Forestry in Germany: Adapting history and tradition to a modern world.

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For 456 – International Forestry – 2011 tour

2011.12.28
**Introduction**

In August of 2011, five University of Alberta, ten Université Laval students, one professor from the U of A (Dr. Phil Comeau) and one professor from Université Laval (Damase Khasa) travelled to Germany to take part in an International Forestry course (FOR 456) in collaboration with the University of Göttingen. The tour began in Göttingen, and from there, we embarked on a three-week tour of the country. The purpose of this trip was to learn about the current management strategies, concerns, and utilization of German forests and forest resources. As forest management and sustainability issues become more important on a global scale, it is crucial to understand and expand our knowledge of forest practices around the world. By learning about the management of forests in other regions, we develop a better understanding of the similarities and differences between the two continents. Moreover, this trip encouraged us to think critically and consider management alternatives to Canadian practices. Along with the social networking and educational benefits, immersion in the German culture provided participating students with valuable life experiences. Funding support for this course was provided through the Transatlantic Exchange Partnership Program of the Canada-EU Program for cooperation in higher education, training, and youth.

The following pages provide an overview of what we saw during our visit to Germany.
For 456 – International Forestry – 2011 visit to Germany – Locations visited.

Locations of the field trip

1. Gottingen
2. Eberswalde
3. Freudenstadt
4. Reutlingen
5. Schongau
6. Osterseen
7. Munchen
8. Walchensee
9. Miemswald
10. Munchen
11. Landsbut
12. NPP Bayerischer Wald
13. Spessart

Visit to Germany:
- Management of mixed hardwood forests – working on a single tree basis
- Natural mixed pine stands and conversion of pure pine stands to mixed stands, visiting Berlin
- Black Forest, the classical example of unbeatenen stafung
- The concept of slow–to–nature forestry in the biosphere reserve "Schwäbische Alb"
- Growth and yield of pure and mixed Norway spruce stands
- Nature conservation and recreation in sensitive ecosystems
- Management of urban forests, watershed management
- Restoration of alpine protection forests, soil and slope protection in the Alps
- Forest management in the mountains
- Conversion of pure stands into mixed stands, water status of differently thinned Norway spruce stands
- National Park Bayerischer Wald: forest succession after bark beetle infestation, recreation, wildlife management
- Traditional management of oak stands at the Spessart area
# Itinerary

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<th>Date</th>
<th>Time</th>
<th>Main Issue</th>
<th>Location</th>
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<tr>
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<td>09.00-10.00</td>
<td>Program presentation</td>
<td>Gottingen</td>
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<td>Mon</td>
<td>10.00-13.00</td>
<td>Management of mixed hardwood forests – working on a single tree basis</td>
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<td>Welcome by the Dean of the Faculty of Forest Sciences and Forest Ecology</td>
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<td>Management of European beech</td>
<td>Solling mountains</td>
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<td>Long-term ecological research</td>
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<td>17.08.</td>
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<td>Restoration in a national park, an oxymoron? The example of the Harz National Park</td>
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<td>Growth and yield of pure and mixed Norway spruce stands</td>
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<td><strong>Restoration of alpine protection forests, soil and slope protection in the Alps</strong></td>
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<td>Museum of violin construction</td>
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<td><strong>Water status of differently thinned Norway spruce stands</strong></td>
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<td>16.00-18.00</td>
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<td><strong>National Park Bayerischer Wald: forest succession after bark beetle infestation, recreation, wildlife management</strong></td>
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<td>Bus drive to Rothenbuch</td>
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<td>Wed</td>
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<td><strong>Traditional management of oak stands at the Spessart area</strong></td>
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<td>17.30-20.30</td>
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Management of Mixed Hardwood Forests
Adelebesen
August 15, 2011

Background – Beech/Mixed Hardwood Ecology:

Beech (*Fagus sylvatica*) is a widespread native species and occurs together with a number of other broadleaved tree species in the forests of central and northern Germany. After a stand replacing event (i.e. past clearcutting, large windstorms, or conversion from coppice systems), “future” beech forests are dominated by fast-growing “noble hardwoods” [e.g. ash (*Fraxinus excelsior*), sycamore-maple (*Acer pseudoplatanus*), Norway Maple (*Acer platanoides*), sessile oak (*Quercus petraea*), pendunculate oak (*Quercus robur*), etc.] that thrive under early-seral/high light conditions. Shade tolerant and slower growing beech establish in the noble hardwood understory, eventually achieving parity with the noble hardwoods. After attaining dominance, beech close most canopy gaps, exhibit accelerated growth, and compete aggressively with the noble hardwoods for light. Through this process, beech eliminates most noble hardwoods through competitive exclusion (Figure 1). Continued beech dominance is maintained through “small gap” disturbance (i.e. insects, disease, or single-tree selection) that facilitates shade tolerant beech regeneration. Alternately, large-scale disturbance (i.e. extreme windstorms, ice storms, or group selection) events may revert beech-dominated forests into a noble hardwood phase, restarting the successional process.

