [%]	Cones [%]	Bark [%]	Lichen [%]	∑ [%]
<0,6	21,50	18,92	15,18	2,51	1,52	-	59,63
0,6-2,5	20,45	-	-	12,79	2,16	-	35,40
2,5-7,5	-	-	-	3,31	1,66	-	4,97
Total	41,95	18,92	15,18	18,61	5,34	-	100,00

Table 14: Average fuel amounts [dry kg/ha] of the main fuel particles in the fuel size classes in MR.

MR Fuel size [cm]	Downed woody material [dry kg/ha]	Litter [dry kg/ha]	Vegetation alive [dry kg/ha]	∑ [dry kg/ha]
<0,6	1351	1001	804	3156
0,6-2,5	1873	-	-	1873
2,5-7,5	263	-	-	263
Total	3487	1001	804	5292

5.1.6 Fuel Load of Downed Woody Material Along Transects

The number of downed woody material intersections along the transects were calculated into kg/ha following BROWN (1974, p. 15). As shown in table 15, most of the downed woody material is sampled along the transects in PL. Especially the fuel size class 2,5-7,5 cm contributes to high fuel loads. Summing up the downed woody material of all fuel size classes, the samples of the TH comprise the smallest load and the samples of the PL the biggest.

Table 15: Estimation of downed woody material [kg/ha] along transects in the FMCs.

Downed Woody Material [cm]	TH [kg/ha]	PL [kg/ha]	MR [kg/ha]	$\overline{x}$ [kg/ha]
<0,6	1598	1389	769	1252
0,6-2,5	2796	6098	4287	4394
2,5-7,5	8898	11477	10340	10238
>7,5 sound	194	1009	1261	821
>7,5 rotten	547	1315	2277	1380
Total	14033	21288	18934	18085

As downed woody material, was sampled twice using two different methods, a comparison of the results seems likely. In table 16, the shares of the downed woody material in the fuel size classes and the FMCs counted along the transects is compared to the weighted downed woody material originating from the subplots. Here the lying poles were excluded, to be able to compare the distribution in the smaller fuel size classes.

Table 16: Shares of the amount of downed woody material counted and weighted in the fuel size classes and the FMCs [%].

Downed Woody Material	COUNTED along **transects**				WEIGHTED from **subplots**			
[cm]	TH [%]	PL [%]	MR [%]	∑ [%]	TH [%]	PL [%]	MR [%]	∑ [%]
<0,6	3,35	2,91	1,61	7,87	8,50	17,41	13,20	39,11
0,6-2,5	5,87	12,80	9,00	27,67	19,70	15,25	18,30	53,25
2,5-7,5	18,67	24,09	21,70	64,46	0,16	4,91	2,57	7,64
Total	27,89	39,80	32,31	100,00	28,35	37,57	34,07	100,00

The distribution of kg/ha in the FMCs and fuel size classes is diverging between the 2 sampling methods. According to the transect-method, the fuel size class 2,5-7,5 cm is predominant (64,46%) and the fuel size class <0,6 cm is marginal (7,87%). With the subplot-method the 1st and 2nd fuel size class are the dominating ones (39,11% and 53,25%). Considering the relations of the total amount of downed woody material in the different FMCs, both sampling methods have similar results. PL have the most downed woody material, followed by MR and TH.

Apart from the distribution in the fuel size classes, also the kg/ha reach different amounts. The amounts for the transect-method were presented in table 15 and the amounts for the subplot-method were presented in the tables: 10, 12, 14.

5.1.7 Duff and Litter

The average amount of dry duff in TH is 9316 kg/ha. This is only about half of the average amount found in PL, which is 18478 dry kg/ha. The average duff amount in MR lies in between TH and PL with 1537 dry kg/ha.

The duff and litter heights are similar in all of the sampled subplots. In TH the duff height is 1,6 cm on average and litter 1,4 cm. PL have an average duff height of 1,7 cm and 1,4 cm litter. The highest duff and litter accumulations were measured in MR with 2,0 cm duff and 1,8 cm litter.

5.1.8 Fuel Moisture Content

The analysis of the fuel moisture content is essential for estimating fire susceptibility. Table 17 describes the shares of dry fuel amounts in moisture content classes. Looking at all FMCs as a whole, the driest fuels represent 19,37% of the total fuel load. Adding up the 2 driest fuel classes, 43,04% of all fuels have a moisture content below 41% – 35,99% of which is downed woody material. On the other hand, 20,38% of all fuels, mainly live vegetation and large downed woody material, have more than 100% moisture content .

Table 17: Moisture content [%] in classes of all fuels.

FMC Moisture content Fuel size [cm]	**0-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**	**>100%**
<0,6	12,31	11,57	8,57	4,23	5,16	15,04
0,6-2,5	6,96	10,76	3,11	10,76	2,86	2,41
2,5-7,5	0,10	1,35	0,99	0,55	0,34	2,93
Total	**19,37**	**23,67**	**12,67**	**15,54**	**8,36**	**20,38**
Fuel particle [%]						
Downed woody material	15,82	20,17	9,49	13,92	4,35	8,4
Litter	3,55	3,02	2,04	1,62	3,07	3,76
Vegetation alive	0	0,49	1,14	-	0,94	8,22

In TH nearly 47,17% of all fuels have a moisture content between 21-40% (table 18). The great part (42,15%) of that class is comprised of downed woody material. Most of the litter (8,38%) in TH is found in the 81-100% class. The moisture content of live vegetation in TH is distributed in 4 classes. Most of the sampled vegetation (4,81%) has a moisture content between 41-60%.

The moisture content of duff was also determined. The conditions concerning humidity seem very variable in TH, this can also be seen in the moisture contents of the duff samples – extremes of 10% and of 220% were sampled.

Table 18: Moisture content [%] in classes of all TH-fuels.

TH **Fuel size [cm]**	**0-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**	**>100%**
<0,6	6,61	9,25	17,68	3,68	12,98	3,54
0,6-2,5	5,47	37,92	0,91	-	1,60	0,02
2,5-7,5	-	-	0,35	-	-	-
Total	**12,09**	**47,17**	**18,93**	**3,68**	**14,57**	**3,56**
Fuel particle [%]						
Downed woody material	8,87	42,15	10,98	1,70	2,30	-
Litter	3,21	2,95	3,14	1,98	8,38	0,02
Vegetation alive	-	2,07	4,81	-	3,89	3,54

In PL (table 19) the conditions are much dryer compared to TH. 28,64% of the fuel amount has a moisture content below 21% – mainly downed woody material. Yet 11,20% of this fuel particle have a moisture content >100%. All of the vegetation (5,46%) is found in the moisture class >100%. Contrary to TH, the duff moisture content in PL is much more homogenous and lies at an average of 150%.

Table 19: Moisture content [%] in classes of all PL-fuels.

PL **Fuel size [cm]**	**0-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**	**>100%**
<0,6	16,22	14,75	6,93	4,39	2,98	11,24
0,6-2,5	12,20	3,76	6,02	9,14	1,37	0,50
2,5-7,5	0,22	1,36	2,11	-	-	6,82
Total	**28,64**	**19,86**	**15,06**	**13,52**	**4,36**	**18,55**
Fuel particle [%]						
Downed woody material	25,29	16,25	13,15	11,43	3,05	11,20
Litter	3,34	3,61	1,91	2,10	1,31	1,90
Vegetation alive	0,00	0,00	0,00	0,00	0,00	5,46

In MR only about 24,47% of the fuel amount have a moisture content up to 40% (table 20). Here, downed woody material has a much higher moisture content compared to the other FMCs. 25,84% of which have a moisture content between 61-80% and 10,76% have a moisture content >100%.

The share of live vegetation is comparable to the one in TH, yet in MR nearly all of it has more than 100% moisture. In no other FMC there are such high moisture contents. Also the duff layer reflects the moist conditions. There is a variation again, but less compared to the extremes in TH. Moisture contents from 110% to 223% were sampled in MR.

Table 20: Moisture content [%] in classes of all MR-fuels.

MR **Fuel size [cm]**	**0-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**	**>100%**
<0,6	11,33	9,12	4,20	4,41	2,42	28,15
0,6-2,5	1,26	0,46	0,91	20,52	5,68	6,57
2,5-7,5	-	2,29	-	1,66	1,02	-
Total	**12,60**	**11,87**	**5,11**	**26,59**	**9,12**	**34,72**
Fuel particle [%]						
Downed woody material	8,54	9,55	3,70	25,84	7,50	10,76
Litter	4,06	2,31	1,41	0,74	1,55	8,85
Vegetation alive	-	-	-	-	0,07	15,11

5.1.9 Summarizing the Fuel Situation at the Study Site

Summarizing the fuel situation at the study site is best done by comparing the results of the FMC (table 21). It is very clear, that the plots sampled as TH show the most differences – compared to the other FMCs, the slope degree is very low, regeneration cover is highest, herbs/grass cover lowest, the most branches lower than 200 cm are found here.

In plots classified as TH, the fuel load and its composition (figure 12) differs very much in comparison to the plots in MR and in PL: Although the average fuel load is the lowest, the great part of the sampled fuel in TH is sized between 0,6-2,5 cm. Fuels between 2,5-7,5 cm are marginal. In PL, for instance, the share of this fuel size class is the biggest. In MR most fuels are found in the smallest size class (table 21).

Table 21: Comparison of properties relevant to fire behaviour in the FMCs.

Properties relevant to fire behaviour	**FMCs in ascending order**
Slope degree [°]	TH < PL < MR
Herbs/Grass cover [%]	TH < PL < MR
Moisture content >100 [%]	TH < PL < MR
Fuel Load <0,6 cm [dry kg/ha]	TH < PL < MR
Total fuel load [dry kg/ha]	TH < PL < MR
Moisture content 0-20 [%]	TH < MR < PL
Downed woody material [dry kg/ha]	TH < MR < PL
Fuel Load 2,5-7,5 cm [dry kg/ha]	TH < MR < PL
Litter [dry kg/ha]	PL < TH < MR
Live vegetation [dry kg/ha]	PL < TH < MR
Regeneration cover [%]	PL < MR < TH
CBH <200 cm [%]	PL < MR < TH
Fuel Load 0,6-2,5 cm [dry kg/ha]	PL < MR < TH
Soil cover [%]	MR < TH < PL

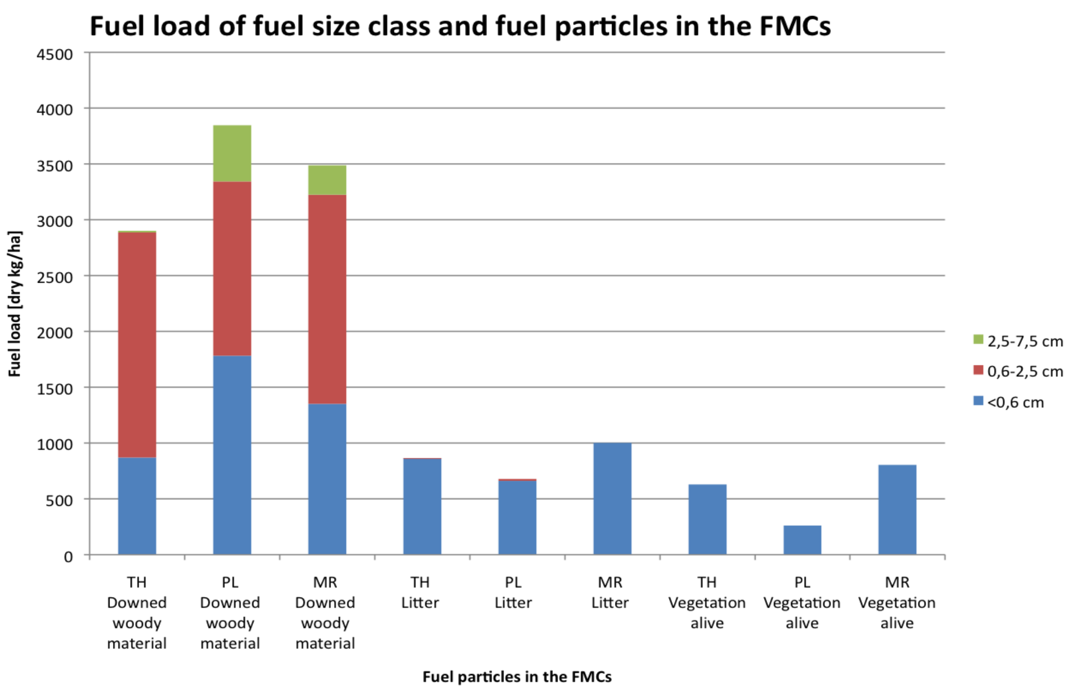


Figure 12: Fuel loads [dry kg/ha] in the FMCs.

5.1.10 Identifying Fuel Types

After analysing the fuel data, the fuel types were determined for each plot, following the concept of SCOTT et BURGAN (2005) (see appendix IV). It was necessary to take the Austrian conditions in *Pinus sylvestris* dominated stands into account, hence, 3 fuel types were developed by ARPACI et al. (2010 a, s.p.). 2 of the newly developed fuel types were identified for the sampled plots. In the following the fuel types relevant for the study are listed:

- **Pinus Austria_low 51, PiL**: The conditions found in Austria in south oriented *Pinus* dominated forest stands are represented. The information regarding spread rate and flame length are still unknown.
- **Pinus Austria_moderate 52, PiM**: The conditions found in Austria in south oriented *Pinus* dominated forest stands are represented. The information regarding spread rate and flame length are still unknown.
- **Timber Understory, TU1**: Fire carrying material is grass or shrubs mixed with litter from the forest canopy. The fuelbed consists of low grass or shrub and litter loads. Both spread rate and the flame length are described as low. (SCOTT et BURGAN, 2005, p. 11)

Due to the slope correction factor the plot sizes vary, therefore each plot contributes to its FMC with a different share. The percentage of each fuel type was calculated with the corresponding plot size. Here the sampled plot on the blank was included to complete the impression – its fuel type was identified as 100% TU1. All plots in TH were rated as PiM. The plots in PL were identified as PiL in 40% of the cases and as PiM in 60% of the cases. Also the plots in MR were not uniformly identified as one fuel type only. So 83% of the MR plots were identified as PiL and 17% as PiM. The share of each FMC of the study site and the corresponding fuel types are shown in table 22.

Table 22: Shares [%] of the FMCs of the study site and their fuel types.

Fuel type	TH	PL	MR	BL	∑
PiL	-	16,40%	28,01%	-	44,41%
PiM	20,94%	26,26%	4,01%	-	51,21%
TU1	-	-	-	4,38%	4,38%
∑	20,94%	42,66%	32,02%	4,38%	100,00%

In order to give and overview, the following figures (13-16) show how some plots looked like and which fuel type was identified.

Figure 13: Example plot 23: Thicket stand, Pinus Austria_moderate.

Figure 14: Example plot 14: Pole stand, Pinus Austria_low.

Figure 15: Example plot 16: Mature stand, Pinus Austria_moderate.

Figure 16: Example plot 7: Blank, Timber-Understory 1.

5.2 Habitat Evaluation

5.2.1 Species Present

During the pellet search on the transects a rich data collection was established. Not only pellets were found, but also trails, feathers, holts, fraying marks, browse, and observations were made. Yet those additional findings were not used in the following data processing. The pellets were identified according to species and location. Pellets of the following game species were found: *Capreolus capreolus, Rupicapra rupicapra, Lepus, Tetrao urogallus,* and *Cervus elaphus*. Details are listed in table 23.

The pellet findings correspond to the declaration of the hunter's association as mentioned in chapter 3.5.

Table 23: Pellet findings [n/100m²] on the transects per game species.

Species pellets	∑	%	Average distance [m]	n/100 m²
Cervus elaphus	6	1	1024	0,1
Rupicapra rupicapra	95	23	65	1,5
Capreolus capreolus	213	52	29	3,5
Lepus	74	18	83	1,2
Tetrao urogallus	27	6	227	0,4
Total samples	415	100	15	6,8

The pellet data was applied to the FMC-map (GIS), showing the study site, to find out whether there is a pattern in pellet findings. With that, the exact number of pellet findings could be determined for each FMC. It was also tried to apply the pellet data to a GIS map showing the fuel types – considering the pellet findings in the fuel types – however the scales conflicted, so this task was dismissed.

The overall pellet findings are very dense, approximately 1 finding every 15 m, on a total transect length of 6141 m. For further research the pellet findings were also expressed as pellet finding per 100 m² (n/100 m²).

The majority of pellets found, originate from *Capreolus capreolus* (52%), followed by *Rupicapra rupicapra* (23%) and *Lepus* (18%).

Especially in TH a lot of pellets were found (table 24) – mainly from *Capreolus capreolus* (8,6/100 m^2) but none from *Lepus.* The least pellet findings were counted on the blank (5/100 m^2), of all species. The pellets of *Cervus elaphus* were only found on the blank and in sparse MR (0,1/100 m^2). *Tetrao urogallus* could be detected indirectly in all FMCs (0,4/100 m^2), yet in TH there are 1,6 pellet findings per 100 m^2.

Table 24: Pellet findings [n/100 m²] in the FMCs and fuel types by game species.

