Report

Improvement of the forest ecological knowledge base for sustainable forestry and forest conservation in Montenegro

Verbesserung der waldökologischen Informationsbasis für eine nachhaltige Waldbewirtschaftung und den Waldnaturschutz in Montenegro

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Zielsetzung und Anlass des Vorhabens

Aktuell fehlen für die Wälder Montenegros grundlegende Entscheidungsinformationen zur Sicherung einer nachhaltigen, naturschutzgerechten Waldwirtschaft. Das Projekt „Verbesserung der waldökologischen Informationsbasis für eine nachhaltige Waldbewirtschaftung und den Wald-Naturschutz in Montenegro“ soll helfen, die wichtigsten ökologischen Informationsgrundlagen für eine nachhaltige, naturnahe Waldbewirtschaftung in Montenegro durch Zusammenführung vorhandener Unterlagen (Dateien, Karten), innovativer Erhebungsmethoden und IT-Lösungen bereit zu stellen.

Um die Ziele und Grundsätze einer multifunktionalen, nachhaltigen und naturnahen Waldbewirtschaftung erreichen zu können, benötigt der montenegrinische Forstsektor wichtige ökologische Basisinformationen zu den Waldökosystemen. Derzeit fehlen dem Management als Planungsgrundlage und Entscheidungsunterstützung: Informationen über die Waldstandorte (Nährstoff-, Wasser-, Temperaturhaushalt), die potenziellen natürlichen Waldgesellschaften sowie aktuelles Wissen über naturschutzrelevante, seltene und gefährdete Arten, Biotope und Habitate. Im Moment sind in Montenegro die folgenden Probleme zu erkennen:

- Es existiert keine forstliche Karte der Waldstandorte, lediglich eine kleinmaßstäbige Bodenkarte (1:100.000), die für die Bewirtschaftung von Wäldern auf Bestandesebene nicht genau genug ist. Klimatische Faktoren eines Waldstandortes werden darin nicht berücksichtigt.
- Es stehen derzeit nur veraltete Vegetationskarten auf nationalem Skalenniveau (1:1 Mill.) neben der ebenfalls sehr kleinmaßstäbigen "Map of the Natural Vegetation of Europe" (Bohn et al., 2000) zur Verfügung.
- Das „Emerald Network" inventarisiert Vorkommen von seltenen und gefährdeten Arten, Biotopen und Habitaten, jedoch fehlt eine systematische Kartierung. Derzeit wird die Definition von zu schützenden Biotopen/Habitaten erarbeitet. Viele Daten zu Vorkommen von Faunen- und Florenelementen sind verteilt über verschiedene Institutionen, Nichtregierungsorganisationen oder – wie im Beispiel der Wildarten - nur im Jagd-Sektor zu finden. Die Informationen sind nicht genügend aufbereitet und stehen für eine nachhaltige, naturschutzgerechte Waldbewirtschaftung nicht zur Verfügung.

Hauptziel dieses Projekts ist es daher, ein innovatives Konzept zur Verbesserung der ökologischen Datengrundlage für eine nachhaltige Waldbewirtschaftung und den Waldnaturschutz bereitzustellen und durch Fallbeispiele exemplarisch zu erproben.

Darstellung der Arbeitsschritte und der angewandten Methoden

Das Hauptziel des Projektes wird durch die Bearbeitung folgender Teilziele und Aufgaben bzw. mit folgenden Herangehensweisen erreicht:

- Verbesserung der Informationen zu Waldstandorten durch Kompilation aller verfügbaren Unterlagen;
- Aufbereitung von Waldnaturschutz-Informationen und Integration der ökologischen Basisinformationen in eine öffentlich zugängliche „Waldökologische Geodatenbank";
- Verbesserung der Informationen zu den Standortseigenschaften durch Kombination von Boden-, Klima- und Vegetationsparametern, Aufnahme von Probeflächen in zwei Testgebieten (Štitovo, Bielasica), Auswertung durch multivariate Methoden (Ordination, Klassifikation);
- Exemplarische Ableitung der potenziellen natürlichen Waldgesellschaften in zwei Testgebieten (Štitovo, Bielasica);
- Exemplarische Umsetzung der neuen ökologischen Informationen in „Sustainable Forest Management Plans" inklusive Definition und Zuordnung von Waldentwicklungstypen (WET) zu Standorts- und Vegetationstypen;
- Integration aller verfügbaren Datenbanken in das neue „Forest Information System" (FIS);
- Wissenstransfer durch Qualifizierung von montenegrinischem Forstpersonal;
- Wissenstransfer durch Qualifizierung von zwei jungen montenegrinischen Doktoranden mit standortskundlicher Themenstallung (Doktorarbeiten in Belgrad; Betreuung durch Professoren aus Belgrad und Freiburg);
- Exemplarische Erstellung eines Managementplans für einen Forstbetrieb.

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1 ZUSAMMENFASSUNG

Dieses DBU-Projekt greift die fehlenden grundlegenden Entscheidungsinformationen zur Sicherung einer nachhaltigen, naturschutzgerechten Waldwirtschaft für die Wälder Montenegros auf. Die generelle Projektidee war, die wichtigsten ökologischen Informationsgrundlagen für eine nachhaltige, naturnahe Waldbewirtschaftung in Montenegro durch Zusammenführung vorhandener Unterlagen (Dateien, Karten), innovativer Erhebungsmethoden und IT-Lösungen im Sinne eines umfassenden Umweltinformationssystems zu entwickeln.

Hauptziel des Projekts war, ein innovatives Konzept zur Verbesserung der ökologischen Datengrundlage für eine nachhaltige Waldbewirtschaftung und den Waldnaturschutz bereitzustellen und durch Fallbeispiele exemplarisch zu erproben. Mehrere Teilziele und Aufgaben waren damit verbunden:

- Verbesserung der Informationen zu Waldstandorten und zur Waldvegetation;
- Verbesserung der Informationen zu „Potenziellen natürlichen Waldgesellschaften";
- Aufbereitung von Waldnaturschutz-Informationen und Integration der ökologischen Basisinformationen in eine öffentlich zugängliche „Waldökologische Geodatenbank";
- Exemplarische Umsetzung der neuen ökologischen Informationen in „Sustainable Forest Management Plans" inklusive Definition und Zuordnung von Waldentwicklungstypen (WET) zu Standorts- und Vegetationstypen;
- Integration aller verfügbaren Datenbanken in das neue „Forest Information System" (FIS);
- Wissenstransfer durch Qualifizierung von montenegrinischem Forstpersonal;
- Exemplarische Erstellung eines Managementplans für einen Forstbetrieb.

Dieses internationale Projekt wurde von der Albert-Ludwigs Universität, Freiburg (Professur für Standorts- und Vegetationskunde) geleitet und in Zusammenarbeit mit folgenden Partnern durchgeführt:

- **Deutsche Partner**: UNIQUE forestry and land use sowie die Firma Soilution;
- **Montenegrinische Partner**: Ministerium für Landwirtschaft und ländliche Entwicklung (MARD) inklusive der dort zugeordneten staatlichen Forstverwaltung (Forest Administration); das Ministerium für nachhaltige Entwicklung und Tourismus (MSDT); die Environmental Protection Agency (EPAM); das Hydrometeorologische Institut und die Real Estate Agency (REA);
- **Serbische Partner:** Universität Belgrad, Forstwissenschaftliche Fakultät (Bodenkunde, Vegetationskunde).