![Figure 1. Beech dominated forest near Göttingen. Few noble hardwoods are present in this image.](image)

Past Management Practice

Prior to 1850, Beech/Mixed Hardwood forests were managed for fuelwood using coppice systems, emphasizing ash, sycamo re-maple, and (to a lesser degree) beech. These coppice forests also served important secondary roles as pastureland and a source for animal feed. After
1850, fuelwood remained the dominant management objective; however, coppiced stands were converted into closed-canopy high forests through successive low thinnings, ultimately favouring shade tolerant beech (Figure 2).

Figure 2. Beech/Mixed Hardwood forest near Göttingen. Since the 1850’s, the gradual conversion from coppice turned this stand into a beech-dominated “high forest. However, remnant ash (photo right) from former coppice management still remain.

**Noble Hardwood Emphasis: 1950-1970**

In the middle of the twentieth century, the economic value of “noble hardwood” timber increased, leading to a re-evaluation of noble hardwood management. To emphasize remnant noble hardwoods, heavy crown thinnings were implemented in (now) beech-dominated forests; moreover, noble hardwood regeneration was encouraged through 10-20 hectare group selection cuts.

**Current Management Practice**

Given changing public demands, current Beech/Mixed Hardwood management emphasizes single-tree selection of mature trees, limited group-selection (40m gaps) for noble hardwood regeneration, and diameter-limit cuts. Ultimately, these silvicultural practices create park like uneven-aged forests with variable vertical and lateral structures. On noble hardwood-leading gaps or sites, aggressive precommercial thinning and heavy crown thinnings are implemented to maintain the noble hardwood component and mediate beech dominance (Figure 3). Stand density is steadily reduced to 120 trees/ha over time, releasing growing space and maintaining crop tree form (Figure 3).
On state forestland, government (i.e. Lower Saxony) targets define species composition, tree size, tree age, and regeneration standards for specific site types. For example, noble hardwood-leading stands are recommended on nutrient-rich sites; full composition, size, age, and regeneration targets are listed in Table 1.

Table 1. State target for noble hardwood-leading sites in Lower Saxony.

<table>
<thead>
<tr>
<th>Target Species Composition:</th>
<th>40-60% Ash/Sycamore-maple, 30-40% Beech, and 10% suppressed Beech/Hornbeam</th>
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</thead>
<tbody>
<tr>
<td>Target Regeneration:</td>
<td>40-60% Ash/Sycamore-maple, 20-30% Beech, and 10-20% other species</td>
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<td>Diameter Target:</td>
<td>Ash/Sycamore-maple: 70cm @ 100-180yrs, Beech: 60cm @ 100-180yrs, and other species: 50cm @ 60-140yrs</td>
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Welcome by the Dean of Forest Science/Ecology: Cristoph Klein

Göttingen

August 16th 2011

The Dean of Forest Science at the Georg-August-Universität Göttingen (Göttingen University) welcomed us to Germany and give us a brief summary of the education and general layout of Germany and its forest resources. The main difference between Canada and Germany is the ratio of population to land base, specifically Germany has double Canada’s population (80 million) on a fraction of the land base. Germany has a forest landbase of 11 million hectares which is second (in area) only to agriculture in land use. This fact is very important due to Germany’s high population and minimal natural resource availability. However, Germany has the largest timber growing stock in the EU and manages that base in a way that benefits the maximum amount of the population.
As a federal state, the responsibility of German forest management is upheld by the state, or Lander. Although national policies are set by the Federal Government, it is up to the Lander to implement these targets.

**Management of European Beech**

* Solling Mountains 
* August 16, 2011

Ecosystem research in the Solling Hills has been underway since 1966. High inputs of sulfur were detected in this area in the early 1970’s (acid rain), however sulfur inputs declined dramatically after 1986. Deposition of Nitrogen increased from 1970 to 1980 and has only decreased slightly since then. Several ecological studies continue at this site.

![Figure 4. Solling Hills ecological studies of nitrogen and sulfur deposition and flux.](image)

The world’s forests are facing challenges in relation to carbon storage and climate change; foresters will have to adapt and design thinning procedures to maximize outputs from the forest while keeping inputs low (i.e. Close to nature forestry). In the Solling region of Lower Saxony, we visited a European beech thinning experiment that investigated growth maximization in relation to stocked area, striving to answer these questions (Figure 5).

The Solling region is an intensively managed research area. The beech crop trees are selected and grow with very little competition from other vegetation (beyond intraspecific competition). Individual crop trees in this stand are numbered for long term analysis, a practice not common in Canada. Initial planting densities are 500,000 stems/ha and gradually lowered through successive thinnings to 150 stems/ha. This results in a low branch-shoot ratio and good form (i.e. high timber quality). Beech trees are harvested when reaching a target diameter between 60-70 cm or damaged through wind or disease.
This experiment demonstrated that varying the thinning intensities can alter stand characteristics and benefit different values. By thinning heavily, fewer trees are left; however, the remaining trees are of higher quality.