	Pellet findings in the FMCs [n/100 m²]			
FMC	BL	TH	PL	MR
∑ area size [m²]	2468	243	750	2680
Capreolus capreolus	2,6	8,6	3,9	3,7
Rupicapra rupicapra	1,2	2,5	2,0	1,6
Lepus	1,0	-	0,8	1,6
Tetrao urogallus	0,2	1,6	0,9	0,4
Cervus elaphus	0,1	-	-	0,1
∑ pellet findings [n/100 m²]	5,1	12,8	7,6	7,5
∑ pellet findings	125	31	57	202

Now, an approximate description is given, where the pellets were found (illustrated in figure 17). Starting with the 27 findings of ***Tetrao urogallus***, it is obvious that they are only found in the western stands surrounding the blank. In the north-western part, findings were surprisingly made in a dense thicket-like pole stand. The north-western part seems to be somehow attractive, as pellets were also found directly on the blank. Here, the slope is not as steep as in the centre of the blank and the complete slope is overviewed.

Lepus prefers sparse stands. It is found on the blank and in the old stands, mainly in the eastern part of the blank, nearby the blowdowns and the salvage logged parts. In total, 74 pellet findings were found of this species.

Only 6 pellets of ***Cervus elaphus*** were sporadically found and only in the edge zones of the area.

As there are very steep rocky areas west of the blank, ***Rupicapra rupicapra*** is mainly found there. In total, 95 pellets were found. Moving towards the blank, the amount of pellet findings decreases. In comparison, only few pellets are found directly on the western part of the blank. However, pellets are quite numerous in the north-eastern part of the blank. There is a mature stand between the blank and a windthrow patch which seems to attract *Rupicapra rupicapra* as well as *Capreolus capreolus.*

Finally, it can be stated that the 213 ***Capreolus capreolus*** pellets are found nearly all over the site. Yet, the distribution is similar to *Rupicapra rupicapra* in the western part as well as in the north-eastern part. Figure 17 shows the pellet findings along the transects differentiated by species. The findings were added to a GIS map showing the FMCs.

For all species it can be stated that the pellet findings decrease towards the centre of the blank.

Therefrom, the edges of the blank were calculated in the GIS map. The total edge length surrounding the blank is about 5600 m. The two forest roads crossing the blank are about 1600 m long. However, the data sampled is not appropriate to give a statement concerning any edge effects.

Figure 17: Pellet findings of different species along the transects (ÖBF, 2005, modified FMC-map).

5.2.2 Identifying Wildlife Ecological Stand Types

Several properties carrying relevant habitat information – referring to REIMOSER (1986, s.p.) for *Capreolus capreolus* and to SCHATZ (1992, s.p.) and ZEILER (2001, s.p.) for *Tetrao urogallus* – can be directly retrieved from the fuel analysis: elevation, slope degree, aspect, cover types, tree species, regeneration height, tree height, DBH, stocking density, downed woody material, snags, ground vegetation height, and vegetation types.

In order to apply the concept of the WESTs to the study site, each sampled plot was evaluated following the WEST-guideline (see appendix V). The first step is done by determining the FMC of an area, as the WESTs refer to the FMCs. Subdivisions describe certain stand characteristics in a more detailed way and give information about structural properties in terms of wildlife suitability. Ground cover, stocking density, mean DBH and height, regeneration density and height of each plot are examined to identify the WEST most suitable. Now, each plot corresponds to exactly one WEST, but the FMCs comprise shares of diverse WESTs. The next step is to assess these stand types regarding the habitat demands of *Capreolus capreolus* and of *Tetrao urogallus*. In the following, the WESTs relevant at the study site are presented. At the same time, the WEST-values for the 2 species are also introduced.

5.2.2.1 Identified Wildlife Ecological Stand Types

The WESTs are identified independently of the general setting, such as elevation, aspect, slope degree, tree species composition and canopy cover. As this setting is important, especially for *Tetrao urogallus*, see chapters 5.1.1, 5.1.2 and 5,1.3.

The WESTs identified for the sampling plots, are listed in the following, describing the habitat structure features and their value for *Capreolus capreolus* (REIMOSER, 1986, s.p.) and *Tetrao urogallus* (ZEILER, 2001, s.p.).

022: Describes **idle grassland** with shrubs or trees higher than 0,7 m - from the “Non Forest Stand Types”.	
Microclimate and snow cover: Are valued as not favourable, for there is no sufficient shelter from sun, wind and rain, also leading to high snow accumulations in winter.	
Value for *Capreolus capreolus*: As food supplier, this WEST is especially valuable in spring and eventually in autumn. In winter, the food resources might not be accessible due to high snow cover, which also negatively affects mobility. However some shrubs and single trees might provide little food resources. Hiding shelter might be given in summer and autumn by rich ground vegetation, which can exceed 1 m in growth height. Thermal cover is not given. With that this WEST is not used as lodge.	**Value for *Tetrao urogallus***: Grass and shrubs can provide sufficient food resources especially in summer. Mobility in the air is not restricted, as the area is mainly unstocked – good accessibility. On the ground the mobility might be restricted due to a dense and high grass cover. This also limits the view range, so this WEST is not favoured as hiding shelter on the ground. Hiding shelter above ground is not given as well as thermal cover. This WEST is not suitable as lodge.

093: Describes the last developmental stage of a **thicket** before it is classified as pole stand. The trees are higher than 1,3 m, the canopy cover is very dense and the space between the stems is partially accessible - the stem pruning has begun, but only on less than 50% of the area.	
Microclimate: These stands provide good shelter against weather, as they are very dense. Snow cover: Due to the vegetation features, the snow cover can be very unstable and long-lasting. These stand are avoided by some wildlife species in winter, because mobility is constraint and escaping costs much energy.	

Value for *Capreolus capreolus*:	Value for *Tetrao urogallus:*
Depending on the dispersion of the trees, the amount of food can vary but is often lacking. A stand of this type primarily provides hiding shelter and thermal cover, especially in summer. In winter these stand types are often abandoned, due to the unstable snow cover. As lounge it is not favoured because view range as well as mobility are limited by trees and dense branches.	This stand type is too dense to provide food from ground vegetation. Mobility and access are limited in the air and on the ground. This WEST is unsuitable as lodge, although thermal cover and hiding shelter are given. This stand type is rather favoured by *Bonasa bonasia* (Hazel Grouse).

101: Describes a **pole stand**, with a maximum average DBH of 25 cm. The ground vegetation covers less than 50% in this stand type, whereupon ground vegetation is not higher than 1,3 m and not more than one third of the area is covered with ground vegetation higher than 70 cm.	
Microclimate: Due to a dense canopy cover thermal shelter is very good, the microclimate is well balanced. Snow cover: The hight of the snow cover is less than on blanks, because snow interception is reduced. The snow cover quality is very stable and it melts earlier than in thickets.	
Value for *Capreolus capreolus*: With ground vegetation falling below 50%, food is sparse. Hiding shelter possibilities are rather good and mobility is not restricted by vegetation or snow. Thermal shelter is given. These stands are favoured as lodge in winter, because microclimate and mobility are good (energy aspects).	**Value for *Tetrao urogallus:*** Food availability in summer is not given, as there is nearly no ground vegetation. Mobility and access are restricted due to dense vegetation structures. Thermal cover and hiding shelter might be given. This stand type is not appropriate as lodge.

102: Describes a **pole stand**, with a maximum average DBH of 25 cm. The ground vegetation cover exceeds 50%, whereupon ground vegetation is not higher than 1,3 m and not more than one third of the area is covered with ground vegetation higher than 70 cm.	
Microclimate: The thermal shelter is reduced – good to mediocre, depending on the understory vegetation. Snow cover: The snow cover heights are less than in unstocked habitat types. The snow cover quality is compact and it melts comparatively early.	
Value for *Capreolus capreolus*: The canopy cover is not so dense, which increases the overall food supply. With that the hiding shelter and thermal cover are reduced. No major mobility problems due to understory vegetation or snow are expected. The conditions as lodge are mediocre.	**Value for *Tetrao urogallus:*** Food availability in summer is not sufficient. Mobility and access are possible but restricted due to dense stocking. Thermal cover and hiding shelter are given. This stand type might be used as lodge.

103: Characterizes a **pole stand with regeneration** – due to small scaled disturbances – higher than 70 cm on more than one third of the area.	
Microclimate/snow cover: Microclimate is very unstable and heterogenous, as well as the snow cover quality.	
Value for *Capreolus capreolus*: This stand type is more heterogeneous than the other pole stand types. Gaps due to windfall or windbreak are recolonized and create regeneration patches, which provide food, hiding shelter and spatially thermal cover. View ranges are	**Value for *Tetrao urogallus:*** Partially this stand type is too dense, but the boundaries are beneficial to food supply in summer and winter. The density enhances thermal cover. Hiding shelter is available, but mobility and access are limited.

spatially reduced, due to dense regeneration. The regeneration patches can be described similar to thickets. With that mobility and lodge qualities are comparatively low.	As lodge this WEST is valued as indifferent.

111: Describes a **mature stand** with an average DBH bigger than 26 cm. The canopy covers over one third of the area. The ground vegetation cover is less than 50%.	
Microclimate: The microclimate in such dense mature stands is well-balanced. Snow cover: The snow cover is less than on blanks, because snow interception is reduced. The snow cover quality is very stable and it melts comparatively early.	
Value for *Capreolus capreolus*: The ground vegetation is limited but mostly present, providing some food in summer only. Thermal cover is given well enough and hiding shelter is also existent, without restricting mobility. This stand type is preferred as lodge.	***Value for Tetrao urogallus:*** There is ground vegetation in summer, but limited. In winter the old coniferous trees provide food resources. Thermal and hiding shelter are available. Mobility and access are limited in the air, but not on the ground. As lodge this WEST is valued as indifferent.

112: Describes a **mature stand**, rich in ground vegetation, the ground vegetation, not higher than 1,3 m, exceeds 50%. Woody vegetation higher than 70 cm does not cover more than one third of the area.	
Microclimate/snow cover: Microclimate and snow cover quality are mediocre.	
Value for *Capreolus capreolus*: The food supply is excellent and	***Value for Tetrao urogallus:*** Rich ground vegetation provides

better accessible than on blanks. Mobility might be reduced due to the snow cover but not due to vegetation. Thermal cover is given but hiding shelter is sparse. This stand type is also used as lodge.	enough food in summer. It is not too high, so there are good shelter and escape-possibilities. In winter the old coniferous trees provide sufficient food resources. The access is easy and lodge is given.

121: Describes **natural regeneration under a canopy** cover (> 30%) of a mature stand. Woody ground vegetation between 0,7 m and 1,30 m is present on more than 30% of the area.	
Microclimate/snow cover: Microclimate is very unstable and heterogenous. The snow cover quality is unstable and irregular.	
Value for *Capreolus capreolus* : This stand type is very heterogeneous. The food supply is sufficient in summer and winter. Mobility can be restricted by vegetation and bad snow conditions. More hiding shelter than thermal cover is provided. The use as lodge is only sporadically and mostly in summer.	***Value for Tetrao urogallus:*** Food supply is very good in summer and in winter. The spatial density enhances thermal shelter and hiding cover, but still mobility and access are given. In winter the old coniferous trees provide good food resources. As lodge this WEST is valued as indifferent.

123: Describes a **thicket-like regeneration**, which covers more than 30% of the area, under a canopy cover (> 30%) of a mature stand.	
Microclimate/snow cover: Microclimate is very unstable and heterogenous. The snow cover is unstable, irregular and long lasting.	
Value for *Capreolus capreolus*: This stand type is very heterogeneous. The food supply is	***Value for Tetrao urogallus:*** Partially this stand type is too dense, but the boundaries might be

rather low in summer and winter. Mobility is constraint by vegetation and bad snow cover quality. Hiding shelter and thermal cover can be spatially limited. As lodge this stand type is insufficient.	beneficial to food supply. The density enhances shelter possibilities, however mobility is constraint. In winter the old coniferous trees provide sufficient food resources. As lodge this WEST is valued as indifferent.

124: Describes a **pole stand-like regeneration**, which covers more than 30% of the area, under a canopy cover (> 30%) of a mature stand.	
Microclimate/snow cover: The microclimate is very heterogenous. The snow interception is reduced.	
Value for *Capreolus capreolus*: This stand type is heterogeneous. The food supply is low in summer and winter. Mobility is mediocre, as the vegetation is not as dense and the snow cover is not so high. Hiding shelter and thermal cover are given well enough. This stand type provides good lodge conditions.	***Value for Tetrao urogallus:*** Depending on stand density, food supply in summer is mainly good. In winter the coniferous trees provide food. Hiding shelter and thermal cover are given. Mobility might be spatially constraint, but it is mainly possible to move sufficiently. As lodge this WEST is valued as comparatively good.

131: Describes a stand type characterized as **high forest** in which only selected trees are harvested. Saplings, pole sized trees and mature trees compose a multilayered habitat. The ground vegetation up to 1,3 m covers less than 50% of the area.	
Microclimate/snow cover: The microclimate is very heterogenous. The snow interception is reduced.	

Value for *Capreolus capreolus*:	***Value for Tetrao urogallus:***
Because of the low ground vegetation cover, the food supply is poor. Mobility is not restricted. The structure diversity provides sufficient hiding shelter, thermal cover and lodge.	There are only few food resources in summer and winter, additionally this stand type is not ideal, as multiple layers cause mobility restrictions. Thermal cover and hiding shelter are given. As lodge this WEST is valued as unsuitable.

132: Describes a stand type characterized as **high forest** in which only selected trees are harvested. Saplings, pole sized trees and mature trees compose a multilayered habitat. The ground vegetation up to 1,3 m covers more than 50% of the area.	
Microclimate/snow cover: The microclimate is very heterogenous. The snow interception is reduced.	
Value for *Capreolus capreolus*: This stand type is rich in food supply but mediocre in providing hiding shelter, thermal cover and lounge, as structures can be very dense limiting view range and mobility.	***Value for Tetrao urogallus:*** This stand type provides sufficient food resources. Mobility and access are restricted, however this multilayered stand type not too dense, so it provides lodge.

5.2.2.2 Shares of Wildlife Ecological Stand Types

Now, the shares of the WESTs in the FMCs are presented (table 25). The plots classified as TH comprise 5 different WESTs, the ones classified as PL comprise 6 different WESTs and the ones classified as MR comprise 4 WESTs.

The wildfire in 2003 created a blank, which is now dominated by shrubs, herbs and grass. Artificial regeneration of deciduous trees has been planted on the eastern part of the blank, but it is not taken into account, as it is still very small – only 1 WEST was identified.

Table 25: Percentages of WESTs which contribute to each FMC (100%).

Keywords	**WEST in TH**	**Share of WEST**
Thicket	**093**	34%
Pole stand like regeneration under mature trees	**124**	18%
Thicket-like regeneration under mature trees	**123**	16%
Regeneration under mature trees	**121**	16%
Idle grassland	**022**	16%
	WEST in PL	
Pole stand, rich in ground vegetation	**102**	44%
Pole stand, poor in ground vegetation	**101**	17%
Idle grassland	**022**	12%
High forest, rich in ground vegetation	**132**	10%
Pole stand, regeneration in gaps	**103**	9%
High forest, poor in ground vegetation	**131**	8%
	WEST in MR	
High forest, rich in ground vegetation	**132**	42%
Mature stand, rich in ground vegetation	**112**	30%
Idle grassland	**022**	15%
Mature stand, poor in ground vegetation	**111**	13%
	WEST in BL	
Idle grassland	**022**	100%

5.2.3 Comparing the Situations Pre-fire and Post-fire

At this point of the study, fuel types and WESTs are used to describe the forest stand structures of the different FMCs. Therefore the FMC-maps – as output of the forest inventory – can be used to link the FMCs to the fuel types and to the WESTs. Using the FMC-map of 2004, the post-fire and post-blowdown situation is represented. The pre-fire and pre-blowdown situation can be replicated by using the FMC-map of 1998. Insofar, the procedure of comparing the changes of fuel types and WESTs is done only for the area of the blank (32,26 ha).

5.2.3.1 Shift of Fuel Types on the Blank

Post-fire, the blank is characterized as 100% fuel type TU1. Before the disturbances, the area was composed of the fuel types PiL (78,53%) and PiM (21,47%).

In consequence of the wildfire, fuel structures contributing to the moderate fuel type were replaced. There was a shift from the fuel type PiM and PiL to the fuel type TU1. The fire behaviour of TU1 is described as having low spread rates and low flame lengths (SCOTT et BURGAN, 2005, p. 11). The extent in ha for each fuel type is shown in table 26.

Table 26: Post-fire and pre-fire fuel types [ha; %] on the area of the blank (32,26 ha).

Post-fire	**PiL**	**PiM**	**TU1**
Fuel type [ha]	**-**	-	**32,26**
Fuel type [%]	**-**	-	**100**
Pre-fire			
Fuel type [ha]	25,33	6,93	-
Fuel type [%]	78,53	21,47	-

5.2.3.2 Shift of Wildlife Ecological Stand Types

Post-fire, the blank represents a grass-shrub-habitat, which is related to the WEST type 022 on the full extent of the blank.