Der empirische Teil des Pilotvorhabens wurde in Form einer **Standorts- und Vegetationserhebung** in zwei ökologisch unterschiedlichen Forsteinrichtungseinheiten (Štitovo, Bjelasica) umgesetzt. Diese 2 Forsteinrichtungseinheiten befinden sich im Norden und im Zentrum Montenegros und verfügen über verschiedene Geologien (Kalk, Silikat) und Klimate (oromediterran, illyrisch) sowie unterschiedliche Pflanzen- und Baumartenvielfalt.

Die neu entwickelte Methodik bietet die Grundlage für detaillierte, fein aufgelöste thematische Standorts- und Vegetationskarten, welche in FoSiM integriert sind. Diese Karten fassen die ökologischen Informationen im Bezug zu Wasser- und Nährstoffhaushalt zusammen, sie sind die Grundlage für weitere Standortsanalysen. Die Methode ist prinzipiell auf andere Regionen übertragbar.

Die Analyse der im Gelände erhobene Boden- und Vegetationsmerkmale diente der Identifizierung der ökologischen Grenzen für das Wachstum der wichtigsten Baumarten und damit verbunden der

Ableitung verschiedener Waldentwicklungstypen in den zwei ausgewählten Forsteinrichtungseinheiten (Štitovo, Bjelasica).

Aufgrund der naturnahen Ausprägung der Inventurplots konnten Vorkommensbereiche und –grenzen wichtiger Baumarten identifiziert und durch Umweltparameter charakterisiert werden. Dies erlaubt Rückschlüsse auf die potentielle natürliche Verbreitung dieser Baumarten.

Getrennt von den auf empirischen Erhebungen basierenden Erhebungen erfolgte die **Entwicklung eines web-basierten umfassenden Umweltinformationssystems**, in dem die verschiedenen Formate der Umweltdaten in einer waldökologischen Datenbank vergleichbar gemacht werden, GIS-basierte Karten erstellt werden und über eine zu schaffende **Internet-Plattform** öffentlich zugänglich gemacht werden. Eine Vorläuferversion mit allen relevanten Funktionen konnte innerhalb des Projektes entworfen und mit den Projektpartnern abgestimmt werden. In diese können neue Daten eingepflegt werden und Karten erstellt werden, beispielsweise von der beiden Testgebieten (Štitovo, Bjelasica). Weitere Auswertungen hinsichtlich der Baumarteneignung in der Waldwirtschaft wären möglich, konnten jedoch aufgrund fehlender Waldinventurdaten aus den beiden Testgebieten nicht umgesetzt werden.

Die Projektziele wurden nicht alle erreicht, verschiedene **Herausforderungen** haben die Umsetzung der Projektziele erschwert. Änderungen in der Legislative in Serbien und der Verwaltungsstruktur in Montenegro haben dazu geführt, den Auftakt der Geländearbeit in der ersten Vegetationszeit zu verzögern. Der Abschluss von Verträgen zur Zusammenarbeit zog sich über mehrere Prüfinstanzen bis zu 2 Jahre hin. Dies hat dazu geführt, den bürokratischen Aufwand zu erhöhen und erhebliche Zeitverzögerungen bewirkt. Darüber hinaus hat dieses Projekt gezeigt, dass bei der Erstumsetzung der Methode die Anzahl der zu erhebenden Daten stark unterschätzt werden kann. Erst im Laufe der Analyse wurde offensichtlich, dass mehr Proben notwendig sind, um die Varianzen besser einschätzen zu können. Nicht alle benötigten Daten konnten den Probeflächen zugeordnet werden. Dies gilt beispielsweise für die Modellierung von Niederschlagsdaten im Bergland aus extrem wenigen Klimastationen. Auch stellten die Messung der pH-Werte und die Tiefe der Bodenprofile unter 60 cm ein großes Problem dar. Dies entstand v. A. aufgrund mangelhafter zeitlicher (z. B. nicht genügend Zeit für Proben-Wiederholung) sowie technischer Kapazitäten (z. B. nicht verfügbare Ausrüstung vor Ort).