![Figure 5. Beech density trial.](image1)

We also visited the Solling Roof experiment, a research station that was established to manipulate rainfall inputs and to monitor effects on soil chemistry, litter decomposition, and productivity. Specifically, the station monitored drought stress, acid rain inputs, root activity (i.e. root cameras) and nutrient cycling (Figures 6-7)

![Figure 6. Solling roof experiment. The “roof structure” controls natural rainfall input.](image2)
Figure 7. Solling roof experiment (Close-up).

Forest Restoration in National Park Harz

Harz Mountains

August 17, 2011

Figure 7. The Harz Mountains, Harz National Park.

Germany’s National Parks are part of their natural heritage and the Harz National Park is of outstanding importance for nature conservation and protection. The Harz National Park is located near central Germany in Lower Saxony and covers approximately 24,700 hectares and two federal states. Upper Harz National Park was established in 1990 and consists of 8,900 ha of
land, and Lower Harz National Park was annexed to the western portion of the park in 1994, adding another 15,800 ha. Of this large area approximately 96% of it is forested.

In the lower altitudes below 700m above sea level, beech and other broadleaf species dominate the landscape. Between 700-800m, a mix of beech and Norway spruce predominate with areas above 800m occupied by Norway spruce. Allowing growth and successional patterns to occur naturally through minimal intervention is one management strategy. Currently 82% of the forest cover consists of spruce stands, and only 12% are European Beech. The Harz was partly deforested in the 19th century, and given their rapid growth, spruce trees were used for reforestation. As a result of this planting strategy, the park is dominated by monocultures of spruce.

Beyond forestlands, the Harz has a wide variety of other ecosystem types, including raised bogs called ‘hoch-moore’ and areas of dwarf shrubs (Figure 8). There are over 1,000 species of ferns mosses, and flowering plants that grow in Harz National Park. The peat bogs here are preserved in their original form and provide habitat for animals, plant, and insect species. Since the last ice age, the damp cool climate and stony ground underneath allowed for high water saturation where the plants could only partly decompose. Over time, the peat moss developed into peat bogs, and some of the bogs are continuously saturated and now up to 7 meters in depth.

Figure 8. A raised bog or “hoch-moore” in the Harz Mountains.

Bark beetles are closely managed in the Harz through park zonation and buffering. In the central “Natural Dynamics Zone”, the main bark beetle strategy is to monitor population size and movement; however, no proactive management occurs in this zone. Near the park boundary, bark beetle populations are actively controlled through salvage logging, and at the boundary itself, vulnerable neighbouring forests stocks are protected by a 500m wide strip.

Red deer, roe deer, and wild boar are the large herbivores inhabiting the Harz forest. In particular, roe deer populations often reach levels that interfere with forest regeneration. Unlike national parks in Canada, hunting is the only roe deer population control, and fences are used to help protect broad leafed regeneration (Figure 9).
Old Growth Beech Forest – “Grumsiner Forst”

Brandenburg-Ziethen
August 18, 2011

The Federal state of Brandenburg is a 6.9 million hectare area in the northeastern German lowlands. The Northern and central landscapes originated from the last Vistula glacial period and the southern regions originated from the Elster glacial period. Being one of the driest areas in Germany with precipitation rates ranging from 700mm/yr to less than 500mm/yr and high evapotranspiration rates the trees are subject to frequent drought events.

During the middle ages, approximately 1/3 of the forested area was exploited as agricultural land. Cattle grazing, pig feeding, and the export of litter and humus led to the destruction of the natural forest structure with vast areas of severe desertification. What was once a broadleaf dominated forest with European Beech (*Fagus sylvatica*), Sessile oak (*Quercus petraea*), and Pedunculate oak (*Quercus robur*) representing the main tree species, is now dominated by approximately 70% Scots Pine (*Pinus sylvestris*). With the emergence of silviculture practices 200 years ago it was possible to cultivate previously damaged sites by planting Scots pine. The low nutrient and soil water demands of Scots pine made it an ideal species to reforest the once devastated natural forest.

Repeated insect attack, weed issues, and other phytosanitary problems arose in the pure Scots pine plantations. Since the 1990s, approximately 70,000 ha of homogenous Scots pine forests have been transformed into mixed and broadleaf forests. This is an example of the 'close
to nature' forestry practices with the conversion of these forests to more natural mixed wood forests.

The nature reserve 'Grumsiner Forst/Redenswalde' is a 657 hectare closed forest area in the German Federal state of Brandenburg. This area that we visited on our trip was an example of the high-value old growth European Beech (140 yrs old) (Figure 9). Swamps and bogs are common in the area creating suitable habitats for Cranes (*Grus grus*), Black Storks (*Ciconia nigra*), and European Terrapin (*Emys orbicularis*) (Figure 10). This area has had little human influence, except for long-term removal of dead trees, with the recent vegetation corresponding to the potential vegetation. The area was once a restricted access hunting reserve for higher government official. The area has been designated as a World Heritage site to provide an example of the valuable, ancient and primeval beech forests that were once common throughout Germany.