Before the wildfire (table 27), the area of the blank was dominated by mature stands: 37,29% multilayered high forest stands rich in ground vegetation (WEST 132), 26,44% mature stands rich in ground vegetation (WEST 112) and 10,85% mature stands poor in ground vegetation (WEST 111). 10,69% of the area were composed of WEST categories describing thicket stands and pole stands. The share of the WEST 022 idle grassland, which contributes to each FMC with 12%-16% (table 25) covered 14,72% of the area before the wildfire. In terms of calculations this WEST was not lost in the wildfire, or shifted to another WEST. It is now idle grassland, as it was before, but, it was also burned and therefore changed – especially in its context.

So, actually the whole area of the blank was altered by the wildfire, calculated 85,28% of the area definitely changed from different WESTs to the WEST 022 idle grassland – which gained 27,51 ha.

Table 27: Post-fire and pre-fire WESTs [ha; %] on the area of the blank (32,26 ha).

Post-fire	**132**	**112**	**22**	**111**	**102**	**93**	**101**	**124**	**121**	**123**	**103**	**131**
WEST [ha]			**32,26**									
WEST [%]			**100**									
Pre-fire												
WEST [ha]	12,03	8,53	4,75	3,5	0,93	0,71	0,37	0,38	0,34	0,34	0,2	0,18
WEST [%]	37,29	26,44	14,72	10,85	2,88	2,2	1,15	1,18	1,05	1,05	0,62	0,56

5.2.3.3 Change in Habitat Suitability for *Capreolus capreolus*

With the knowledge about which WESTs were changed in the area of the blank, the change in habitat properties describing the quality of the WESTs can be estimated as well. Table 28 shows the WEST composition and the habitat properties on the area of the blank prior to the fire. The properties: Food, mobility, thermal cover and hiding shelter, can be drawn out of the fuel analysis and refer to general habitat resources. The differentiation between summer and winter mainly results from the factor snow, as it influences the availability of other resources. The validation (referring to REIMOSER, 1986, p. 166 ff) of the properties in the WESTs is:

“+” meaning comparatively high;

“-” meaning comparatively low;

“o” meaning comparatively indifferent.

The reference of the properties to the habitat structures is explained in the following (REIMOSER, 1986, p. 171). Note that only the positive aspects are demonstrated, converse the statements when validated as comparatively low or indifferent.

Food +	More than 50% of the area is covered with ground vegetation.
Mobility +	Mobility is not limited by dense vegetation or snow-related aspects.
Hiding shelter +	Vegetation may not be too dense to restrict escaping and view range but it needs to be dense enough to give shelter.
Thermal cover +	Due to vegetation structures like canopy cover a relative stable microclimate can develop. In winter, snow covers do not build up so high and in summer, rain interception and shading is high. The microclimate is important referring to thermal shelter. Vegetation structures provide cover against wind, rain and sun.
Lodge +	Forest stands which unite several suitable habitat properties such as: A stable microclimate, no mobility restrictions, sufficient view range, areas to rest with thermal cover and hiding shelter.

The shares of the WESTs in the area of the blank, as well as the percentages of comparatively high, comparatively low, or indifferent valued habitat properties for *Capreolus capreolus* are summed up in table 28. Based on the valuation, 36% of the area are estimated to have been well suitable and 39% are valued indifferent for *Capreolus capreolus*. So, the habitat situation was suitable well enough on the great part of the area before the wildfire. Especially the availability of food resources in summer and winter as well as mobility, thermal cover and lodge are estimated to have been in favour of *Capreolus capreolus*. The hiding shelter possibilities however, are estimated to have been rather mediocre.

Table 28: WESTs on the blank (32,26 ha) prior to the wildfire in 2003 and valuation of habitat properties for Capreolus capreolus.

Pre-fire	**WEST Valuation of habitat properties [%] *Capreolus capreolus***												**Total share within the area [%]**		
Share of the area [%]	**022**	**093**	**101**	**102**	**103**	**111**	**112**	**121**	**123**	**124**	**131**	**132**	**+**	**o**	**-**
	15	2	1	3	1	11	26	1	1	1	1	37	36	39	25
Food															
summer	+	-	-	+	+	o	+	o	-	-	-	+	82	12	6
winter	o	-	-	+	+	-	+	o	-	-	-	+	67	16	17
Mobility															
snow	-	-	+	o	-	+	o	-	-	o	+	+	50	30	20
vegetation	+	-	+	o	-	+	+	-	-	o	+	-	54	4	42
Hiding shelter															
summer	o	+	+	o	+	o	-	+	+	+	+	o	8	66	26
winter	-	+	+	o	+	o	-	+	+	+	+	o	8	51	41
Thermal cover															
summer	-	+	+	o	o	+	+	+	+	+	+	o	44	41	15
winter	-	o	+	o	o	+	o	o	o	+	+	o	14	71	15
Lodge	-	-	+	o	-	+	+	o	-	+	+	o	40	41	19

Compared to the WEST valuation prior to the fire, the current situation is assessed quite different. The change in habitat suitability due to the disturbances is shown in figure 18. The columns show the increase and decrease of area size providing the valued habitat properties. The area in which food resources are available in summer increased on about 6 ha. Unlike the food availability in winter, which decreased on about 16 ha. The area in which hiding shelter is provided increased (6 ha), however this is only valid for summer or autumn, when the shrubs on the blank have grown big enough. This also applies to the suitability of hiding shelter in summer (increase of 6 ha). For the winter time the hiding shelter decreased (19 ha). The ability of unrestricted mobility due to vegetation increased on about 14 ha, as dense branches from regeneration were burned in the wildfire. In winter however, mobility is restricted (26 ha) due to high snow covers. The estimated area on which thermal cover in summer and winter is suitable for *Capreolus capreolus* decreased after the wildfire on the entire burned area.

The change of habitat suitability for *Capreolus capreolus* can be summarized as a decrease on 85% and an increase on 15% of the area. Currently, there is the WEST 022 idle grassland only on the blank, and its overall value for *Capreolus capreolus* is not favourable on 60%, comparatively good on 20%, and mediocre on 20% of the area.

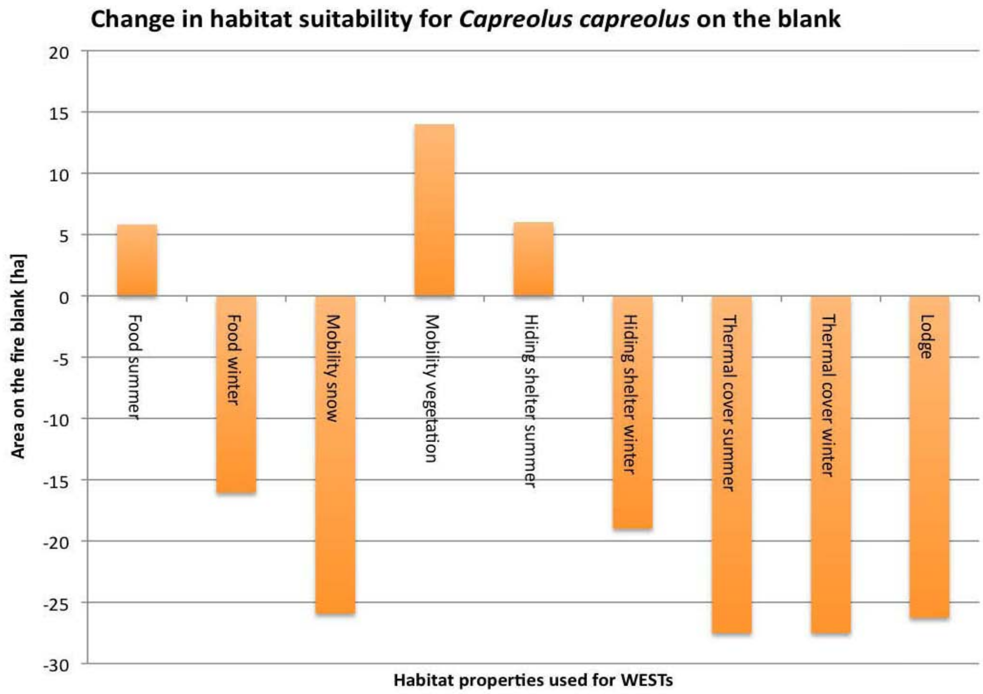


Figure 18: Change in habitat suitability for Capreolus capreolus due to the change in WESTs on the blank.

Table 29 shows the habitat suitability (sum of the habitat properties valued: “+”, “-” and “o”) of the forest stands according to the inventory map, in which the fuel sampling was conducted. This area comprises 99,29 ha and has a share of 11,31% BL, 17,79% TH, 49,67% PL and 21,23% MR. In total 29,41% of the area can provide comparatively well suitable habitat properties. Except for TH the unsuitable habitat properties are outnumbered. On the other hand the great part of the area (42,01%) is valued neither suitable nor unsuitable.

Table 29: Habitat suitability for Capreolus capreolus in the sampled forest stands.

Capreolus capreolus Habitat suitability	**+** [%]	**o** [%]	**-** [%]	**Share of FMC** [%]	[ha]
TH	33,80	19,80	46,40	17,79	17,66
PL	29,00	54,20	16,80	49,67	49,32
MR	31,70	43,80	24,50	21,23	21,08
BL	20,00	60,00	20,00	11,31	11,23
∑ of suitability in the sampled forest stands	29,41	42,01	28,59	100,00	99,29

5.2.3.4 Change in Habitat Suitability for *Tetrao urogallus*

In order to analyse the change in habitat properties due to the wildfire for *Tetrao urogallus*, the same procedure as for *Capreolus capreolus* is conducted in the following.

The habitat properties are slightly modified for *Tetrao urogallus*, referring to the valuation done by SCHATZ (1992, p. 55): Food, mobility, thermal cover, hiding shelter, accessibility and lodge, can be drawn out of the fuel analysis and refer to general habitat resources. The differentiation between summer and winter mainly results from the factor snow, as it influences the availability of other resources. The validation of the properties in the WESTs is:

"+" meaning comparatively high;

"-" meaning comparatively low;

"o" meaning comparatively indifferent.

The reference of the properties to the habitat structures is explained in the following (REIMOSER, 1986, p. 171 and SCHATZ, 1992, p. 55). Note that only the positive aspects are demonstrated, converse the statements when validated as comparatively low or indifferent.

Food +	More than 50% of the area is covered with ground vegetation. Coniferous needles (especially from *Pinus* species) are provided in winter by mature trees.

Mobility +	Mobility is not limited by dense vegetation on the ground, when moving on foot, or by dense branches when moving in the air (flying aisles).
Hiding shelter +	Vegetation may not be too high to restrict the view range, or too dense to restrict escaping but it needs to be dense enough to give shelter.
Thermal cover +	Vegetation structures provide cover against wind, rain and sun. (Suitable snow conditions for roosting caves, are not considered).
Accessibility +	Forest stands can be entered easily , without vegetation-barriers. Securely moving form one habitat patch to the other is enabled.
Lodge +	Forest stands which unite several suitable habitat properties such as: A stable microclimate, no mobility restrictions, sufficient view range, areas to rest and sleep with thermal cover and hiding shelter.

As for *Capreolus capreolus,* the shares of the WESTs in the area of the blank, as well as the percentages of comparatively high, comparatively low or indifferent valued habitat properties for *Tetrao urogallus* are summed up (table 30). The habitat properties: Mobility due to snow cover and snow cover quality are excluded in this analysis. The aspect that the snow cover quality has the greatest impact on the ability to create snow barrens was considered. However dismissed, as the assessed slope is south oriented and fully exposed to sunshine, and it is presumed that the snow conditions do not allow the creation of snow barrens on the first place. The WEST evaluation for *Tetrao urogallus* additionally includes the air space and the general accessibility of the WESTs as mobility-aspects. Based on the assessment, 24% of the area are estimated to have been inadequate and 19% are valued indifferent for *Tetrao urogallus*.

The great part of the area is estimated to have been comparatively well suitable (57%) for *Tetrao urogallus* prior to the wildfire. The share of the areas which are estimated to have been mostly unsuitable, are predominant for the habitat properties: Mobility in the air and on the ground.

Table 30: WESTs on the blank (32,26 ha) prior to the wildfire in 2003 and valuation of habitat properties for Tetrao urogallus.

Pre-fire	**WEST Valuation of habitat properties [%] *Tetrao urogallus***												**Total share within the area [%]**		
Share of the area [%]	**022**	**093**	**101**	**102**	**103**	**111**	**112**	**121**	**123**	**124**	**131**	**132**	**+**	**o**	**-**
	15	2	1	3	1	11	26	1	1	1	1	37	57	19	24
Food															
summer	+	-	-	-	+	-	+	+	+	+	-	+	82	0	18
winter	-	-	-	-	+	o	+	+	+	+	-	+	67	11	22
Mobility															
air	+	-	-	-	-	o	+	+	+	o	-	-	43	12	45
ground	o	-	-	o	o	+	+	o	-	o	-	-	37	21	42
Hiding shelter															
flight	-	+	+	+	-	+	+	-	+	+	+	+	83	0	17
ground	-	+	+	+	o	o	o	o	o	+	+	+	45	40	15
Thermal cover															
summer	-	+	+	+	-	+	o	o	o	+	+	+	56	28	16
winter	-	-	o	+	-	+	o	o	o	o	+	+	52	30	18
Access	+	-	-	o	o	+	+	+	+	+	-	-	55	4	41
Lodge	-	-	-	o	o	o	+	o	o	+	-	+	64	17	19

Compared to the WEST valuation prior to the fire, the current situation is assessed quite different. The change in habitat suitability due to the disturbances is shown in figure 19. The columns show the increase and decrease of area size with the valued habitat properties. The estimated area in which the habitat properties are valued in favour of *Tetrao urogallus* partially decreased completely. Mobility and accessibility are the main habitat properties, which improved after the wildfire. The area providing food resources in summer also increased (5,69 ha).

Summarizing, it can be stated that the habitat suitability for *Tetrao urogallus* decreased on 80% of the area, whereas it increased on 20%.

Currently, there is the WEST 022 idle grassland only on the blank and its overall value for *Tetrao urogallus* is not favourable on 60%, comparatively good on 30%, and mediocre on 10% of the area.

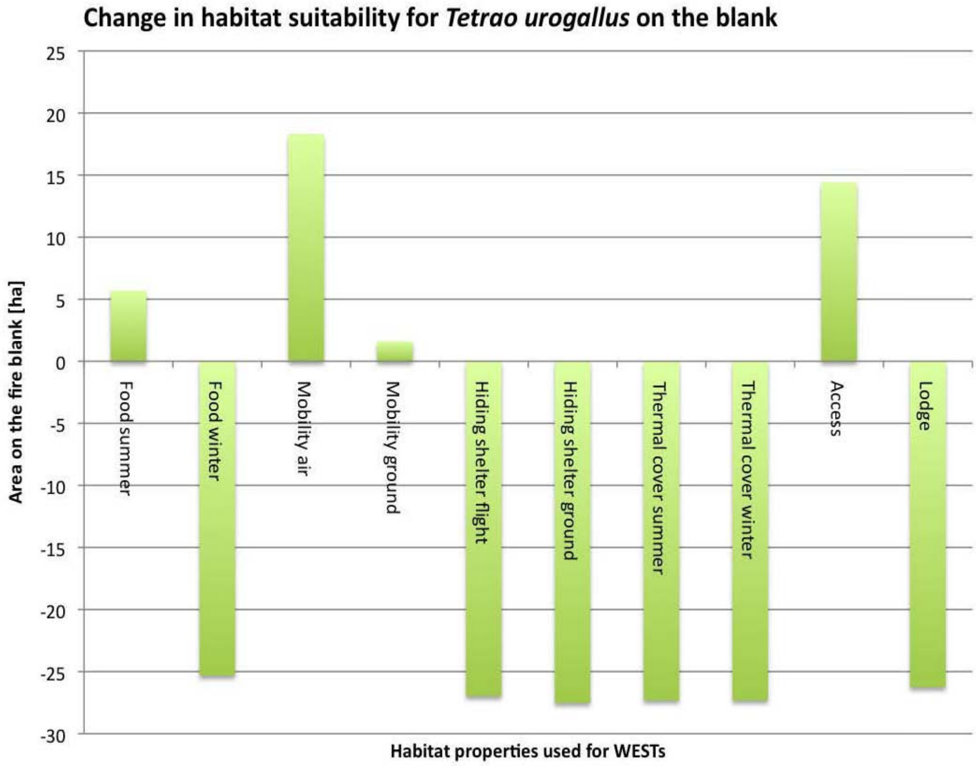


Figure 19: Change in habitat suitability for Tetrao urogallus due to change in WESTs on the blank.

In addition, table 31 shows the habitat suitability (sum of the habitat properties) of all of the forest stands, according to the inventory map in which the fuel sampling was conducted (99,29 ha). As MR are clearly suitable (63,00% "+") for Tetrao urogallus, TH provide nearly equal shares for suitable (39,73%) and unsuitable (38,53%) areas. PL and the blank comprise the biggest shares of unsuitable areas (44,57% and 60%). In total the unsuitable area has a share of 41,25%. The share of areas valued as neither suitable nor unsuitable comprises 19,84%. Areas providing habitat properties valued as well suitable make up 38,91% of the regarded forest stands.

Table 31: Habitat suitability for Tetrao urogallus in all sampled forest stands.