Trotz dieser Herausforderungen liefert dieses Projekt die allererste ökologische Geo-Datenbasis für Boden- und Vegetationsinformationen in Montenegro. Diese Datenbasis ist nicht nur die allererste systematische Sammlung von ökologischen Informationen in Montenegro, sondern auch eine Grundlage für Weiterentwicklung und follow-up Tätigkeiten im montenegrinischen sowie regionalen Forstsektor.

Die Montenegrinischen Partner aus Politik und Verwaltung haben die Vorteile eines holistischen standortskundlichen Ansatzes sowie die Bedeutung eines umfassenden Umweltinformationssystems erkannt, das beispielsweise für Planungen und Reporting eingesetzt werden kann. In transparenter Weise können damit Ministerien, Planungsinstitutionen (z.B. Forst-, Umweltbehörden) sowie die interessierte Öffentlichkeit auf diese Informationen zugreifen und als Diskussions- und Entscheidungshilfe anwenden. Auch andere südosteuropäische Nachbarländer haben die Bedeutung eines derartigen Umweltinformationssystems erkannt. Damit besteht die Grundlage für eine weiterführende Zusammenarbeit, wie sie zurzeit mit Serbien in Form einer IPA2 Cross border Kooperation sowie einem weiteren Testprojekt in Zentralserbien in Vorbereitung befindet.

2 BACKGROUND AND GOALS OF THE PROJECT

In a country where forests covers 69.4% (0,96 mio ha, the total of Montenegro is 1,4 mio ha), forest are not only the characteristic landscape element but also a great natural resource. Almost 52% of the Montenegrin forest is state owned and 48% of the forests are privately owned.

These forest provide a wood volume of 122 million m³ (previously estimated 72 mio m³) and an increment of 2. 9 million m³/a (vs. 1.4 mio m³/a) in wood volume. The potential for wood harvest for was estimated as 1.8 mio m³/a (60% of the increment) for the period 2011 – 2020. If this potential would be optimally used in modern wood industry it would provide an added value of 1,600 mill €/, and could provide work for 48,000 employees in the forestry and wood cluster.

But the forest landscape also have a high environmental value because of its high amount of dead wood (7.2 m³/ha) and 46% of the forest area was also classified as potential Annex I habitats regarding Natura 2000. Additionally 23% of forests and forest land provides protection function.[1]

New challenges for the forest sector in Montenegro are the adaptation to climate change and preservation of biodiversity. The latter is especially important as a preparation for the EU biodiversity strategy to meet the requirements of the EU Natura 2000 framework.

With the National forest policy (MARD 2008) and the new forest law Montenegro (MARD 2010) committed itself to sustainable and multifunctional forest management and conservation and enhancement of biologic and landscape forest biodiversity, and its environmental quality. This nation-al commitment was supposed to adopt an "ecosystem approach to forest management"(NFP prin-ciple) integrating the protection of biologic and landscape forest biodiversity as well as "close-to-nature forest management". Specifically the following principles should guide forest management: (1) Ecological stability of forest ecosystems by making use of site information and (2) Orientation on site conditions which means to match species - site and the natural potential forest vegetation; and (3) Utilization of natural processes to reach the desired management objectives and "low input management" making use of natural regeneration.

However, the forest administration of Montenegro was lacking fundamental ecological and economic data for decision making to ensure sustainable, conservation-oriented forestry. This DBU-funded project aimed to provide the most important environmental information base for sustainable, natural forest management in Montenegro by pooling of available documents (files, maps), drafting of innovative research methods and IT solutions.

In order to achieve the objectives and principles of a multi-functional, sustainable and natural forest management, the Montenegrin forest sector needed ecological base information on forest ecosystems. The forest management is missing the following information as a basis for planning and decision support: information on forest sites (nutrients, water, temperature), which could be linked to forest inventory data; the fine-scale potential natural forest vegetation; as well as updated knowledge about rare and endangered species and habitats.