![Figure 9. Grumsimer Forest.](image)

![Figure 10. Example of a bog in the Grumsiner Forst](image)
Management of Pine Stands and the Conversion of Pine Monocultures

Eberswalde

August 19, 2011

Scot’s pine (*Pinus sylvestris*) monocultures dominate nearly 70% of the forestland in northeastern Germany. Geology, climate, historic land use, and silvicultural practices have all influenced the establishment of these forests. Today, increased ecological awareness, changing public demands, and shifts in climate are driving the conversion of pine monocultures into mixed species stands with irregular structure.

**Geology and Climate of Northeastern Germany**

Glacial action defines the geological history of northeastern Germany. Through multiple advances and retreats over the last 2.5 million years, glaciers deposited course, Scandinavian parent material across the region. Subsequent fluvial action from melting glaciers then sorted these substrates, creating the region’s dry, sandy, and nutrient poor soils.

Although relatively close to the Baltic Sea, northeastern Germany has a continental climate with mean annual temperatures around 8°C, mean summertime temperatures around 18°C, and an annual precipitation of 600 mm.

Cumulatively, sandy soils, warm summers (high evapotranspiration), and relatively low annual precipitation, leave northeastern Germany in a state of moisture deficit throughout the growing season.

**Reclamation with Scots Pine**

In the middle ages, the primeval beech/oak forests of northeastern Germany were cleared for agriculture or pasture. On sites incapable of supporting agricultural activity, forests were converted into coppice systems and/or heavily exploited through grazing and litter mining. These land use practices often lead to site degradation and occasionally desertification. With the advent of silviculture in the early 1800’s, Scot’s pine plantations were established on degraded sites across the region. Scot’s pine, with its ability to tolerate droughty and low-nutrient conditions, was extraordinarily well suited to site reclamation.

**Traditional Pine Management**

Historic pine management in northeastern Germany emphasized single cohort pine monocultures under a high intensity thinning regime. With the availability of low cost manual labor, plantations were often initiated through direct seeding at high densities (~10,000 trees/ha). High density stands forced crown uplift and reduced branch-stem ratio. Successive low thinning then brought stand densities down, optimized stocking, and eliminated “wolly” dominant pine (Figure 11). At maturity (~120yrs), pine monocultures were (historically) clearcut and replanted to Scot’s pine.
Social and ecological concerns, including site acidification (conifer leachate), climate change resilience, low monoculture species diversity, and the restoration of natural vegetation types (i.e. beech/oak forests) are driving the conversion of Scot’s pine plantations into mixed structures. Furthermore, low pine prices and the (relatively) slow growth of Scot’s pine, make mixed stands more economically desirable, particularly when exotic conifers (i.e. Douglas-fir/grand fir) are introduced. Finally, clearcutting, a staple of traditional Scot’s pine management, is no longer legal or socially acceptable, making single cohort pine stands difficult to establish.

Mixed Species Conversion

After approaching culmination age, Scot’s pine monocultures are thinned to moderate or low densities. Then, beech, oak, or other exotic species are underplanted in the Scot’s pine understory. Thinning intensity is highest when underplanting seral oak and less severe when underplanting beech. After understory species establishment, stands are managed under single-tree or group selection, fostering a mixed species composition with variable.
Black Forest Plenterwald: Classic Example of Unevenaged Silviculture

Freudenstadt
August 21, 2011

The Black forest in Germany is a very important forest with many values and a rich turbulent history. The word Plenterwald refers to the single tree selection method used in the black forest.

After WWI, this area was heavily deforested due to war reparations by the French and allies. These unsustainable clearcuts led to forest degradation and foresters have been trying ever since to recover a more desirable forest structure. In the 1970s forest managers began using continuous cover/single tree selection methods for the black forest. The strategy was to harvest the largest most vigorous trees and provide space for the regeneration while thinning the residual stand.

During World War II, the black forest was used as a natural fortification and as a border defense. The black forest is essentially a “green wall” (Figure 12) with unique geology consisting of different soil types along the slopes. The red sandstone on top of granite can create natural springs because of the less permeable layers and higher quality soils. For farmers in the area this can present a problem due to the low nutrient content of the soil which is in turn lost due to erosion and compaction of grazing animals.

Two thousand years ago Beech and Silver fir dominated the landscape; presently the stands are comprised of 60% Norway spruce, 5% broadleaf and 5% other conifers (i.e. Pinus mugo). This is a community forest and is broken down and sub-divided into many compartments. This presents challenges for foresters as some of the stands are only 30 meters x 30 meters.

Single tree selection makes sense in this forest for several reasons. First, the natural shade tolerance of Silver fir allows for abundant regeneration. Second, continuous cover allows for multiple ecological (biodiversity), aesthetic (forested landscape) and timber quality (low branch-stem ratio) benefits. Third, single tree selection allows for continuous revenue over time.