Tetrao urogallus Habitat suitability [%]	**+** [%]	**o** [%]	**-** [%]	**Share of FMC** [%]	[ha]
TH	39,73	21,75	38,53	17,79	17,66
PL	30,34	25,10	44,57	49,67	49,32
MR	63,00	11,20	25,80	21,23	21,08
BL	30,00	10,00	60,00	11,31	11,23
∑ of suitability in the sampled forest stands	38,91	19,84	41,25	100,00	99,29

6 Discussion

6.1 Wildfire Research in Austria

The discussion is opened with the commonly accepted statement that Austria has no real fire ecosystems. However, the introducing tables (2 and 3) presented in this study, show numerous wildfire events. Indeed, most wildfires are very small in size, but this is most probably the result of the profound fire fighting tradition in Austria – the density of fire fighting stations is uniquely high (EFFIS, 2004, p. 18). Under this condition it is very difficult for a wildfire to fully develop. However, GOSSOW et FRANK (2003, p. 8) mention 2 isolated canyons in southern Austria, where it obviously burns from time to time. This example shows that forests in Austria might not be part of a fire ecosystem but they are at least more or less fire susceptible. The predisposition – that there are already “fire hot spots” in Austria – is thought-provoking since the fire susceptibility of forests is tendentiously rising due to climatic conditions (GOSSOW, 2004, s.p.). Climate change is said to heavily effect the alpine region (IPCC, 2007, s.p.).

Especially in the context of global warming, extreme meteorological events are predicted to increase. At the study site, – nearby it has already burned repeatedly – the risk of wildfires is also enhanced due to decreasing precipitation, hotter summers, more wind- and thunderstorms (RUDOLF-MIKLAU, 2009, p. 30), or extreme annual fluctuations of cold, wet and hot, dry conditions: An increasing climate variability, in other words. With the increase of thunderstorms, it is to be mentioned, that in 2003 the phenomenon of “dry lightning” could be observed in some Alpine regions, a type of thunderstorm increasing wildfires, because there are no heavy rainfalls (CONEDERA et al., 2008).

Maybe Bad Bleiberg is a nice example for what can happen when the weather varies from the usual conditions and incidences overlap – recalling the happenings: A storm caused a windthrow in November. The wildfire in the following March started in that windthrow. The source of ignition was carelessness. Now, in terms of forest management, carelessness – as cause of fire outbreak – may not be discounted to being a coincidence or even be excused for not being ecological. Because "...people are the overwhelming cause of fires in every region, for a wide range of seasons." (FAO, 2007, p. v)

SPLECHTNA et GRATZER (2005, p. 57 f) for instance, state that disturbances interact with each other. The severity of an ecological disturbance is reinforced and its predictability reduced by the interaction of disturbances (AULD et al., 2009, p.81). Besides, in central Europe, windthrows play an essential role in the dynamics of forest ecosystems and are described as a forestry problem since the last century (HETZEL, 1998, p. 1). The increase of storm and snowbreakage events means an increase in potential fuel (GOSSOW et FRANK, 2003, p. 9). From this point of view, the fire susceptibility of the study site might increase dramatically. The risk will also increase at other fire hot spots in Austria and critical areas not yet conspicuous. Fire susceptible areas to be mentioned especially in Carinthia, which is influenced by the continental and mediterranean climate, are: South-oriented slopes with *Pinus* or *Larix* stands, or windthrows and clear cuttings with a high load of fuel (GOSSOW et FRANK, 2003, p. 8).

Additionally, fuel build up will be enhanced by increased productivity during wet years – high moisture contents minimize fire outbreak. During dry years, fuel build up of vegetation, is limited because of water stress at lower elevations. At higher elevations, an increase in fuel build up was detected – no water stress here, more snow free days, lengthening the growing season. Consequentially, the high productivity leads to an increase in fire susceptibility at low and high elevations. (JOLLY et al., 2005, p. 4)

Sticking to the thought about an increase in drought periods, tree mortality could reach serious levels. Recent forest dieback occurred all over the globe in different climatic zones – worth mentioning is the dieback of *Pinus sylvestris* forests in the Swiss Alps. However, tree mortality mostly involves many factors like: heat stress, water stress, insect pests and diseases. (ALLEN, 2009, s. p.)

Again the interaction of disturbance-factors is obvious.

The changes discussed have effects on wildlife: fluctuations in food supply and unstable habitat resources – thinking of the *Pinus sylvestris* dieback, resulting in a total loss of potential habitat for *Tetrao urogallus* – to give an example for an increasing unpredictability of habitat quality and sustainability (GOSSOW, 2011, s.p.).

Global statements about climate change cannot be simply applied to a small study site. Especially because the local climatic conditions resulting from, for instance seeps, concave pockets, or cold air drainages play a major role in fire susceptibility and fire behaviour (NORTH, et al., 2010, p. 31).

Nevertheless, fuel analysis might become advantageous when managing forests and with that being prepared also for a fire outbreak and its consequences – admitting that the concept of fuel analysis and fuel management is still unfamiliar in Austria. In former times, this approach of fuel management was not needed, as a “clean forestry” was practiced, avoiding fuel accumulations and subsequent fire danger. Promoted by nature conservationists, there now is a trend towards a forestry practice, which aims at enhancing the structural diversity by not harvesting dead standing and laying trees and other downed woody material. This biomass remains in the forests and contributes to more sustainable and natural forests. At the same time however, this accumulation of dead wood also contributes to a rapid increase in fuel load. In this conflictive situation it is indispensable to question how much dead wood is acceptable in view of a raising fire susceptibility (GOSSOW, 2011, s.p.). With good cause, the Food and Agricultural Organisation states in its fire management assessment, that “fire management is an essential part of sustainable forest management” (FAO, 2007, p. v). Because forest management is practiced for many generations, the basis for forest management including fire management has to be planned today, to prepare the forests for tomorrow – this definitely justifies the ambitions of the AFFRI project.

6.2 Fuel Sampling Method

In correspondence to the Swiss researchers HARVEY et al. (1997), it seemed necessary to adopt the American fuel sampling methods (US Forest Service) to achieve sufficient fuel descriptions for alpine regions. However the fuel models for Switzerland (HARVEY et al., 1997, s.p.) were further developed to best serve the needs of the AFFRI. Because the study site in Bad Bleiberg is a reference site for wildfire research in Austria, the data sampling was designed to be very extensive. As a matter of principle, the fuel data should be compatible with Austrian forestry data for further data processing. Thus, some properties, which were sampled, were not used for this thesis, but serve as data basis for the AFFRI.

At first, the fuel sampling was structured following the forest management classes (FMCs) of the mainly *Pinus sylvestris* dominated stands of the forest in Bad Bleiberg. This approach was also followed in the related study on central European Scots pine stands by HILLE et DEN OUDEN (2005, p. 154). With that, it is possible to compare the fuel loads of this study with the results of their findings (chapter 6.3.3 Fuel Load) .

A difference of the fuel sampling in this study can be found in the thorough sampling of tree species and surface vegetation species. It is commonly known, that the different species have different combustion characteristics for instance, due to cellulose density, oils, resins or life cycle. So, *Pinus* species have “'explosive' burning characteristics” (HARVEY et al., 1997, p. 2) and also *Rubus* species (like Blackberries, Raspberries) are very fire susceptible (KÖNIG, 1996, p. 47). In addition, a relation of ground vegetation species and duff moisture content is suggested by HILLE et DEN OUDEN (2005, p. 157) to describe fire susceptibility. It was shown that duff samples beneath *Avenella flexuosa* (Wavy Hairgrass) are significantly drier than samples beneath *Erica tetralix* (cross-leaved heath). These aspects were not jet worked on in this paper, but could be considered in future research.

Moreover, there are some differences concerning the tree sampling. As it is common to sample trees smaller than 2 m (HARVEY et al., 1997, p. 6) or 3 m (BROWN et al., 1982, p. 2), to take ladder fuels into account, bigger trees or mature trees are often only included by sampling their crown base height (branches up to 2 m height). This sampling is done on an area of about 13 m^2 (BROWN, et al., 1982, p. 2 and HARVEY et al., 1997, p. 6). In the case of this study, the small trees (DBH <10 cm and height <2 m) are sampled on all 8 subplots, which comprise 25 m^2. In addition, all mature trees in a macroplot are sampled (height, DBH, CBH, crown class, vitality and species). This enables further research on crowning of surface fires and other crown fire related aspects. The slope correction factor is applied to each macroplot directly during sampling, so the area sizes are between 650 m^2 and 1225 m^2. TANSKANEN et al. (2007, p. 415) chose a similar scale, but the plot size was mainly designed for experimental burning. At this point the influence of the forest inventory method for estimating fuel loads is evident in the design of the Austrian fuel sampling. It was the aim to draw a complete picture of the stand composition, for further research and modelling.

The canopy cover and the cover of shrubs, grass and soil was estimated on each macroplot, to give a general impression of the vegetation density and stand homogeneity. In addition, also the cover types of each subplot were estimated, refining the plot information.

Also fuel was sampled at a very fine scale, by differentiating size and particles. The fuel load is collected in 2 squares (0,50 m^2), which lie on 2 random subplots. HARVEY et al. (1997, p. 3) suggest a slightly bigger area (0,60 m^2) and the location of the sampling plots is fixed. Another approach is given by HILLE et DEN OUDEN (2005, p.154): 8 samples of 0,70 m^2 (5,68 m^2) litter and duff are collected. The comparison of the fuel loads estimated in this study with other studies is rather difficult. In addition to the destructive sampling on every 4th subplot, a nondestructive sampling was done. Referring to BROWN (1974) the planar intersect method was used to estimate the downed woody material. The results of the downed woody material loads of the two sampling methods were compared.

The calculations of the downed woody material load along transects delivered a multifold amount per ha (especially for the bigger fuels) compared to the fuel load of downed woody material on the subplots. Moreover, the ranking of fuel load per FMC changed. Referring to SIKKINK et KEANE (2008, p. 370) – who tested the performance of 5 fuel sampling techniques against a reference sampling method, on which the fuel was clipped – the results of the planar intersect come very close to the clipping sample of the fine fuels (<0,6-7,5 cm). The planar intersect is rated as best method for estimating the fuel load of poles (fuel >7,5 cm diameter). As no poles were sampled on the subplots (because they could not be clipped), there is no comparison of the two methods for that fuel size class in this study. Further on, SIKKINK et KEANE (2008, p. 367) mention, that the appropriate wood density value is an important input for the fuel load calculations of the planar intersect. However it was not possible to determine the specific gravity for the fuels collected at the study site. For that reason the average and composite values suggested by BROWN (1974, p. 15 ff) were used.

6.3 Fuel Analysis

6.3.1 Forest Stand Characteristics

The amount of sampled seedlings is very low. Only 4 seedlings were counted on the macroplots at the study site. It is presumed, that the grassy vegetation is too dense for the seeds to germinate, or for the seedlings to develop. The determination of the HUFNAGL-Types showed the predominance of the *Erica-type* and the *Seslerium* – both of which develop very dense ground covers. Especially *Camalagrostis* species, which were as well sampled at the study site, are notorious in preventing *Picea abies* from regenerating successfully (OTTO, 1994, p. 359). But also the duff layer is stated to have a major influence on germination success: Referring to CHROSCIEWICZ (1970, p. 3) the complete consumption of humus by a fire improved seedbed quality and the establishment of seedlings (*Pinus banksiana*, Jack Pine). Since also *Pinus sylvestris* definitely is a pioneer species, open mineral soil supports germination (WALENTOWSKI et al., 2007, p. 38).

KEELEY et ZEDLER (1998, p. 236) describe *Pinus* (especially in mixed stands) as being adapted to "... catching disturbance-generated waves and riding them..." having the ability of rapid growth and to exploit open conditions, staying ahead of shade tolerant species. Having this in mind, and the dense ground cover mentioned above, only few patches remain for successful regeneration – not considering wildlife foraging on seedlings. Just to give a relation, about 400 saplings per ha were planted on parts of the blank during the afforestation measures in 2004 and 2005 (HONSIG-ERLENBURG et MORITZ, 2004, p. 23).

The highest density of regeneration counted at the study site is that of *Picea abies* followed by *Pinus sylvestris*. In plots classified as thicket (TH), about 10% of the regeneration is *Pinus sylvestris* and 90% *Picea abies*, although 60% of the mature trees are *Pinus sylvestris* and only 40% are *Picea abies.* A similar situation is found on plots classified as pole stands (PL), which have the highest density of regeneration. In plots classified as mature stands (MR) the regeneration is nearly equally distributed between *Pinus sylvestris* and *Picea abies,* although about 70% of the mature trees are *Pinus sylvestris.* This might indicate a change in tree species composition from *Pinus sylvestris* dominated to *Picea abies* dominated stands. Possible reasons are given by WALENTOWSKI et al. (2007, p. 43), who predict the increase of soil quality due to a change in forest practice since the 20th century and due to the increase of nitrogen input from the air – *Picea abies* will dominate over *Pinus sylvestris* on better soils (WALENTOWSKI et al., 2007, p. 43). Besides, also HILLE et DEN OUDEN (2005, p. 158) hypothesise a major impact due to high nitrogen inputs, by changing the ground vegetation species and therefore influencing duff moisture contents. LEXER (2009, p. 237) summarizes the situation of forest ecosystems as follows: In addition to the nitrogen inputs, also the increased CO_2 concentration in the atmosphere has a fertilizing effect. In combination with the now practiced more sustainable silviculture and the increasing vegetation periods, the productivity of forests has been rising since the 1980^{ies}.

As indicated by the HUFNAGL-Types, the water and nutrient situation is rather poor. In addition, the determination of the site index showed that the stands are of low productivity. The *Picea abies* dominated stands are generally classified a bit better than the *Pinus sylvestris* stands and in TH the site index is more favourable compared to the other FMCs. However the poor growing conditions are typical for south oriented steep karst slopes. This enhances the trees' susceptibility for diseases, insect pests and finally fire (DESPREZ-LOUSTAU et al., 2005, p. 3). The possibly ongoing change in tree species composition is most likely linked to a change in fire susceptibility and of fire behaviour as well.

6.3.2 Moisture Content

Referring to GORTE (2009, p. 2), fuels are burnable, when moisture content is not higher than 20-30%. Certain resins or oils (depending on species) might allow ignition at higher moisture content levels (WHELAN, 1995, p. 27). For the study site, this means that about 20% of all sampled fuels were in a burnable condition during sampling: Only 12% in TH, 29% in PL and 13% in MR were classified as “critical fuels”, as they could have supported the ignition of a wildfire. BURGAN et ROTHERMEL (1984, p. 46) mention the dead fuel moisture of extinction, which is the average moisture content of dead fuel, above which the fire can no longer spread uniformly. With that, burnable fuels need to have a moisture content below the moisture of extinction. The moisture of extinction was not calculated in this thesis, as the fuel depth was not sampled or calculated. TANSKANEN et al. (2007, p. 420) state that the spread rate, in “15–45-year-old *Pinus* stands”, is highest at 7-11% moisture content and that a plus of moisture content above 17% does not further reduce fire spread rates.

Small changes in moisture content between the range of 50% - 120% are said to heavily effect the humus consumed during a fire. This points out the range of spatial and temporal variations in humus moisture content, leading to variations in humus consumed, differences in overstory mortality, and post-fire succession. (HILLE et DEN OUDEN, 2005, p. 157)

6.3.3 Fuel Load

Note that it is very difficult to reasonably compare fuel loadings, as the sampling methods do not allow a direct comparison of the results. Nevertheless a rough discussion of other study-results can be given.

In the study by HARVEY et al. (1997, p. 38) the estimated fuel load for "cultivated conifer forests" in Switzerland is about 2,3 times higher (9740 kg/ha), compared to the average fuel loads in Bad Bleiberg (4316 kg/ha). The fuels <0,6 cm are predominant (96%) in the Swiss model, all other fuels are marginal (HARVEY et al. 1997, p. 38). The distribution of the estimated fuel loads in Bad Bleiberg is around 57% for fuels <0,6 cm. The fuels between 0,6 -2,5 cm have a share of 46% in TH, 33% in PL and 35% in MR. Further on there is no fuel sized 2,5-7,5 cm or live herbaceous fuel loading given for the compared model in HARVEY et. al. (1997, p. 38). A study of *Pinus sylvestris* and *Picea abies* stands in Finland (TANSKANEN et al., 2007, p. 418) presents downed woody material estimates of 890 kg/ha in sparse semi-mature *Pinus sylvestris* stands. Comparing that result to the downed woody material of sparse PL in Bad Bleiberg (3846 kg/ha), the amount is 4,3 times higher on average. On the other hand, the average amount of fuel load for *Pinus sylvestris* stands, independently of stand age, given by HILLE et DEN OUDEN (2005, p. 155) is 3,9 times higher – fuel loads around 15000 kg/ha, ranging between 8000-23000 kg/ha. Further, HILLE et DEN OUDEN (2005, p. 155) state that the humus load increases with stand age. This relation was not found in the case study of Bad Bleiberg, but also the humus load of 9300-18500 kg/ha at the study site is less compared to 18000-44000 kg/ha from the cited study. In SCOTT et BURGAN (2002, p. 18) the timber litter fuel models range from 500 kg/ha to 16000 kg/ha in the smallest fuel size class (1700-2400 kg/ha in Bad Bleiberg), from 400 kg/ha to 10000 kg/ha in the second fuel size class (1600-2000 kg/ha in Bad Bleiberg), and from 0 to 20000 kg/ha in the third fuel size class (15-500 kg/ha in Bad Bleiberg). Living herbaceous vegetation reaches loads of 1600 kg/ha (460 kg/ha in Bad Bleiberg). The fuels <0,6 cm are not necessarily predominant in these models, unlike in Bad Bleiberg. This again shows how broadly the fuel loads can vary, depending on species composition, topographic aspects, and forestry practice and ecosystem (site-)productivity, determining how much fuel is accumulated.