At the beginning of the project, the following problems have been identified in Montenegro:

- There was no existing map of forest sites, only a small-scale soil map (1: 100,000), which did not have sufficient precision to be used for the management of forests to stand level. Climatic site factors were not integrated into the site classification system.

[1] Data are taken from the first National Forest Inventory (Dees et al. 2013)

- Then there existed only imprecise vegetation maps at national scale (1 : 1 million) in addition to the also very small-scale "Map of the Natural Vegetation of Europe" (Bohn et al., 2003).
- The "Emerald Network" inventoried the occurrence of rare and endangered species, biotopes and habitats, however, no systematic mapping was performed. The definition of the protected biotopes / habitats was not developed. Many data on the occurrence of fauna and flora elements were distributed isolated throughout different institutions, non-governmental organizations, or - as in the case of animal species concerning hunting – could e only obtained from hunters. The existing information was not systematically processed, it was not available for a sustainable, conservation-oriented forest management.

Objectives

General objectives of the Montenegrin partner:

- Increase the competitiveness of the forestry sector and
- Thereby foster rural development in Montenegro by improving and securing close-to-nature sustainable forest management that fulfill key EU standards on forest management and protection as well environmental protection standards.
- Implement a modern, innovative methodological approach for improvement of the ecological information base for sustainable forest management and forest conservation and
- To test it in several pilot areas of Montenegro.

Project objectives:

The main project objective of the project was to provide an innovative approach to improve the environmental database for sustainable forest management and forest conservation; and to develop methods for a systematical forest site and vegetation inventory which will be tested in exemplary case studies.

Several detailed objectives and tasks were derived:

- Improving information on forest site conditions
- Improving the information on the potential natural forest vegetation
- Preparation of forest conservation information and its integration in a publicly accessible "forest ecological geodatabase"
- Exemplary implementation of the new environmental information in "Sustainable Forest Management Plan", including definition and classification of forest development types (FDT) to site and vegetation types
- Integration of all available data in the new "Forest Information System" (FIS)
- Knowledge transfer through training of Montenegrin forestry personnel
- Exemplary preparation of management plans for pilot management units

3 WORKING STEPS AND APPLIED METHODOLOGIES

The **Phase 1:** "Pre-study" served all work packages by compiling and evaluation of available data. This step was followed by a site productivity analysis in relation to existing data from the National Forest Inventory of Montenegro, as should be linked with the Forest Management Plans. The recently finished National Forest Inventory was an important element for an early test of the selection of the model parameters for the method development in this project to classify the forest sites and to derive the potential natural forest vegetation. This pre-study was done in a Master Thesis prior to the project start (Zehfuss, 2013). As a result of this pre-study two out of the 135 Montenegrin "Forest Management Units" were selected as areas to test the developed methodology of site and vegetation survey, analysis and mapping.

The test areas were used in **Phase 2** to develop and in **Phase 3** to implement the methods of the work packages 1-3. After developing the inventory method, it was applied to assess site and vegetation data. The site mapping was performed mainly applying the forest site classification of the German Federal State of Rhineland-Palatia (Arbeitskreis standortskartierung in der Arbeitsgemeinschaft Forsteinrichtung 2016). A prognostic analysis step of regionalization and validation of the site forecast model was tested, a Web-GIS application for the forest ecological geodatabase was developed to provide maps of forest sites conditions as thematic information layers.

With respect to the forest vegetation, in total 271 sample plots were recorded with combined soil and vegetation data. The actual distribution of the tree species provided the base to construct their potential natural distribution and their site limits which is an important step to construct the distribution of the potential natural forest vegetation.

Initially it was planned to construct a map of the potential natural forest vegetation in a following step, based on the assessed vegetation data and the compilation and analysis of historical information. This step was not performed, because the numerical classification of the vegetation data remained preliminary, and their ecological limits were not quantified. This explains also why the methods description in a manual as well as the compilation of all conservation-related information about the test areas remained rudimentary.