Along the tour, we were taken to a 260 year old Silver fir named GroBvatertanne with a DBH of 1.72m, height of 47m, and volume of 36m³ (Figure 13). This was an example of the capabilities of the black forest for producing large trees. A majority of Amsterdam, Holland was built with timber from the Black Forest. During the excursion our crew noticed that many large trees had a tree symbol on them. These symbols marked the 400 largest trees around Freudenstadt as a 400 year anniversary celebration of the town (Figure 14). This area is very popular with locals and tourists and several major hiking trails traverse the forest (Figure 15).
Figure 12. Norway spruce and silver fir forest near Freudenstadt.

Figure 13. Kent claims the silver fir champion: 260 years old, 1.72 m diameter, and 47m height!
Figure 14. Placards marking the 400 largest trees.

Figure 15. Popular hiking trails in the Black Forest where single-tree selection has been practiced to maintain uneven-aged stands.
Close-to-Nature Forestry in the “Schwabische Alb” Biosphere Reserve

Reutlingen

August 22, 2011

Background

The Biosphere Reserve, Schwabische Alb, is located near the city of Reutlingen which includes a former rock quarry, adjacent meadows, and the surrounding forest. The biosphere reserve is structured into a core area with a surrounding buffer zone. Timber extraction is prohibited in the core zone for protection and preservation of different plant species. The purpose of the biosphere is to reconcile biodiversity with conservation goals and provide recreational areas for the public.

Rock Quarry

The rocks from the biosphere’s quarry were used for building the entry gate of the 1936 Olympic stadium. The city of Reutlingen bought the land in 1970 with the intention of rehabilitating it. Over the course of 35 years, foresters transformed the once barren area into a natural looking landscape with artificial lakes (covering approximately 2ha), and planting forest vegetation (Figure 16).

![Rock quarry face with rehabilitated vegetation](image)

Figure 16. Rock quarry face with rehabilitated vegetation

Transition Zone

On the hill slopes above the rock quarry, forest types shift changing soil composition. At the base of the hill, clay content and soil depth are higher allowing beech to thrive. On hill slopes with shallow acidic soils, beech loses its competitive edge due to undesired conditions.
The dry shallow conditions encourage a diversity of tree (noble hardwoods) species and fauna in the area (including rare beetle and bird species).

**Meadows**

In the past the region contained more meadows, however, the proportion of the meadows dwindled from 66% to 10% (as it was 60 years ago). These man made meadows contained sixty different types of plants and high species diversity. To prevent beech encroachment the meadows areas are cut once a year and left unfertilized. Furthermore the meadows are left unfertilized to maintain the natural species succession dynamic (Figure 17).

![Figure 17. Meadow in the Reutlingen reserve. Note the high species diversity and encroaching beech forest](image)

**Modern Forest Management in Reutlingen’s Community Forests**

Reutlingen’s community forests are approved under several forest certification systems. These certifications include: Nature Conservancy certificate, Programme for Endorsement of Forest Certification (PEFC) and Forest Stewardship Council (FSC) Of these certifications, the FSC is the most stringent and recognized internationally.

Prior to the 1970’s Reutlingen’s forests were managed under a strip clearcutting system; however recently, this management practice became socially unacceptable, forcing the adaption of single-tree selection with diameter limits. Single tree selection is a more intensive management system, requiring ample access, a skilled harvesting workforce, and professional (forester) oversight.
Growth and Yield of Pure and Mixed Norway Spruce Stands

Allgäu

August 23, 2011

To gain a greater understanding of growth and yield in mixed stands, several installations in the Bavarian Network of Long Term Monitoring Plots were visited in Schongau (Figure 18). This network was established 130-140 years ago in mixed Norway Spruce and European Beech stands. (The network also encompasses Scots Pine, European Oak, and Silver Fir stands.) The purpose of this study is to monitor the growth of the trees in mixed stands under different surrounding conditions, site conditions and age classes. Specifically, the whole study area consists of 1000 single plots in 8 different sub-areas. Tree ages in the plots range from 45 years to 110 years with volumes ranging from $401 \text{m}^3/\text{ha}$ to $1151 \text{m}^3/\text{ha}$. Although originally established to monitor monocultures, the plots are now being used to model mixed wood stands. By monitoring the different aged plots over time, forest scientists are able to project the growth development of mixed species stands and predict stand conditions in the future.

The data acquired from these plots is now being used to assess the dynamic of single tree growth. On a single tree basis, diameter growth, height, crown diameter growth, and mortality are studied to determine how each property is affected by competition. This system is called the ‘Position Dependent Single Tree Model’ and is used to assess tree interactions with each other on a spatial and temporal scale. The single tree data requires more work but is more accurate and can be used to predict growth on a stand level as well.

Figure 18. Plot within the Bavarian Network of Long Term Monitoring Plots.
Nature Conservation and Recreation in Sensitive Ecosystems

Osterseen

August 24, 2011

Nineteen kettle lakes connected by natural channels make up the Lakes Osterseen (Figure 19). The lakes are situated 50 km south of Munich in the pre-alpine region of upper Bavaria. The lakes are almost exclusively fed by ground water, creating several lakes types with different groundwater inflow and nutrient supplies. These lakes are ideal for comparative limnological studies due to their diversity of hydrological, chemical and biological traits.