6.4 Wildlife Ecological Stand Types and Pellet Findings

The WEST concept was used at a very basic level in this study. In contrast to habitat related studies, implementing WEST (REIMOSER 1986 and SCHATZ, 1992 and PARTL, 2001 and REIMOSER et al., 2003, 2009), no habitat modelling was done. The WEST as a habitat evaluation tool is strongly influenced by the idea of the habitat suitability for *Capreolus capreolus*. With that the WEST is no typical habitat specific approach. In order to avoid that aspect, habitat types according to a predefined typology, would have had to be generated (BASSI, p. 28). Anyway, it was not the aim of this study to develop a new habitat model, but to apply the fuel data to an existing habitat type classification. The WEST was assessed for each plot after field work, out of the fuel data, on basis of the main vegetation structures.

As the WESTs are related to the FMCs, the predominant WEST of each FMC refers to the FMC itself. Roughly speaking the option is to classify a FMC as densely or sparsely stocked and as single- or multilayered. What strongly influences the composition of the FMCs in Bad Bleiberg is the generally sparse and overaged forest, creating canopy free patches and multilayered stands. This is the reason why the WEST “022 idle grassland” appears in every FMC as well as the multilayered-WESTs. In plots classified as TH half of the area is described as regeneration under a mature stand, indicating that it was difficult to find a typical dense thicket stand at the study site.

Although the WEST classification was restricted to the aspects of vegetation structures, a complete habitat evaluation can be developed out of the WEST-fuel data. The fuel data comprises much more information than can be seen in the determined fuel types. Therefore it is necessary to check the raw data before it is aggregated – data like snags, dead logs and stage of decay, CBH, wind breakage, to name some. Climate information is available at meteorological stations. The climatic information was kept in mind for this study, and generalized as favourable: south oriented, fully exposed to sunshine and moderate snow accumulations. Vegetation structure information and slope degree, aspect and elevation are drawn out of the fuel data. Geology and detailed topographic information is found in maps and aerial photos or digital models. It would be especially useful to import topographic information to gain accuracy – hiding shelter might increase due to the diversity of concave and convex micro-relief (REIMOSER et al., 2006, p. 44) as discovered during data sampling. Aside of this, also features such as view ranges, edges and anthropogenic disturbances are missing in the actual study. It would have been especially interesting to take the edges more into account – than just measuring the length – because boundaries between different vegetation stand types can attract wildlife species (LEOPOLD, 1933, s.p.). This is the case, because wildlife seldom finds all needed habitat resources in one stand type (OTTO, p. 246), and boundaries comprise resources of the adjacent habitats. It would have needed more methodological thought about how to grasp the edge structures, the boundaries and their relationship to the blank. Probably the data available for this study is not appropriate to investigate the edge effect, mostly because the distance of the transects to the forest road was too big, or because the edges run vertical to the transects and the intersections are too small.

To check which game species are present on the blank and the adjacent forest stands, the pellet sampling was done. The pellets counted mainly give information about the winter habitat use of the recorded species. REIMOSER (1986, p. 128) assumes that the average timespan, in which pellets can still be identified, is 2 years for pellets dropped in winter and 1 year for pellets dropped in summer. It has to be recognized that the pellet findings cannot be automatically related only to the winter or early spring habitat. Nevertheless it is now firstly documented which game species were present on the blank and its neighbouring stands. On a total transect length of 6141 m, pellets of 5 different game species were found approximately every 15 meters. Worth mentioning are the numerous pellet findings of *Tetrao urogallus* in thicket stands, for this species is said to need old sparse coniferous stands and is very sensitive concerning disturbances (e.g.: ZEILER, 2001, s.p. or MILLER, 2008, p. 80) – although old-growth forests intermixed with patches of early successional stages following a windthrow, snowbreak and/or fire are dealt with as primary habitat (STORCH, 2000, p. 47). Hence, the structures of the young stands at the study site must be more or less suitable for *Tetrao urogallus* (STORCH, 2000, p. 47).

Most pellets (all species) were found in thicket stands – 12,8 pellet findings per 100 m^2. In the study of REIMOSER (1986, p. 142), approximately the same amount of *Capreolus capreolus* pellets were found in thicket stands. However, in the other FMCs, the pellet amounts differ: 33,4 pellets per 100 m^2 in pole stands and 29,4 pellets per 100 m^2 in mature stands (REIMOSER, 1986, p. 142). In this study only 7,6 pellet findings per 100 m^2 were estimated in pole stands and 7,5 pellet findings per 100 m^2 in mature stands. On the blank 5,1 pellet findings per 100 m^2 were estimated. Obviously, in the centre of the blank, pellets were extremely sparse or missing. It could be speculated, that the differences in pellet findings are related to the steepness of the slope, the vegetation cover, the exposure of the pellets to climate – enhancing decay and not being detected (REIMOSER, 1986, p. 129 f). Yet this might explain the differences between the FMCs, but not of the blank itself. It is assumed that the centre of the blank is not favourably used, as it is very exposed and a rocky strip runs from the north to the south (barrier), shelter possibilities are far away, and open larger patches are mostly used only edge-and, with that, shelter-near. However, this assumption does not seem very convincing, because browsing was detected on nearly every tree of the artificial regeneration. There could also be differences in food quality on the blank. Fire severity might has been higher in the centre of the blank, burning the duff layer and the soil, negatively affecting the nutrients and with that, food attractiveness (WHELAN, 1995, p. 20).

6.5 Linking Fuel Types and Wildlife Ecological Stand Types

Additionally, the idea to translate the fuel types into WESTs was followed to establish a direct link from fuel to habitat. This approach is interesting because fuel types influence fire behaviour and are used to estimate the fire susceptibility of a forest stand. The translation might reveal, if and when a habitat itself is fire susceptible, or not. With that, precise management strategies could be implemented. However, the translation was not successful.

As the FMCs function as common classification scheme, the fuel types and WESTs were described for each FMC. A FMC does not necessarily refer to one specific fuel type or one specific WEST. Accordingly each FMC is composed of different shares of fuel types and WESTs. It is not revealed which fuel type share is composed of which WEST share and vice versa – with that, a direct translation of fuel types into WESTs is not possible (table 32). Aside of that, the question arises for how long the identified fuel types and WESTs are assessed as being valid, since the succession of live and dead organic matter and organisms within the FMCs is ongoing as a dynamic development. This is not reflected upon in the fuel types, WESTs and FMCs. Moreover, in case of a wildfire it cannot be assumed that the modification of fuel types and WESTs follows parallel patterns. In other words, the rearrangement of fuel structures does not necessarily correspond to the rearrangement of habitat structures and vice versa – resulting from the fact that fires do not burn uniformly and that the alteration of habitat structures does not systematically contribute to the fuel load.

Table 32: Shares of fuel types and WESTs in each FMC.

Fuel Type in TH	Share of Fuel Type in FMC	WEST in TH	Share of WEST in FMC
Pinus Austria_moderate	100,00%	093	34%
		124	18%
		123	16%
		121	16%
		022	16%

Fuel Type in PL	Share of Fuel Type in FMC	WEST in PL	Share of WEST in FMC
Pinus Austria_low	38,00%	102	44%
Pinus Austria_moderate	62,00%	101	17%
		022	12%
		132	10%
		103	9%
		131	8%

Fuel Type in MR	Share of Fuel Type in FMC	WEST in MR	Share of WEST in FMC
Pinus Austria_low	87,00%	132	42%
Pinus Austria_moderate	13,00%	112	30%
		022	15%
		111	13%

Fuel Type in BL	Share of Fuel Type in FMC	WEST in BL	Share of WEST in FMC
Timber-Understory 1	100,00%	22	100,00%

6.6 Comparison: Pre-fire and Post-fire

The comparison of the change in fuel types and WESTs due to the wildfire was limited to the burned area (32,26 ha).

From the perspective of fuel types, the blank totally changed. The predominant fuel type prior to the fire and windthrow was PiL. The data sampling 6 years post-fire, revealed the fuel type TU1. How the estimated fire behaviour actually changed, was not investigated.

However, these fuel type changes should not lure into applying this result to the change in habitat quality as already explained above.

As the blank is quite homogenous in terms of the WEST-scale, the determination of the current WEST was accomplished easily. The decrease in stand diversity is obvious – the total blank is identified as 1 WEST only. Before the wildfire and the windthrow, all FMCs were present in the area, with that 12 WESTs composed the stand diversity. So, considering only the blank, the habitat qualities for this area, in terms of WESTs, have decreased in total. This was also shown using the examples of *Capreolus capreolus* and *Tetrao urogallus*. However, the value of the unstocked area may not be underestimated in the context of the whole forest area. Because clear-felling (exceeding 2 ha) is restricted by Austrian forest law, and afforestations following clear-felling or natural disturbances are compulsory (FORSTGESETZ, 1975, s.p.), a wildfire or other disturbances seem to be an additional driver for dramatic impacts on forests which lead to increased patchiness and diversity (REICHHOLF, 2005, p. 213). A great number of wildlife species is dependant on forest clearings, for instance for reproduction, and for foraging (REICHHOLF, 2005, p. 214). Patch quality very much depends on the fire severity, the extension and shape of the burned area. The patchiness of a wildfire is influenced by several features of fire behaviour: the heterogeneity in landscape topography and vegetation, as well as the changes of climatic aspects while burning (WHELAN, 1995, p. 48 f). This creates patches unburned due to topography, wind and local climate and humidity conditions. Unfortunately, such left overs are usually salvage logged and the edges straightened to reestablish a new, clearly defined stand. With that the plus in structural diversity due to a wildfire is diminished (KURULOK et MACDONALD, 2004, p. 10). For this reason, the forestry practice to clear all areas after a disturbance and to homogenize all edges of such areas is to be viewed critically. This thought targets the situation of the different patches, their shape and their edges. Smaller scaled fire blanks, which are interwoven into the old stands might be higher valued from the perspective of wildlife ecology – this especially applies to *Tetrao urogallus*, to give an example.

In addition to the structural benefit, wildfires with low intensities, as now estimated for Bad Bleiberg, can also have very positive effects on the nutrient cycles (PYNE et al., 1996, p. 193). Nutrients are released during a fire, and the ash can function as a fertilizer, which would lead to a temporary increase in plant productivity – stimulating food quality and attracting wildlife. This effect is subject to the condition that the fire is of low intensity and does not burn the duff layer and the seed bank in the soil. ARNDT (2007, p. 121) states in a study that pioneer stands on burned sites show extensive browsing damage giving evidence about its significance as a food source, for instance for *Capreolus capreolus*.

So, it is at least a matter of time, scale and location (FORMAN, 1995, s.p.) – thinking of the patchiness of a forest stand and its edges – how sudden changes in habitat types concern the different wildlife species. How the change is rated, of course, is a matter of interest.

7 Conclusion

7.1 Fuel Analysis

Initially, this thesis describes the initiation of fuel sampling and analysis in Austria. It includes:

- the implementation of the fuel sampling method developed for Austrian forest conditions;
- the calculations for fuel load estimates in *Pinus sylvestris* dominated forest stands of 3 different FMCs;
- the creation of a basis for fire behaviour modelling in Austria.

The sampled data was used to develop new fuel models for *Pinus sylvestris* dominated forest stands in Austria (conducted in another AFFRI project). The new fuel models were partially used in this study, to determine the fuel types pre- and post-fire.

Whether the methods used, to estimate the fuel loads of the FMCs in Austria, are appropriate or not cannot be verified at this point. At least the results of the fuel analysis can serve as a baseline for other studies in similar settings.

7.2 Fuel Data Reveals Habitat Structures

The second major task of this study was to check in how far the fuel data can be used for habitat evaluations.

This study shows that fuel data is very well suitable for gaining information about habitat structures – this needs to be pointed out. *Per se,* however, this data is insufficient to generate an all-embracing habitat evaluation. The scales of fuel sampling and WEST evaluation are not sufficiently compatible. For instance the fuel sampling provides very detailed data about amounts of downed woody material or regeneration, its distribution and arrangement however, are not taken into account. With that a key habitat feature – the composition of resource patches – is not transported by the fuel data sampling. At this point it is not suggested to start such a fuel sampling for the only purpose of evaluating habitats. However, it was demonstrated that the use of fuel sampling data for habitat related purposes, which is at first restricted to the structure analysis only, does have some benefit. This benefit might be improved by further developing the fuel sampling method in respect of habitat evaluation.

The examples (*Capreolus capreolus* and *Tetrao urogallus*) given in this study worked quite well. Although, the combination of showing how the changes can be revealed and showing how the habitat suitability can be assessed with the fuel data is not target aimed, when limited to the burned area. That is the reason, why the results for the habitat suitability focusing only on the blank, are rather alarming. However several trails of *Tetrao urogallus* were detected especially in the boundaries of the blank and the adjacent forest stands. When extending the view range, it can be stated that the forest of Bad Bleiberg does provide very suitable habitat patches for *Tetrao urogallus*. It is essential not to forget the surroundings of the area in which the habitat research is done. The WESTs only represent an estimate of conditions given by “nature”, suitable for *Capreolus capreolus* or *Tetrao urogallus*. As the presence of wildlife species in an area is mostly a result of the trade-offs between multiple habitat demands, this does not necessarily mean that the conditions really are suitable, but rather relatively suitable in relation to the surrounding. The generalized approach by estimating the habitat suitability excludes more or less frequent individual cases, mainly caused by human activities. What is meant are not f.i. hikers, but impacts on wildlife species distribution due to hunting activities or wildlife feeding. Between the poles of hunting and feeding it is challenging to tackle down the ecological possibilities of a certain species and the “truth” about an area´s attractiveness.

With the awareness that the WESTs hypothesize its wildlife attractiveness under “natural” conditions, it is clear that the approach has the character of a model, as a Null-hypothesis to test against given situations.

7.3 Revealing the Changes due to the Wildfire

The third approach of this study was to reconstruct the fuel types and the habitat structures prior to the wildfire. To do so, the FMC-maps of the forest inventory were used. Of course, this is no precise hindcasting of the stand structures, but rather a rapprochement. This enables estimations about successional developments or wildlife-related questions. It is also not possible to say if the blank attracts or deters more wildlife species than the area would have done prior to the wildfire, or how the species spectrum has changed. Again, the above mentioned feeding-hunting activities, which partly evolved from the wildfire, need to be considered. It depends on the habitat type, what impact a fire has on the species. The latter should have become more obvious in the second and third year after both disturbances (windthrow and wildfire). Of course, it would be very interesting to repeat the wildlife sampling for some years in order to observe the impact of succession on the blank. Following that, certainly more thorough statements could be made. The study has shown that the change in fuel types cannot be put on one level with the change in WESTs. The WESTs contribute especially to the composition of forest stand structures, more than the fuel types do. Moreover, the context of the WESTs is indispensable when speaking of habitat suitability.

7.4 A Note on Disturbances

A wildfire is regarded as an ecological disturbance, yet the firefighting activities such as the forestry activities following a burn are generally not considered. In conjunction to wildlife ecology these anthropogenic disturbances should be included. Often chemicals are used to combat a wildfire, so it is advised to consider its effects on the flora and subsequently on wildlife. The effects of salvage logging and afforestation activities often last for at least one or more seasons scaring off wildlife.

At the study site, for instance, the regeneration needs to be protected from browsing, so the hunting activities on the blank are very intensive. This additionally makes it complicated to give a statement about the wildfire impacts on wildlife. Nevertheless, from the perspective of ecology it is definitely worth following the successional development of the blank and focusing on its effects on wildlife.

8 Critique

This first fuel analysis conducted in Austria is described as part of the AFFRI project. The fuel data sampling method of this study was developed in close cooperation with the AFFRI team (ARPACI et al., 2010, s.p.) and tested in Bad Bleiberg. Choosing Bad Bleiberg as reference site for fire research in Austria can be seen critical, because the fire started in the blowdowns of a storm (modified fuel load) and due to carelessness, and not due to natural ignition, as by lightning strikes (c.f. CONEDERA et al., 2008, s.p.). However the fire event is well documented and the forest at this site can be labeled as fire susceptible, also because fires repeatedly happened on the slopes near Bad Bleiberg.

The fuel sampling method was very complex and it took time to find the most effective sampling procedure. A focus was set on the sampling of mature trees, which was very time intensive. However, the comparison of the sampling-results (stocking density, standing volume and basal area) with the ÖBf forest inventory data reveals totally diverging values – most apparently the result of different sampling scales. Moreover the sampled plots were often very heterogeneous. This may be the case, because the stands in Bad Bleiberg are very heterogeneous *per se* and the predominance of *Pinus sylvestris* is very patchy at a small scale. On that location, it might have been more reasonable to design the fuel sampling for mixed stands (*Pinus sylvestris* and *Picea abies*). This is most relevant for the reconstruction of the stand structures prior to the wildfire, and it also appears more representative for many fire prone forests in Austria. In order to be able to reconstruct the conditions prior to the disturbance, the samples must be representative, of course.