Also in **Phase 3** it was originally planned for these two test areas to introduce the results in new forest management plans. These should be based on the updated and more precise new information about site factors, vegetation and other habitat parameters, and the forest revised inventory data from the two selected Management units. This step was not be performed because of incomplete analysis of the vegetation-site relationships, and the failing new forest management plan.

The originally planned forest ecological geodatabase, despite remaining rudimentary, became a module for the developing Forest Information System (FIS). The planned workflow and results are presented in Figure 1.

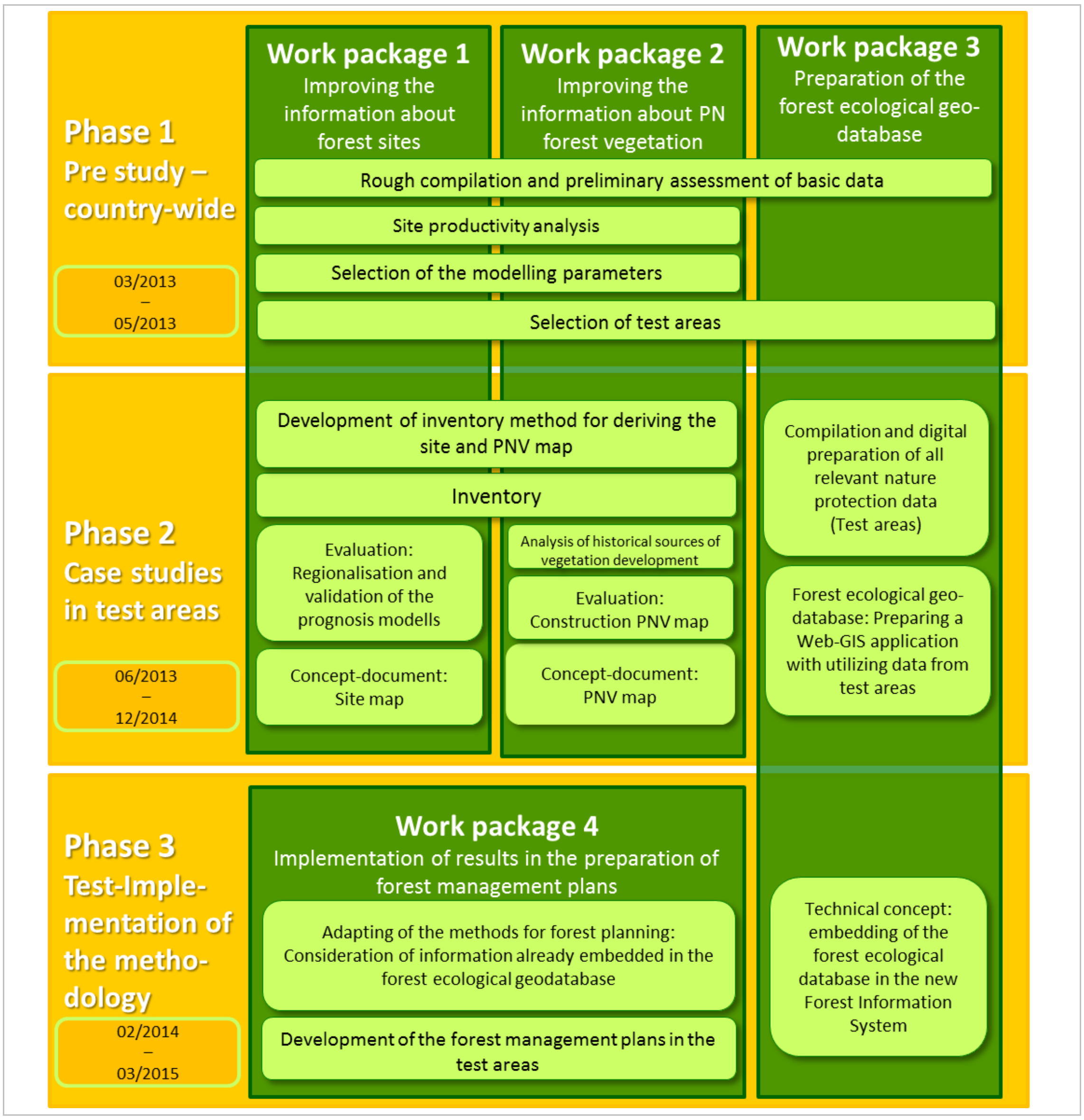


Figure 1. Project phases and tasks within the work packages

3.1 Work package 1: Improving the information on forest site conditions

In work package1, a statistical approach for spatial prediction of site properties was developed and tested from forest sites, which is adapted to the specific physiographic conditions. The goal is to develop a method that can provide the ecological information base for sustainable, close-to-nature forest management.

The results are:

- An innovative mapping and modelling concept for assessing spatial forest site information
- Maps with soil, climate and site conditions for forest areas (goal 1: 25,000), which served as a base for deriving the potential natural forest vegetation (WP2). For forest management, these maps provide the base for evaluating tree species suitability and productivity.

3.2 Work package 2: Improving the information on the Potential Natural Forest Vegetation

In direct connection with the first stage of the forest site sampling, a vegetation sampling and mapping was planned, but remained incomplete and restricted to demonstrate the method to derive the ecological limits of the most important tree species. The transfer to the analysis of the limits of the actual forest types, and the transfer to the potential natural forest vegetation limits, could not be achieved, and also affected the mapping.

3.3 Work package 3: Developing a Forest Ecological Geodatabase (FEGDB)

As decision support system for the forest management and publicly accessible information platform a "forest ecological geodatabase (FEGDB)"should be developed. It shall compile the information from different new sources:

- Forest site geodatabase (see WP 1)
- Geodatabase on potential natural forest vegetation (see WP 2)
- Information relevant for nature protection, wildlife management and biodiversity