Besides being a hydrological research area, the Lakes Osterseen is a popular recreation destination. Recreational areas face heavy pressures from the public due to the high population (i.e. nearby München) and a limited recreation landbase.

Figure 19. Swimming at one of the Osterseen lakes.

Part of 'close to nature forestry' is to provide protected areas and incorporate public involvement when developing forest management plans. There is public pressure not only for recreation areas but also for land for food production. Biodiversity has become threatened by the intensification and expansion of agriculture. Along the same line as 'close to nature forestry' practices, sustainable farming systems such as organic farming are viewed as a potential solution to loss of biodiversity. Organic farming receives support in the form of subsidy payments through the European Union and national government legislation. The ideas and principles behind organic farming date back nearly a century with such practices as crop rotation, nutrient cycling with organic fertilizers, and restricted external inputs (Figure 20). These practices are similar to the efforts in forestry to create a sustainable and ecologically harmonious landbase.
Forests provide many critical ecosystem services, including watershed protection and as a municipal water source. The relationship between forests and drinking water is particularly strong in Munich. With a population of 1.4 million, Munich receives 80% of its drinking water from forested watersheds south of the city. Furthermore, Munich proactively encourages responsible land management to protect the city’s water quality.

**Munich’s Municipal Water Source**

Prior to 1881, Munich received the majority of its drinking water from onsite wells. Unfortunately, these wells were susceptible to contamination, prompting the development of an aqueduct/waterworks system sourced in forestland 40km south of the city. This water source collects artesian groundwater of the highest quality, requiring no additional chemical treatment.
Success through Proactive Land Management

Although most of Munich’s municipal watershed is forested, approximately 30% contains agricultural land. Beginning in the 1950’s, high-yield agriculture began contributing to increased nitrate concentrations in Munich’s prized drinking water. To offset this effect, Munich began to subsidize organic farming in 1992, paying farmers at a rate of €150/ha. Over time, the conversion to organic farming within Munich’s municipal watershed successfully reduced fertilizer inputs and subsequent nitrate levels.

Forest Management for Watershed Protection

On the site of Munich’s artesian wells, the city manages 1500ha of (predominantly) Norway spruce forestland for groundwater protection. These forests are FSC certified and managed under continuous cover (i.e. low intensity single-tree selection on a 5 year return interval). No exotic species or fertilizers are used; however, hunting is strongly encouraged to aid forest regeneration. Currently, the “waterworks forest” is slated for conversion into a mixed forest of Norway spruce, silver fir, and beech. Beyond increasing species diversity, this conversion will decrease nitrate leaching and reduce interception losses by Norway spruce foliage.
This particular day was very interesting and beautiful. We began with a long steep hike in the Alps to learn of the challenges of steep slopes and sensitive soils and how to protect them. Protection forestry is the science of protecting the soils, slopes and regenerating forests from avalanches and erosion.

In order to protect the ecosystem, trails/ski hills, roads and infrastructure forests must use their knowledge of the soil and conditions to protect these values at risk so they may be maintained. Walchensee being the deepest and largest Alpine lake in Germany with breathtaking views of 3 different countries from the top of the hill it is easy to see why these values must be protected sensibly and vigilantly. Out of the 140,000 hectares of protection forest around 10% is considered severely damaged by external factors that compound the effects of avalanches. These factors are storms, insects, and high browsing pressure. These can lead to missing regeneration with open or sparse canopy. Lack of regeneration can create negative feedback from erosion and lack of habitat for animals.

*Our guides laid out two main types of protection forestry:*

1. Protection of infrastructure/villages (Forests to reduce Avalanches)
2. Protection of the forest stand itself (Soils, Regeneration, Ground roughness)

For the first type of protection forestry there are a few strategies for protecting valuable infrastructure. This can be done by making sure tree species are specifically suited for resisting browsing and harsh winter conditions. The Austrian/German border is a mixed mountain zone comprised of Scots pine, Sycamore maple and Silver fir. The Scots pine in these stands is relatively old (150-500 years) and is literally dying of old age. This cause reduced regeneration which can lead to open canopies that can be prone to avalanche events. Scots pine is a valuable species in this region due to its hardiness to poor eroded soils. During the middle ages the goats and sheep grazed and had ruined the soil, the pines survived this but are now at risk. With sparse open canopies the development of matted Lahnergras (tall grass on steep slopes) in the fall can create perfect conditions for wet slide avalanches that can wreak havoc on infrastructure and water quality.

With the steep slopes and generally deep organic layer that Spruce and Silver fir need are at risk and the development of these grasses can be troublesome. In order to counteract this we can plant spruce climax species like sycamore maple that can regenerate in the grass and set the stage for later successional species and better protection in the stand. Therefore by planting pioneer species we can use these as both protection and maintenance for a future stand.