What might be a methodological problem is the lack of regeneration of a certain size class (0,61-1,3 m) – that was especially unpleasing during WEST identification and considering ladder fuels. Moreover the sampling of seedlings delivered only a few observations. The 1 m diameter subplot might be too small, or the seedling situation is really poor – this should be verified.

The quality of the fuel load estimates along the transects is not yet rated in this study. However, it is most likely that accuracy can be improved by adjusting the needed specific gravity and other coefficients. Furthermore, the definition of downed woody material may be blurred in the context of litter – some particles <0,6 cm on subplots might have been identified as litter and not as downed woody material.

Furthermore the conditions during data sampling in 2009 were very humid. This is reflected in the seldom sampling of dead herbaceous vegetation. Even the shadeless blank was totally green in high-summer, in contrast to the observations of the locals, who pointed out that it usually is brown at that season of the year. At this point it can be questioned, if this fuel sampling was done in a so called "fuel build-up year", and if this needs to be specially considered during fuel modelling. Besides, weather conditions varied during the period of the fuel sampling, certainly influencing the fuel moisture contents – in how far does this act upon fuel modelling?

It remains unclear, whether the identified fuel types are appropriate to conclude on fire behaviour in Bad Bleiberg and consequentially in Austria. This might only be verified after a new wildfire, for the Austrian laws do not allow prescribed burning for experimental purposes.

As the link between fuel type and WEST was tried to be established in this study – not successful –, it would be interesting to think about the WESTs and the HUFNAGL-Types as fuel types right away.

A further task, which could not be solved, was to apply the pellet locations to the GIS-fuel type map, in order to follow the same procedures as for the FMC-map. Unfortunately the scale of the provided fuel type map was inappropriate.

Another point to be further discussed, is in how far the WEST is comprehensive on its own – the WEST is often used as input variable for habitat models – and in how far the number of sampling points for the fuel analysis is biasing the habitat evaluation. It may be reasonable to check the pros and cons of other habitat type classifications concerning application of fuel data. In this study that thought was left aside because Austrian forestry is familiar to the WEST, and for that it seemed more reasonable.

It was planned to support the wildlife sampling data, with data from the hunting activities at the site. Statistics of hunted wildlife might have revealed some relevant information about the impacts of the fire. Unfortunately the data was not released.

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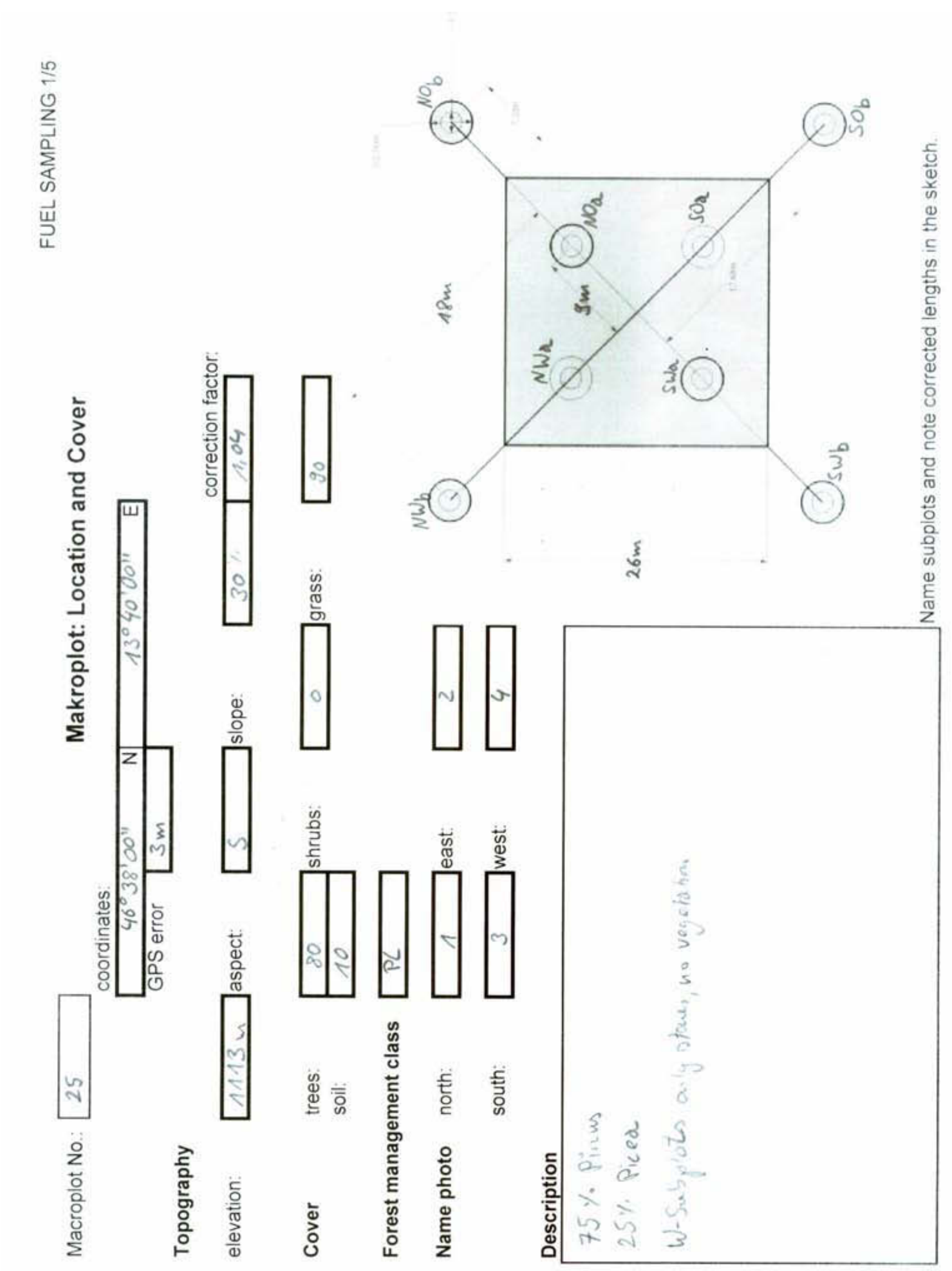
[May, 02,2010]

10 Appendix

Appendix I: Fuel Data Sampling Form



Macroplot No.: 25
Transects

Transects: Downed Woody Material

1 hr — > 0.6 [cm] — collect 5 - 7 m from centre

22 NO	10 SO	53 SW	8 NW

10hrs — 0.6 - 2.5 [cm] — collect 5 - 7 m from centre

10 NO	0 SO	32 SW	5 NW

100hrs — 2.5- 7.5 [cm] — collect 5 - 10 m from centre

2 NO	0 SO	0 SW	0 NW

>7.5 [cm] — collect 5 - 25 m from centre

tree species	diameter [cm]	rate of decomposition
Pinus	8	3
Pinus	10	2

Macroplot No.: 25
Subplot No.: NO b

Subplot: Cover, Regeneration and Seedlings

Vegetation Cover:

	alive	dead	height				
woody [%]	90	10					
herbaceous/grass [%]	100	0	10	11	7	18	cm

litter [%]	stones [%]
0	0

Herbs/Grass
Shrubs/Regeneration
in 2 m subplot

species	height	species	height	species	height
Pinus	4 cm				
Pinus	4 cm				
Pinus	6 cm				
Picea	12 cm				
Picea	53 cm				
Pinus	12 cm				
Pinus	26 cm				
Picea	12 cm				
Erica c.					
Galium					
Hepatica n.					
Knautia a.					
Polygala c.					

Seedlings
in 1 m subplot

species	height
/	

Macroplot No.: 25

Macroplot: Standing Trees

No.	species	DBH cm	height m	crown class	CBH cm	vitality
1	Pinus	18	15,2	1	150	1
2	Pinus	18,5	14,5	2	>200	1
3	Pinus	20	14,0	1	>200	1
4	Pinus	15	11,0	3	160	3
5	Picea	18	12,0	1	0	1
6	Picea	19	15,2	1	70	1
7	Pinus	18	14,3	2	>200	1
8	Picea	20	11,0	1	>200	2

	coring	coring	coring	coring	average	
Age	63	68	85		72	
Species	Pinus	Pinus	Pinus		Pinus	

Macroplot No.: 25
all Subplots

Subplots: Litter and Vegetation

Litter
fresh weight [g]

litter fraction	<0.6		0.6-2.5	2.5-7.5
dead wood	58g		362g	
litter	26g			
bark	7g			
crown			14g	

Vegetation alive
fresh weight [g]

<0.6	0.6-2.5	2.5-7.5
14g	/	/
20g		

Debth [cm]

litter		duff
1,8	NOa	2,3
2,0	SOb	2,0
1,9	average	2,15

Appendix II: Pellet Sampling

Wildlife: Pellet Sampling

Date: 04/04/10

Transect No.: T1

Direction: E -> W

Location at m	sample	species	notes
3	Pellet	Capreolus	PL
10			Forest street beg.
15			Forest street end
19	Pellet	Capreolus	TH
25	Pellet	Capreolus	TH
30	Pellet	Lepus	PL
33	Pellet	Lepus	PL
40	Pellet	Tetrao	PL/BL
80	Pellet	Capreolus	MR
85	Feather	Tetrao	MR
87	Pellet	Tetrao	MR
115	Trail	Cervus	BL
119	Pellet	Rupicapra	BL

Appendix III: Fuel Sampling Data

BLANK

FMC	BLANK (BL)
Plots No.	7
Sampled Area [ha]	0,09
Mean Altitude [m]	1294
Mean Slope [deg]	30
Aspect	S

Pin	***Pinus sylvestris***
Pic	***Picea abies***
Lar	*Larix decidua*
Sor	*Sorbus auquparia*

MACROPLOT-DATA	TH	*Pin*	*Pic*	*Lar*	*Sor*
Total Nr. of Trees	8		3	4	1
Nr. of Mature Trees					
Nr. of Regeneration	8		3	4	1

Trees per ha Classified Height [m]	TH	*Pin*	*Pic*	*Lar*	*Sor*
0-0,3					
>0,3-0,6	24		796		
>0,6-1,3	48		398	796	398
>1,3-2	24			796	
>2-10					
>10-15					
>15-20					
>20					

COVER BL

Macroplot		**Subplot**	
Canopy [%]	5	Woody Alive [%]	7
Regeneration [%]	20	Woody Dead [%]	0
Herbs/Grass [%]	75	Herbs/Grass Alive [%]	75
Soil [%]	5	Herbs/Grass Dead [%]	3
		Litter [%]	4
		Soil [%]	11

FUEL LOAD BL

Fuel Particles in Fuel Size Classes	Total Dry Biomass		Average Moisture Content	Fuel Particles in Fuel Size Classes	Total Dry Biomass		Average Moisture Content
Subplots	**kg/ha**	%	%	**Subplots**	**kg/ha**	%	%
Total on BL	3351	100					
<0,6 [cm] bark				0,6-2,5 [cm] bark			
<0,6 [cm] cones				0,6-2,5 [cm] cones			
<0,6 [cm] dead wood	163	4,86	40,37	0,6-2,5 [cm] dead wood	443	13,22	22,84
<0,6 [cm] lichen				0,6-2,5 [cm] droppings			
<0,6 [cm] litter	1558	46,49	48,83	0,6-2,5 [cm] lichen			
<0,6 [cm] veg live	1187	35,42	158,91	0,6-2,5 [cm] litter			
<0,6 [cm] total	2908	86,78	70,50	**0,6-2,5 [cm] total**	443	13,22	

2,5-7,5 [cm] bark			
2,5-7,5 [cm] cones			
2,5-7,5 [cm] dead wood			
2,5-7,5 [cm] total			
<0,6 [cm] humus			

Downed Woody Material - Transects	kg/ha	%
Planar Intersect		
<0,6 [cm]		
0,6-2,5 [cm]	730	6,99
2,5-7,5 [cm]	5804	55,59
Sound >7,5 [cm]	1305	12,50
Rotten >7,5 [cm]	2601	24,91
Total	10440	100

HERBS AND GRASS BL

Total Nr. of Herb/Grass Species	24
Species Density	0,95
Mean Vegetation Height [cm]	46,11
Mean Litter Height [cm]	4
Mean Humus Height [cm]	1,50

FOREST TYPE - HUFNAGL	Seslerietum and SL-Erica-Type

Wildlife Ecological Stand Type	WEST	Share of WEST
Idle Grassland	**022**	100,00%

Herbs/Grass Species on Subplots	% of Presence on BL	Herbs/Grass Species on Subplots	% of Presence on BL
Calamagrostis epigeios	14,29	*Adenostyles alliariae*	2,04
Carduus defloratus	10,2	*Atropa belladonna*	2,04
Galium	8,16	*Campanula*	2,04
Hieracium	6,12	*Carex digitata*	2,04
Rubus idaeus	6,12	*Carex flacca*	2,04
Sesleria varia	6,12	*Epilobium angustifolium*	2,04
Brachypodium pinnatum	4,08	*Festuca altissima*	2,04
Carex alba	4,08	*Fragaria vesca*	2,04
Euphorbia amygdaloides	4,08	*Lathyrus laevigatus*	2,04
Helleborus niger	4,08	*Prenanthes purpurea*	2,04
Mercurialis perennis	4,08	*Pteridium aquilinum*	2,04
Trisetum flavescens	4,08	*Senecio Fuchsii*	2,04

THICKET STANDS

FMC	**THICKET STANDS (TH)**
Plots No.	4;5;10;13;23;24
Sampled Area [ha]	0,410
Mean Altitude [m]	1107
Mean Slope [deg]	16
Aspect	S

Pin	***Pinus sylvestris***
Pic	***Picea abies***
Ace	*Acer pseudoplatanus*
Ame	*Amelanchier ovalis*
Lar	*Larix decidua*
Sor	*Sorbus auquparia*

MACROPLOT-DATA	**TH**	***Pin***	***Pic***	*Ace*	*Lar*	Other
Mean Age	33	36	30			
Relation of Species by Basal Area/ha [%]		59	39			
Stocking Density		0,6	0,3			
Standing Yield/ha	124	75	47		2	
Stems/ha	735	454	264	2	15	
Basal Area/ha [m^2]	20	12	8			
LOREY Height [m]		12	11			
Mean Height [m]	12	12	11			
Mean DBH [cm]	17	17	17			
H/D Relation [%]	74	76	70		66	
Quality Class		6	14			
	TH	***Pin***	***Pic***	*Ace*	*Lar*	Other
Mean Crown Class	2	2	2	1	1	
Mean Vitality	2	2	1	1	1	
Mean CBH [cm]	116	161	42	150	28	
Count CBH = 0	85	12	69		4	
CBH = 0 [%]	13,18					
CBH < 201[%]	79,38					

Notes		1 wind breakage
Snags	6	

	TH	***Pin***	***Pic***	*Ace*	*Lar*	Other
Total Nr. of Trees	645	219	411	4	7	4
Nr. of Mature Trees	309	188	114	1	6	
Nr. of Regeneration	336	31	297	3	1	4

Trees per ha Classified Height [m]	**TH**	***Pin***	***Pic***	*Ace*	*Lar*	Other
0-0,3	17374	1326	15650	199		199
>0,3-0,6	2785	265	2454			66
>0,6-1,3	1326	464	796		66	
>1,3-2	796		796			
>2-10	254	132	117	2	2	
>10-15	364	232	120		12	
>15-20	127	85	39		2	
>20	12	10	2			

COVER TH

Macroplot		Subplot	
Canopy [%]	62	Woody Alive [%]	11
Regeneration [%]	15	Woody Dead [%]	1
Herbs/Grass [%]	58	Herbs/Grass Alive [%]	51
Soil [%]	27	Herbs/Grass Dead [%]	14
		Litter [%]	23
		Soil [%]	0

FUEL LOAD TH

Fuel Particles in Fuel Size Classes	Total Dry Biomass		Average Moisture Content	Fuel Particles in Fuel Size Classes	Total Dry Biomass		Average Moisture Content
Subplots	**kg/ha**	%	%	**Subplots**	**kg/ha**	%	%
Total on TH	4395	100					
<0,6 [cm] bark	57	1,29	33,74	0,6-2,5 [cm] bark	23	0,52	40,57
<0,6 [cm] cones	31	0,70	90,78	0,6-2,5 [cm] cones	26	0,60	56,92
<0,6 [cm] dead wood	782	17,80	33,13	0,6-2,5 [cm] dead wood	1967	44,74	39,18
<0,6 [cm] lichen				0,6-2,5 [cm] droppings			
<0,6 [cm] litter	863	19,63	57,05	0,6-2,5 [cm] lichen	2	0,05	98,61
<0,6 [cm] veg live	629	14,31	184,64	0,6-2,5 [cm] litter			
<0,6 [cm] total	2362	53,74	85,69	**0,6-2,5 [cm] total**	2018	45,91	51,85

2,5-7,5 [cm] bark	15	0,35	51,35
2,5-7,5 [cm] cones			
2,5-7,5 [cm] dead wood			
2,5-7,5 [cm] total	15	0,35	51,35
<0,6 [cm] humus	9316		127,97