For the third dataset the existing information about rare and endangered species and habitats relevant for forestry, hunting and nature conservation sector should be integrated into the FEGDB. It was foreseen to collaborate with the Ministry of Sustainable Development and Tourism (MSDT) to develop a systematic and permanent access to this data for all stakeholder and institutions that are active in nature conservation, in forestry and in the hunting sector. In order to complement and update the existing data which is very scattered, an active access for relevant actors and institutions should also be considered, which allows to add information on the occurrence of rare or/and endangered species, biotopes and habitats to the database.

Expected results:

- Web-based forest ecological geodatabase as decision support for the forest sector and publicly accessible information system and interactive application
- Technical concept for the integration of the forest ecological geodatabase as a module in the newly planned Forest Information System (FIS).

3.4 Work package 4: Implementation of the new ecological information into Sustainable Forest Management Plans

In the two selected test areas, the new ecological information (results of WP 1, 2 and 3) should be used directly in two case studies for forest management planning. It would be the first time that the objectives of a sustainable and natural forest management are planned making use of the new forest ecological information.

Therefore, the project plans to support the Forest Administration in the adaptation of planning manuals and techniques. How and where the new ecological information can be used during the Forest Management Planning process will be added to the existing Forest Management Planning Manual and the future utilization of the ecological information will be described in the by-law on forest management planning.

Expected results:

- New version of the „Manual for Forest Management Planning" under inclusion of the new forest ecological information and proposal for a updated version of the by-law on forest management planning
- Sustainable Forest Management Plan for the two test Forest Management Units (MU) created using the new forest ecological geodatabase (FEGDB).

4 RESULTS AND OUTCOMES

4.1 Preparation phase

The development of a method to classify Montenegrin forest sites had to use the available site and vegetation data. Because not all needed data for each plot could be measured or recorded in the field, they had to be modeled using existing nearby measurements, e.g., from climatic stations, or existing soil profile descriptions.