For the second type of protection we are trying to protect the forest from avalanches and hazards of the like. In higher altitudes the snowpack can become very deep (200-300cm) and this is where we find the metal avalanche zone (Figure 22). There are wooden
installations that are built partway up the mountain and aids in preventing avalanches and preventing trees from getting ripped apart during snow events (Figure 23). These are tremendously sturdy but require hard labour and funds (500€ / installation) and many parts need helicopters for transport. The second installations are large metal hammocks which increase surface roughness that doubles as protecting the smaller plants at high altitudes but also the highway far below from both avalanches and large rocks. These structures are even more labour intensive/expensive to build. Moreover, they can replace the function of trees as protection when the trees themselves can’t grow fast enough. Although they provide many benefits to the situation, a negative of this practice is the high cost and the fact that they aren’t as durable as the wooden structures.

Protection forestry is a key element in the Alps and continues to ensure both the forest and infrastructure is well maintained and safe for public recreation.
Bavarian Forest Species Composition on an Elevation Gradient

Mittenwald
August 27, 2011

The Bavarian forest varies in terms of species composition due to the altitude difference. The observable difference in tree species composition can be attributed to the change in climatic conditions and soil regime.

The four different forest communities relative to the sea level in the Bavarian Alps:

- 500m-800m beech-fir
- 800m-1100m beech-fir-spruce
- 1100m-1400m spruce-fir-beech
- 1400m-1700m spruce

Conversion of Pure Stands into Mixed Stands

Landshut
August 29, 2011

We visited a research site where the objective of the study is to test beech seedling growth and development relative to direct seeding or planting grown under similar conditions. This study was conducted in two pure Norway Spruce stands in Munich University’s forest which was established in 1997. The goal is to convert the pure stand into a mixed wood stand, and the traditional way to do this was through planting.
There were a total of six treatments applied; three were treated with direct seeding, two with planting, and one with natural regeneration. The soils and yield classes of the stands are similar and are representative of many other Norway Spruce stands in Germany.

The direct seeding of beech was carried out at three randomly selected plots. Different additives were applied with the direct seeding treatments as well. In one, they added leaf litter in order to insulate and add cover to protect from predation from snails and mice. Norway spruce is known to cause top soil acidification, so lime was added to the second trial to see if there would be a higher success rate. The remaining third direct seeding plot was left untreated.

Two planting treatments were also done and differed according to age of the planted seedlings. They used 1 and 2 year old bare root seedlings on the two different sites.

The timing of direct seeding is important as well. Seeds should be added shortly after watering. If the wait time is too long, there can be issues with fungi on the seeds or if there is a late spring frost or flooding, the seeds can be lost.

Direct seeding provides the highest regeneration density, around 100,000 stems/ha, but after 100 years the density will decline to about 120 stems/ha. Direct planting is controlled at about 5000 stems/ha. Seeding costs €3000/ha and planting is approximately €5000/ha so there are major price differences. Seeding can be beneficial because of the low cost and because of the tight planting density. Moreover, the high densities caused by direct seeding cause less branching which may lead to higher quality wood. Direct seeding success is variable because germination is difficult to control, and competing vegetation may impair establishment. Planting is an effective method for controlling tree placement, but is limited by its high cost and the potential for development of trees with poor root form (and concern for future tree stability).

**Water Status of Differently Thinned Norway Spruce Stands**

*Landshut*

*August 29, 2011*

In 2008, a research area was established in a 24-year-old Norway Spruce monoculture near Landshut. In this study, the forest researchers are investigating the soil water availability with Norway Spruce managed to different thinning intensities. (The primary hypothesis is that water availability increases with the decreasing tree density). In February 2009, the stand was partly thinned to three different intensities: no thinning (2775 trees/ha), medium thinning (2150 trees/ha), and heavy thinning (450 trees/ha). The different levels of thinning are intended to give the researchers an idea of the amount of rain reaching the forest floor. The most through fall recorded was in the heavy thinning, where precipitation interception was reduced from 52% to 22%.

Base line site conditions were investigated prior to the thinning. Factors such as climate, soil properties, root distribution and density, and soil moisture are among some of the key aspects that were considered. In the first growing season, the heavy thinning plots had the most evident changes; increased soil moisture content was recorded along with an increased growth with the declining tree density. These results show that with thinning treatments there is improved water availability to the target trees.
One concern that was noted during the experiment was that after the thinning treatments, the root biomass did not increase. This could be an issue in the face of climate change and the possibility of increased drought and the ability of the roots to get enough water.

**National Park Bayerischer Wald - Succession Post Bark Beetle, Recreation, Wildlife Management**

*Bayerischer Wald*

*August 30, 2011*

Bayerischer National Park is very special because it was the first National park in Germany and occupies the former demilitarized zone between soviet Czechoslovakia and West Germany. Established in 1970, Bayerisher National Park is the largest tract of contiguous forest in central Europe when combined with the adjacent Bohemian forest park in Czech Republic. Like Canadian national parks, Bayerischer National Park follows a non-interventionist policy against forest disease, windthrow, and insect attacks. Ultimately, this policy “allows nature to take its course” through natural succession, an unusual occurrence in Europe.