Downed Woody Material - Transects	kg/ha	%
Planar Intersect		
<0,6 [cm]	1598	11,39
0,6-2,5 [cm]	2796	19,92
2,5-7,5 [cm]	8898	63,41
Sound >7,5 [cm]	194	1,38
Rotten >7,5 [cm]	547	3,90
Total	14033	100

HERBS AND GRASS TH

Total Nr. of Herb/Grass Species	63
Species Density	0,38
Mean Vegetation Height [cm]	17,58
Mean Litter Height [cm]	1,42
Mean Humus Height [cm]	1,58

FOREST TYPE - HUFNAGL	Erica-Type and SL-Erica-Type

Wildlife Ecological Stand Type	WEST	Share of WEST
Thicket	**093**	34%
Pole stand-like regeneration under mature trees	**124**	18%
Thicket-like regeneration under mature trees	**123**	16%

Regeneration under mature trees	**121**	16%
Wildlife Ecological Stand Type	**WEST**	**Share of WEST**
Non Forest Types		
Idle Grassland	**022**	16%

Herbs/Grass Species on Subplots	**% of Presence in TH**	**Herbs/Grass Species on Subplots**	**% of Presence in TH**
Polygala chamaebuxus	6,21	*Carex flacca*	0,93
Bryophyta	5,59	*Knautia silvatica*	0,93
Erica carnea	5,59	*Euphorbia cyparissias*	0,93
Brachypodium pinnatum	4,97	*Festuca silvatica*	0,93
Carex alba	4,97	*Pyrola rotundifolia*	0,93
Pteridium aquilinum	4,66	*Ranunculus nemorosis*	0,62
Vaccinium myrtillus	4,35	*Euphorbia dulcis*	0,62
Sesleria varia	3,73	*Lactuca muralis*	0,62
Fragaria vesca	3,42	*Calamagrostis*	0,62
Calamagrostis epigeios	3,11	*Galium odoratum*	0,62
Anemone nemorosa	2,80	*Equisetum silvaticum*	0,62
Melampyrum	2,80	*Viola silvestris*	0,62
Lathyrus laevigatus	2,48	*Epipactis atrorubens*	0,62
Prenanthes purpurea	2,48	*Eupatorium cannabium*	0,31
Carduus defloratus	2,17	*Pyrola chlorantha*	0,31
Epipactis helleborine	2,17	*Dactylis glomerata*	0,31
Galium	2,17	*Carex ornithopoda*	0,31
Hepatica nobilis	2,17	*Trifolium alpestre*	0,31
Daphne	1,55	*Pyrola minor*	0,31
Pulmonaria officinalis	1,55	*Carex alba*	0,31
Vaccinium vitis-idaea	1,55	*Trifolium montanum*	0,31
Euphorbia amygdaloides	1,55	*Pyrola*	0,31
Rubus idaeus	1,55	*Campanula*	0,31
Helleborus niger	1,55	*Epilobium dulcis*	0,31
Hieracium	1,55	*Rubus fruticosus*	0,31
Carex digitata	1,24	*Melica nutans*	0,31
Polygonatum verticillatum	1,24	*Oxalis acetosella*	0,31
Knautica silvatica	1,24	*Viola silvatica*	0,31
Euphorbia platyphyllos	1,24	*Scirpus silvaticus*	0,31
Mercurialis perennis	1,24	*Avenella flexuosa*	0,31
Calamagrostis	0,93	*Aposeris foetida*	0,31
Calamagrostis varia	0,93		

POLE STANDS

FMC	POLE STAND (PL)
Plots No.	2;3;11;12;14;17;19;20;21;22
Sampled Area [ha]	0,83
Mean Altitude [m]	1086
Mean Slope [deg]	25
Aspect	S

Pin	***Pinus sylvestris***
Pic	***Picea abies***
Ace	*Acer pseudoplatanus*
Ame	*Amelanchier ovalis*
Lar	*Larix decidua*
Sor	*Sorbus auquparia*

MACROPLOT-DATA	PL	*Pin*	*Pic*
Mean Age	66	65	66
Relation of Species by Basal Area/ha [%]		82	18
Stocking Density		1,5	0,2
Standing Yield/ha	184	151	33
Stems/ha	767	626	138
Basal Area/ha [m^2]	27	22	5
LOREY Height [m]		13	13
Mean Height [m]	13	13	12
Mean DBH [cm]	19	19	19
H/D Relation [%]	70	69	73
Quality Class		2	4

Mean Crown Class	2	2	2
Mean Vitality	2	2	2
Mean CBH [cm]	154	177	48
Count CBH = 0	79	11	68
CBH = 0 [%]	6		
CBH < 201[%]	71		

Notes		4 wind breakage, 3 fire scars	4 fire scars
Snags	44		

	PL	*Pin*	*Pic*	*Ace*	*Lar*	*Sor*	*Ame*	Other
Total Nr. of Trees	1292	733	463	4	1	25	56	10
Nr. of Mature Trees	640	522	115	1	1	1		
Nr. of Regeneration	652	211	348	3		24	56	10

Trees per ha Classified height [m]	PL	*Pin*	*Pic*	*Ace*	*Lar*	*Sor*	*Ame*	Other
0-0,3	25226	6963	11539	119		915	1950	3740
>0,3-0,6	2745	915	1273			40	239	279
>0,6-1,3	756	199	477				40	40
>1,3-2	398	199	199					
>2-10	284	219	60	1		1		2
>10-15	297	243	52		1			1
>15-20	164	135	29					
>20	40	31	8					

FUEL LOAD PL

Fuel Particles in Fuel Size Classes	Total Dry Biomass		Average Moisture Content	Fuel Particles in Fuel Size Classes	Total Dry Biomass		Average Moisture Content
Subplots	**kg/ha**	%	%	**Subplots**	**kg/ha**	%	%
Total in PL	4785	100					
<0,6 [cm] bark			54,94	0,6-2,5 [cm] bark	100	2,15	39,93
<0,6 [cm] cones	60	1,25	97,29	0,6-2,5 [cm] cones	227	4,74	59,72
<0,6 [cm] dead wood	1722	35,97	30,26	0,6-2,5 [cm] dead wood	1233	25,77	42,70
<0,6 [cm] lichen	2	0,04	54,46	0,6-2,5 [cm] droppings	3	0,05	298,23
<0,6 [cm] litter	659	13,77	57,05	0,6-2,5 [cm] lichen	1	0,03	35,09
<0,6 [cm] veg live	261	5,45	196,01	0,6-2,5 [cm] litter	14	0,28	130,22
<0,6 [cm] total	2704	56,48	104,92	**0,6-2,5 [cm] total**	1578	33,02	56,36
2,5-7,5 [cm] bark	25	0,51	19,99				
2,5-7,5 [cm] cones	152	3,18	41,61				
2,5-7,5 [cm] dead wood	326	6,81	184,77				
2,5-7,5 [cm] total	503	10,50	61,60				
<0,6 [cm] humus	18478		153,02				

Downed Woody Material - Transects	**kg/ha**	**%**
Planar Intersect		
<0,6 [cm]	1389	6,52
0,6-2,5 [cm]	6098	28,65
2,5-7,5 [cm]	11477	53,91
Sound >7,5 [cm]	1009	4,74
Rotten >7,5 [cm]	1315	6,18
Total	21288	100

COVER PL

Macroplot		**Subplot**	
Canopy [%]	66	Woody Alive [%]	5
Regeneration [%]	3	Woody Dead [%]	0
Herbs/Grass [%]	59	Herbs/Grass Alive [%]	43
Soil [%]	38	Herbs/Grass Dead [%]	3
		Litter [%]	33
		Soil [%]	16

HERBS AND GRASS PL

Total Nr. of Herb/Grass Species	60
Species Density	0,23
Mean Vegetation Height [cm]	13,38
Mean Litter Height [cm]	1,40
Mean Humus Height [cm]	1,65

FOREST TYPE - HUFNAGL	Erica-Type, SL-Erica-Type and Seslerietum

Wildlife Ecological Stand Type	**WEST**	**Share of WEST**
Forest Types		
Pole stand, rich in ground vegetation	**102**	44%
Pole stand, poor in ground vegetation	**101**	17%

Wildlife Ecological Stand Type	**WEST**	**Share of WEST**
High Forest, rich in ground vegetation	**132**	10%
Pole stand, regeneration in gaps	**103**	9%
High Forest, poor in ground vegetation	**131**	8%
Non Forest Types		
Idle Grassland	**022**	12%

Herbs/Grass Species on Subplots	**% of Presence in PL**	**Herbs/Grass Species on Subplots**	**% of Presence in PL**
Bryophyta	8,49	*Pyrola chlorantha*	1,15
Polygala chamaebuxus	7,57	*Carlina acaulis*	1,15
Euphorbia amygdaloides	5,05	*Cephalanthera longifolia*	1,15
Erica carnea	4,36	*Melica nutans*	1,15
Euphorbia cyparissias	4,13	*Vaccinium vitis-idaea*	1,15
Calamagrostis	3,67	*Daphne*	0,92
Carex alba	3,67	*Calamagrostis arundinacea*	0,92
Hieracium	3,44	*Campanula*	0,92
Epipactis atrorubens	2,98	*Rubus idaeus*	0,92
Galium	2,75	*Equisetum silvaticum*	0,92
Viola silvestris	2,52	*Knautia silvatica*	0,92
Sesleria varia	2,52	*Aposeris foetida*	0,69
Helleborus niger	2,52	*Polygonatum verticillatum*	0,69
Mercurialis perennis	2,52	*Epipactis helleborine*	0,69
Vaccinium myrtillus	2,06	*Ranunculus nemerosus*	0,69
Calamagrostis varia	1,83	*Globularia cordifolia*	0,69
Prenanthes purpurea	1,83	*Pyrola minor*	0,46
Vincetoxicum officinale	1,83	*Pyrola*	0,46
Pyrola rotundifolia	1,83	*Carex flacca*	0,46
Melampyrum	1,83	*Dentaria enneaphyllos*	0,23
Veronica officinalis	1,61	*Trifolium alpestre*	0,23
Fragaria vesca	1,61	*Carduus defloratus*	0,23
Pteridium aquilinum	1,61	*Pyrola rotundifolia*	0,23
Carex digitata	1,38	*Calamagrostis villosa*	0,23
Carex ornithopoda	1,38	*Dactylis glomerata*	0,23
Lathyrus laevigatus	1,38	*Eupatorium cannabium*	0,23
Euphorbia dulcis	1,38	*Festuca silvatica*	0,23
Euphorbia platyphyllos	1,38	*Asperula odorata*	0,23
Brachypodium pinnatum	1,15	*Knautica silvatica*	0,23
Pulmonaria officinalis	1,15	*Blechnum spicant*	0,23

MATURE STANDS

FMC	MATURE STAND (MR)
Plots No.	1;6;8;9;15;16;18
Sampled Area [ha]	0,63
Mean Altitude [m]	1161
Mean Slope [deg]	33
Aspect	S

Pin	***Pinus sylvestris***
Pic	***Picea abies***
Ace	*Acer pseudoplatanus*
Ame	*Amelanchier ovalis*
Lar	*Larix decidua*
Sor	*Sorbus auquparia*

MACROPLOT-DATA	MR	*Pin*	*Pic*
Mean Age	123	121	125
Relation of Species by Basal Area/ha [%]		79	21
Stocking Density		0,9	0,1
Standing Yield/ha	188	143	44
Stems/ha	385	292	93
Basal Area/ha [m^2]	26	21	5
LOREY Height [m]		14	15
Mean Height [m]	14	14	15
Mean DBH [cm]	28	28	25
H/D Relation [%]	54	52	62
Quality Class		2	<4

Mean Crown Class	2	2	2
Mean Vitality	2	2	2
Mean CBH [cm]	154	179	76
Count CBH = 0	24	4	20
CBH = 0 [%]	6		
CBH < 201[%]	66		

Notes		3 wind breakage	1 wind breakage
Snags	6		

	MR	*Pin*	*Pic*
Total Nr. of Trees	399	227	99
Nr. of Mature Trees	241	183	58
Nr. of Regeneration	158	44	41

Trees per ha Classified height [m]	MR	*Pin*	*Pic*	*Ame*	Other
0-0,3	10004	2728	1819	4471	985
>0,3-0,6	758	152	606		
>0,6-1,3	455	152	303		
>1,3-2	455	152	303		
>2-10	77	54	21		2
>10-15	171	133	38		
>15-20	104	89	14		
>20	40	19	21		

FUEL LOAD MR

Fuel Particles in Fuel Size Classes	Total Dry Biomass		Average Moisture Content	Fuel Particles in Fuel Size Classes	Total Dry Biomass		Average Moisture Content
Subplots	**kg/ha**	%	%	**Subplots**	**kg/ha**	%	%
Total in MR	5292	100					
<0,6 [cm] bark	80	1,50	74,53	0,6-2,5 [cm] bark	114	2,20	90,26
<0,6 [cm] cones	133	2,50	104,13	0,6-2,5 [cm] cones	677	12,80	82,45
<0,6 [cm] dead wood	1138	21,50	55,74	0,6-2,5 [cm] dead wood	1082	20,50	89,61
<0,6 [cm] lichen				0,6-2,5 [cm] droppings			
<0,6 [cm] litter	1001	18,90	87,53	0,6-2,5 [cm] lichen			
<0,6 [cm] veg live	803	15,20	172,91	0,6-2,5 [cm] litter			
<0,6 [cm] total	3156	59,60	112,25	**0,6-2,5 [cm] total**	1873	35,40	87,66
2,5-7,5 [cm] bark	88	1,70	64,40				
2,5-7,5 [cm] cones	175	3,30	56,26				
2,5-7,5 [cm] dead wood							
2,5-7,5 [cm] total	263	5,00	58,97				
<0,6 [cm] humus	15367		176,80				

Downed Woody Material - Transects	**kg/ha**	**%**
Planar Intersect		
<0,6 [cm]	769	4,06
0,6-2,5 [cm]	4287	22,64
2,5-7,5 [cm]	10340	54,61
Sound >7,5 [cm]	1261	6,66
Rotten >7,5 [cm]	2277	12,03
Total	18934	100

COVER MR

Macroplot		**Subplot**	
Canopy [%]	62	Woody Alive [%]	5
Regeneration [%]	4	Woody Dead [%]	0
Herbs/Grass [%]	75	Herbs/Grass Alive [%]	54
Soil [%]	21	Herbs/Grass Dead [%]	12
		Litter [%]	18
		Soil [%]	10

HERBS AND GRASS MR

Total Nr. of Herb/Grass Species	64
Species Density	0,36
Mean Vegetation Height [cm]	21
Mean Litter Height [cm]	1,96
Mean Humus Height [cm]	1,8

FOREST TYPE - HUFNAGL	Erica-Type, SL-Erica-Type and Seslerietum

Wildlife Ecological Stand Type	WEST	Share of WEST
Forest Types		
Pole stand, rich in ground vegetation	**102**	44%
Pole stand, poor in ground vegetation	**101**	17%
High Forest, rich in ground vegetation	**132**	10%
Pole stand, regeneration in gaps	**103**	9%
High Forest, poor in ground vegetation	**131**	8%
Non Forest Types		
Idle Grassland	**022**	12%

Herbs/Grass Species on Subplots	% of Presence in MR	Herbs/Grass Species on Subplots	% of Presence in MR
Erica carnea	7,03	*Dryopteris disjuncta*	0,81
Polygala chamaebuxus	7,03	*Hepatica nobilis*	0,81
Galium	5,68	*Lathyrus laevigatus*	0,81
Vincetoxicum officinale	4,05	*Mercurialis perennis*	0,81
Euphorbia amygdaloides	4,05	*Pteridium aquilinum*	0,81
Veronica officinalis	4,05	*Avenella flexuosa*	0,54
Carex alba	3,78	*Calamagrostis arundinacea*	0,54
Euphorbia cyparissias	3,78	*Melampyrum*	0,54
Euphorbia platyphyllos	3,78	*Oxalis acetosella*	0,54
Calamagrostis	3,24	*Poa nemoralis*	0,54
Bryophyta	2,97	*Polygonatum verticillatum*	0,54
Sesleria varia	2,97	*Pyrola*	0,54
Carex digitata	2,43	*Ranunculus nemerosus*	0,54
Epipactis atrorubens	2,43	*Trisetum flavescens*	0,54
Daphne	2,16	*Anemone nemorosa*	0,54
Calamagrostis epigeios	1,89	*Calamagrostis varia*	0,27
Fragaria vesca	1,89	*Campanula*	0,27
Globularia cordifolia	1,89	*Dactylis glomerata*	0,27
Viola silvestris	1,89	*Epipactis helleborine*	0,27
Adenostyles alliariae	1,62	*Eupatorium cannabium*	0,27
Brachypodium pinnatum	1,62	*Geranium robertianum*	0,27
Euphorbia dulcis	1,62	*Goodyera rapens*	0,27
Helleborus niger	1,62	*Knautia silvatica*	0,27
Hieracium	1,62	*Knautica silvatica*	0,27
Prenanthes purpurea	1,62	*Lamium orvala*	0,27
Vaccinium myrtillus	1,62	*Melica nutans*	0,27
Carduus defloratus	1,35	*Lactuca muralis*	0,27
Rubus idaeus	1,35	*Dentaria enneaphyllos*	0,27
Vaccinium vitis-idaea	1,35	*Pyrola minor*	0,27
Carlina acaulis	1,08	*Spiranthes spiralis*	0,27
Senecio Fuchsii	1,08	*Trifolium alpestre*	0,27
Carex flacca	0,81	*Vicia sylvatica*	0,27
Cephalanthera longifolia	0,81		

Appendix IV: Fuel Model Selection Guide

SCOTT et BURGAN, 2005, p. 8-12

To select a fuel model:

1. Determine the general fire-carrying fuel type: grass, grass-shrub, shrub, timber litter, timber with (grass or shrub) understory, or slash or blowdown fuels. Estimate which stratum of surface fuels is most likely to carry the fire. For example, the fire may be in a forested area, but if the forest canopy is open, grass, not needle litter, might carry the fire. In this case a grass model should be considered.

2. The dead fuel extinction moisture assigned to the fuel model defines the moisture content of dead fuels at which the fire will no longer spread. This fuel parameter, unique to the Rothermel surface fire spread model, is generally associated with climate (humid versus dry). That is, fuel models for dry areas tend to have lower dead fuel moistures of extinction, while fuel models for wet humid areas tend to have higher moistures of extinction.

3. Note the general depth, compactness, and size of the fuel, and the relative amount of live vegetation.

4. Do not restrict your selection by fuel model name or fuel type. After selecting a fuel model, view its predicted fire behaviour to be sure the predicted behaviour agrees with your expectation or observation.

In this guide we refer to spread rates and flame lengths as being very low, low, moderate, high, very high, and extreme—assuming two-thirds cured herbaceous, dry dead fuels (moisture scenario D2L2), a midflame wind speed of 5 mi/h, and zero slope (table 5).

Table 5*—Adjective class definitions for predicted fire behaviour.*

Adjective class	*ROS (ch/h)*	*FL (ft)*
Very Low	*0-2*	*0-1*
Low	*2-5*	*1-4*
Moderate	*5-20*	*4-8*
High	*20-50*	*8-12*
Very High	*50-150*	*12-25*
Extreme	*>150*	*>25*

The general fire-carrying fuel type is:

1. Nearly pure grass and/or forb type (Grass)

a. Arid to semiarid climate (rainfall deficient in summer). Extinction moisture content is 15 percent.

*i. **GR1** Grass is short, patchy, and possibly heavily grazed. Spread rate moderate; flame length low.*

*ii. **GR2** Moderately coarse continuous grass, average depth about 1 foot. Spread rate high; flame length moderate.*

*iii. **GR4** Moderately coarse continuous grass, average depth about 2 feet. Spread rate very high; flame length high.*

*iv. **GR7** Moderately coarse continuous grass, average depth about 3 feet. Spread rate very high; flame length very high.*

b. Subhumid to humid climate (rainfall adequate in all seasons). Extinction moisture content is 30 to 40 percent.

*i. **GR1** Grass is short, patchy, and possibly heavily grazed. Spread rate moderate; flame length low.*

*ii. **GR3** Very coarse grass, average depth about 2 feet. Spread rate high; flame length moderate.*

*iii. **GR5** Dense, coarse grass, average depth about 1 to 2 feet. Spread rate very high; flame length high.*

*iv. **GR6** Dryland grass about 1 to 2 feet tall. Spread rate very high; flame length very high.*

*v. **GR8** Heavy, coarse, continuous grass 3 to 5 feet tall. Spread rate very high; flame length very high.*

*vi. **GR9** Very heavy, coarse, continuous grass 5 to 8 feet tall. Spread rate extreme; flame length extreme.*

2. Mixture of grass and shrub, up to about 50 percent shrub coverage (Grass-Shrub)

a. Arid to semiarid climate (rainfall deficient in summer). Extinction moisture content is 15 percent.

*i. **GS1** Shrubs are about 1 foot high, low grass load. Spread rate moderate; flame length low.*

*ii. **GS2** Shrubs are 1 to 3 feet high, moderate grass load. Spread rate high; flame length moderate.*

b. Subhumid to humid climate (rainfall adequate in all seasons). Extinction moisture content is 30 to 40 percent.

*i. **GS3** Moderate grass/shrub load, average grass/shrub depth less than 2 feet. Spread rate high; flame length moderate.*

*ii. **GS4** Heavy grass/shrub load, depth greater than 2 feet. Spread rate high; flame length very high.*

3. Shrubs cover at least 50 percent of the site; grass sparse to nonexistent (Shrub)

a. Arid to semiarid climate (rainfall deficient in summer). Extinction moisture content is 15 percent.

*i. **SH1** Low shrub fuel load, fuelbed depth about 1 foot; some grass may be present. Spread rate very low; flame length very low.*

*ii. **SH2** Moderate fuel load (higher than SH1), depth about 1 foot, no grass fuel present. Spread rate low; flame length low.*

*iii. **SH5** Heavy shrub load, depth 4 to 6 feet. Spread rate very high; flame length very high.*

*iv. **SH7** Very heavy shrub load, depth 4 to 6 feet. Spread rate lower than SH5, but flame length similar. Spread rate high; flame length very high.*

b. Subhumid to humid climate (rainfall adequate in all seasons). Extinction moisture content is 30 to 40 percent.

*i. **SH3** Moderate shrub load, possibly with pine overstory or herbaceous fuel, fuelbed depth 2 to 3 feet. Spread rate low; flame length low.*

*ii. **SH4** Low to moderate shrub and litter load, possibly with pine overstory, fuelbed depth about 3 feet. Spread rate high; flame length moderate.*

*iii. **SH6** Dense shrubs, little or no herb fuel, depth about 2 feet. Spread rate high; flame length high.*

*iv. **SH8** Dense shrubs, little or no herb fuel, depth about 3 feet. Spread rates high; flame length high.*

*v. **SH9** Dense, finely branched shrubs with significant fine dead fuel, about 4 to 6 feet tall; some herbaceous fuel may be present. Spread rate high, flame length very high.*

4. Grass or shrubs mixed with litter from forest canopy (Timber-Understory)

a. Semiarid to subhumid climate. Extinction moisture content is 20 percent.

*i. **TU1** Fuelbed is low load of grass and/or shrub with litter. Spread rate low; flame length low.*

*ii. **TU4** Fuelbed is short conifer trees with grass or moss understory. Spread rate moderate; flame length moderate.*

*iii. **TU5** Fuelbed is high load conifer litter with shrub understory. Spread rate moderate; flame length moderate.*

b. Humid climate. Extinction moisture content is 30 percent.

*i. **TU2** Fuelbed is moderate litter load with shrub component. Spread rate moderate; flame length low.*

*ii. **TU3** Fuelbed is moderate litter load with grass and shrub components. Spread rate high; flame length moderate.*

5. Dead and down woody fuel (litter) beneath a forest canopy (Timber Litter)

a. Fuelbed is recently burned but able to carry wildland fire.

*i. **TL1** Light to moderate load, fuels 1 to 2 inches deep. Spread rate very low; flame length very low.*

b. Fuelbed not recently burned.

i. Fuelbed composed of broadleaf (hardwood) litter.

*1. **TL2** Low load, compact. Spread rate very low; flame length very low.*

*2. **TL6** Moderate load, less compact. Spread rate moderate; flame length low.*

*3. **TL9** Very high load, fluffy. Spread rate moderate; flame length moderate.*

ii. Fuelbed composed of long-needle pine litter.

*1. **TL8** moderate load and compactness may include small amount of herbaceous load. Spread rate moderate; flame length low.*

iii. Fuelbed not composed broadleaf or long-needle pine litter.

1. Fuelbed includes both fine and coarse fuels.

*a. **TL4** Moderate load, includes small diameter downed logs. Spread rate low; flame length low.*

*b. **TL7** Heavy load, includes larger diameter downed logs. Spread rate low; flame length low.*

2. Fuelbed does not include coarse fuels.

*a. **TL3** Moderate load conifer litter. Spread rate very low; flame length low.*

*b. **TL5** High load conifer litter; light slash or mortality fuel. Spread rate low; flame length low.*

*c. **TL9** Very high load broadleaf litter; heavy needle-drape in otherwise sparse shrub layer. Spread rate moderate; flame length moderate.*

6. Activity fuel (slash) or debris from wind damage (blowdown) (Slash-Blowdown)

a. Fuelbed is activity fuel.

*i. **SB1** Fine fuel load is 10 to 20 tons/acre, weighted toward fuels 1 to 3 inches diameter class, depth is less than 1 foot. Spread rate moderate; flame length low.*

*ii. **SB2** Fine fuel load is 7 to 12 tons/acre, evenly distributed across 0 to 0.25, 0.25 to 1, and 1 to 3 inch diameter classes, depth is about 1 foot. Spread rate moderate; flame length moderate.*

*iii. **SB3** Fine fuel load is 7 to 12 tons/acre, weighted toward 0 to 0.25 inch diameter class, depth is more than 1 foot. Spread rate high; flame length high.*

b. Fuelbed is blowdown.

*i. **SB2** Blowdown is scattered, with many trees still standing. Spread rate moderate; flame length moderate.*

*ii. **SB3** Blowdown is moderate, trees compacted to near the ground. Spread* *rate high; flame length high.*

*iii. **SB4** Blowdown is total, fuelbed not compacted, foliage still attached. Spread rate very high; flame length very high.*

7. Insufficient wildland fuel to carry wildland fire under any condition (Nonburnable)

*a. **NB1** Urban or suburban development; insufficient wildland fuel to carry wildland fire.*

*b. **NB2** Snow/ice.*

*c. **NB3** Agricultural field, maintained in nonburnable condition.*

*d. **NB8** Open water.*

*e. **NB9** Bare ground.*

Appendix V: Wildlife Ecological Stand Type (WEST)

REIMOSER, 1986, p. 164-169 and

REIMOSER et DUSCHER, 2003, p. 111 ff

translated from German: Wildökologische Bestandestypen (WÖBT)

<u>Non Forest Types</u> *(Canopy cover of trees and shrubs is under 30%)*

010 area poor in vegetation *(rocks e.g.), vegetation cover under 30% in summer*
011 vegetation cover 0%
012 vegetation cover Ω 10%
013 vegetation cover Ω 30%
020 idle grassland*, vegetation cover (grass, herbs, dwarf shrubs) ≥ 30% in summer*
021 idle grassland, no shrubs or trees > 0,7 m
022 idle grassland, with shrubs and/or trees > 0,7 m
023 idle grassland, at timberline with trees > 1,3 m
030 stocked pasture*, vegetation cover (grass, herbs, dwarf shrubs) ≥ 30% in summer*
031 pasture, no shrubs or trees > 0,7 m
032 pasture, with shrubs and/or trees > 0,7 m
033 pasture at timberline with trees > 1,3 m
040 unstocked pasture, *vegetation cover (grass and herbs)100%*
050 field

<u>Forest Types</u>

060 sapling stand with an average height ≤ 0,7 m
061 sapling stand with an average height ≤ 0,7 m, at least in winter shelterless browsing area like clear cuttings and blanks
062 sapling stand with an average height ≤ 0,7 m, at timberline (Pinus mugo, Alnus viridis), at least in winter shelterless browsing area like clear cuttings
070 sapling stand with an average height between 0,7 and 1,3 m*, area provides primarily food and secondarily shelter*
071 sapling stand with an average height between 0,7 and 1,3 m including shrubs, area provides primarily food and secondarily shelter
072 sapling stand with an average height between 0,7 and 1,3 m, at timberline (Pinus mugo, Alnus viridis), area provides primarily food and secondarily shelter
080 regeneration, average height >1,3 m*, vegetation cover is closed on ≤ 50% of the area. area provides primarily food and secondarily shelter*
081 regeneration, average height >1,3 m, including shrubs, vegetation cover is closed on ≤ 50% of the area. area provides primarily food and secondarily shelter
082 regeneration, average height >1,3 m, at timberline (Pinus mugo, Alnus viridis), vegetation cover is closed on ≤ 50% of the area, provides primarily food and secondarily shelter
090 thicket, average vegetation height >1,3 m*, canopy covers ≥ 50% of the area and the stem pruning has begun, but only on less than 50% of the area*
091 early stage of a thicket stand, trees are sparse and distributed unevenly, area provides primarily shelter and secondarily food
092 typical thicket, canopy covers 100% of the area. Stem pruning has not yet begun, area provides only shelter
093 terminal stage of a thicket, canopy covers 100% of the area. Stem pruning has not begun, area provides only shelter

094 thicket, average vegetation height >1,3 m, *canopy covers ≥ 50% of the area and the stem pruning has begun, but only on less than 50% of the area, at timberline*
100 Pole stand, the space between the stems is accessible, average DBH ≤ 25 cm
101 Pole stand, poor in ground vegetation, ground vegetation ≤ 1,3 m, vegetation cover ≤ 50%, area provides primarily shelter
102 Pole stand, rich in ground vegetation, ground vegetation ≤ 1,3 m, vegetation cover >50%, woody ground vegetation >0,7 m covers ≤ 30% of the area, provides shelter and food
103 Pole stand with regeneration >0,7 m on more than 30% of the area (e.g. gaps created by snowbreakage)
110 mature stand DBH ≥26 cm, canopy cover >30%
111 mature stand, poor in ground vegetation, ground vegetation cover ≤ 1,3 m, vegetation cover <50% of the area
112 mature stand, rich in ground vegetation, ground vegetation cover ≤ 1,3 m, vegetation cover >50% of the area, woody ground vegetation >0,7 m covers ≤ 30% of the area, provides shelter and food
113 mature stand, clustered
120 regeneration in late stages, under canopy cover >30%*, woody ground vegetation >0,7 m present on >30% of the area*
121 regeneration with an average height between 0,7 and 1,3 m
122 regeneration with an average height >1,3 m
123 regeneration, thicket-like
124 Regeneration, pole stand-like
130 high forest, multilayered
131 high forest poor in ground vegetation, vegetation cover ≤ 1,3 m, covers <50% of the area
132 high forest rich in ground vegetation, vegetation cover ≤ 1,3 m, covers <50% of the area

Special Types

150 special types
151 forest street, incl. bank.
152 water
153 settlements
154 windthrow area with pioneer vegetation
155 (extend types when necessary)

Appendix VI: Fuel Sampling - Relevancy for Fuel and Habitat Related Aspects.

Fuel Properties Sampled	Calculations	Fire Related Aspects	Habitat Related Aspects
FMC			
Macroplot			
Aspect		Fire susceptibility, weather conditions	Climate conditions
Slope Degree		Fire spread behaviour, possible wind effects	Suitable topography, mobility
Cover Trees		Fuel continuity, horizontal fuel distribution	Shelter, cover, microclimate, food, mobility
Cover Shrubs		Fuel continuity, horizontal and vertical fuel distribution	view range, shelter, cover, microclimate, food, mobility
Cover Grass/Herbs		Fuel continuity, horizontal and vertical fuel distribution	Shelter, cover, microclimate, food, mobility
Cover Soil/Stones		Fuel brake	Food, sand bath
Mature Trees			
Species		Fire susceptibility	Food
DBH	Mean DBH, N/ha, stocking density	Fuel continuity	Favoured successional stage
Height	Lorey height, mean height, H/D relation, stand quality		Favoured successional stage
Crown Class		Fire susceptibility	Shelter, cover, microclimate
Vitality		Fire susceptibility	Snags
CBH		Fuel continuity, ladder fuels	Shelter, cover, view range
Transects			
Downed woody material size <0,6 cm 0,6-2,5 cm 2,5-7,5 cm	Fuel load	Fuel size: fire spread and intensity	Shelter, cover, view range, structural diversity, mobility
>7,5 cm decomposition		Flammability	Shelter, cover, view range, structural diversity, food
Downed woody material particles			Structural information

Fuel Properties Sampled		Calculations	Fire Related Aspects	Habitat Related Aspects
Subplots				
	Cover Woody Live/Dead		Surface fuel continuity, input dynamic fuel model	Shelter, cover, view range, structural diversity, food
	Cover Herbs/Grass Live/Dead		Surface fuel continuity, input dynamic fuel model	Shelter, cover, view range, structural diversity, food
	Cover Stones/Soil		Fuel brake	Structural diversity, food
Regeneration		N/ha		
	Species		Fire susceptibility	Food, successional development, development of habitat suitability
	Height		Fuel continuity, ladder fuels	Shelter, cover, microclimate, snow conditions, food
	Diameter		Fuel continuity, ladder fuels, flammability	Shelter, cover, microclimate, snow conditions, food
Seedlings		N/ha		
	Species		Fire susceptibility, successional development	Food, successional development, development of habitat suitability
Herbs/Grass				
	Species	Hufnagl-Type	Fire susceptibility	Precise food information
	Height		Fuel continuity, ladder fuels	Mobility, shelter, cover, view range
Collected Vegetation				
	Weight	Fuel load		
	Moisture Content		Flammability	Water situation, nutrients
Litter				
	Weight/Height		Fuel load, compactness	Nutrient situation for Vegetation
	Moisture Content		Flammability	Water situation
Duff				
	Weight/Height		Fuel load, compactness	Nutrient situation for Vegetation
	Moisture Content		Flammability	Water situation