**Bark Beetles / Forest Disease**

Within the last decade, Bayerischer National Park has been hit with an unprecedented bark beetle mass attack in the park’s Norway spruce forests. Given the park’s “low intervention” management strategy, this attack was not curbed through forest management or salvage logged post-disturbance. Moreover, this infestation’s scale affected spruce in the park’s lower elevation mixedwood stands. Today, a virtual “ghost forest” now occupies the park’s high altitude regions, creating a stark and “un-parklike” atmosphere (Figure 22). Given aggressive *Calamagrostis* competition, spruce regeneration has been minimal in beetle-killed areas, creating fields of grass (Figure 22).

Figure 24. “Ghost forest” of beetle-killed Norway spruce in Bayerisher National Park. Spruce within the foreground were cut for trailside safety.
Wildlife

Bayerischer National Park is home to many interesting wildlife and fungal species. Among the park’s most renowned creatures are capercaillies. These birds prefer mature spruce stands. The pygmy and Ural owl also calls this park, the latter being recently reintroduced. Finally, red deer, roe deer, and lynx occupy the park. Similar to most regions in Germany, roe deer significantly impair forest regeneration and hunted within the park.

Exotic Species

Near the end of the hike we were shown a cluster of exotic Douglas-fir. With high drought tolerance and impressive growth, Douglas-fir may be an important tree species in Germany under future climate change.

Traditional Oak Management

Spessart
August 31, 2011

Oak (Quercus petraea) has long been a valued forest species in Germany. In medieval times, oak was used to construct durable timber-frame homes that have lasted centuries (Figure 25). Oak was also used to produce coppice fuelwood and feed for prized game and livestock. Today, oak is highly valued for furniture, flooring, veneer, and barrel making, often fetching up to €1500/m³ for veneer and €500/m³ for barrel wood.

Figure 25. Medieval timber-frame construction using oak beams. Constructed in the 14th century, this is the oldest building in the historic city of Hamm-Münden. (Pictured: Martin and Damase)
**Traditional Oak Management**

Under traditional oak management, clearcut areas (30-40ha) were regenerated through high density direct seeding. Subsequent oak stands were very dense and slowly thinned over time to force uplift, create long clear boles (15-20m), and minimize epicormic branching (Figure 24). Any competing beech within these stands were aggressively thinned and maintained as intermediate strata, further limiting epicormic branching in oak (Figure 26). After achieving a “wine glass” form (Figure 27) and a diameter of 80cm, target oak were then harvested. Each “traditional” rotation requires 200-300 years and does not yield a net profit under discount analysis.

![Figure 26. Traditionally managed oak stand at Spessart. Note the long, clear oak boles and intermediate beech.](image)

![Figure 27. “Wine glass” form of traditionally managed oak.](image)
**Modern Oak Management**

Under modern oak management, small shelterwoods (2-3ha) are regenerated through intermediate intensity direct seeding. Subsequent oak stands are well stocked and slowly thinned over time to force crown uplift, create short clear boles (6-8m), and minimize epicormic branching. Throughout the rotation, moderate oak densities are maintained at the expense of clearwood length, creating large oak crowns and faster growth than traditional management. Any competing beech are aggressively thinned and maintained as intermediate strata, further limiting epicormic branching in oak. After developing a broad crown and achieving a diameter of 80cm, target oak are then harvested. Each “modern” rotation requires about 180 years and has better economic performance than traditional management.

**Current Oak Regeneration Practices**

Establishing oak plantations today is a difficult and expensive process, requiring a time sensitive/multistep procedure that costs up to €5100/ha.

Suitable oak sites are selected by their previous stand conditions. To minimize shrub competition after harvest, closed canopy beech stands are preferred.

- Within the selected beech stand, a 2-3ha parcel is harvested to seed-tree densities in mid-summer, prior to an oak mast (Figure 28). (By planting in a mast year, browsing pressure within the oak plantation is reduced.)
- The harvested site is then scarified and plowed to reduce competition, remove organic matter, and create planting microsites (Figure 29). Plowed rows are typically installed at 3-4m spacing.
- Acorns from local seed sources are then planted within the plowed furrows at 650kg/ha (Figure 29).
- Finally, the newly site prepared site is enclosed in fencing to manage deer and boar herbivory (Figure 28).
- After stand establishment, competing beech seedlings (or other species) are thinned (as needed), and the remaining beech overstory is removed by year 10.
- Oak form and growth is then maintained using the “modern” oak management technique.
Figure 28. Thinned 3ha fenced parcel for regenerating oak.

Figure 29. Plantation row of oak. The scarified planting site (i.e. depression) is visible.

Ancient Spessart Oak

If tended and allowed to grow, oak can exceed 300 years in age reach great sizes (Figure 30). However, in the absence of tending, oak will be overtaken by beech and eliminated from a Beech/Mixedhardwood stand. In Figure 30, all tending has stopped within this stand, giving the veteran oak (photo centre) a limited survival window. For historical reasons, Lower Saxony state forests has committed to maintain oak across 25% of the Spessart forest through tending and regeneration activities.
Figure 30. Three hundred year old oak in the “cathedral grove” in the Spessart forest (photo centre). Competing beech are slowly gaining on this veteran in the absence of thinning.

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