4.1.1 Data compilation and parameter selection

Initially, a checklist of potentially available (geo)-data has been created to provide data for several work packages:

- WP 1: Forest Site mapping
- WP 2: Mapping the Potential Natural Forest Vegetation
- WP 3: Information relevant for nature protection, wildlife management and biodiversity

All available forest related datasets and maps were compiled.

The relevant institutions – mainly the partner institution in the project– have been asked to provide all existing and available datasets based on the checklist created. The following institutions were contacted and provided data:

- Real Estate Agency – provided data related to topography and administrative level
- Ministry of Agriculture and Rural Development (MARD) – provided forestry related data such as spatial data of forest management units, forest management plans, the geodatabase of the results of the national forest inventory
- Institute for Hydrometeorology and Seismology (HMZCG) – provided climate related data
- Ministry of environment and Environmental Protection Agency –data on nature protection zones (national parks, Emerald network protection zones)

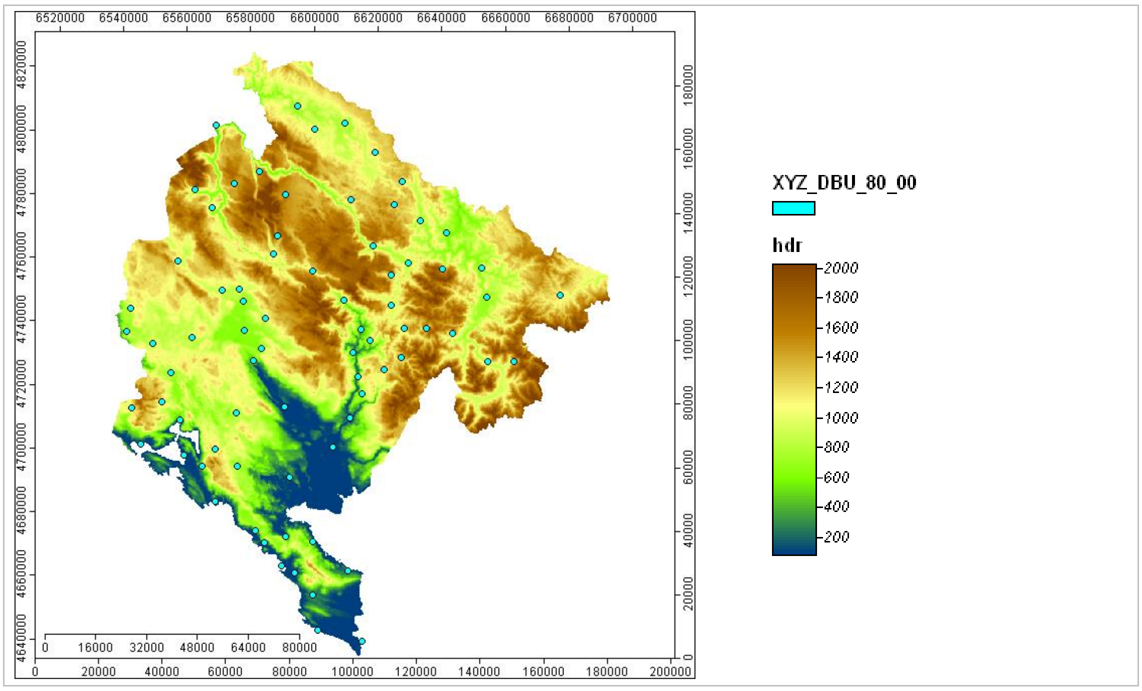
An overview of the requested and obtained data is available in chapter 8, Appendix 1.

In the next chapter we present the available basic data selected for developing the methodologies. The final model parameters selected and derived for the single models are presented in the corresponding chapters 4.2 and 4.3.

4.1.2 Relevant basic data

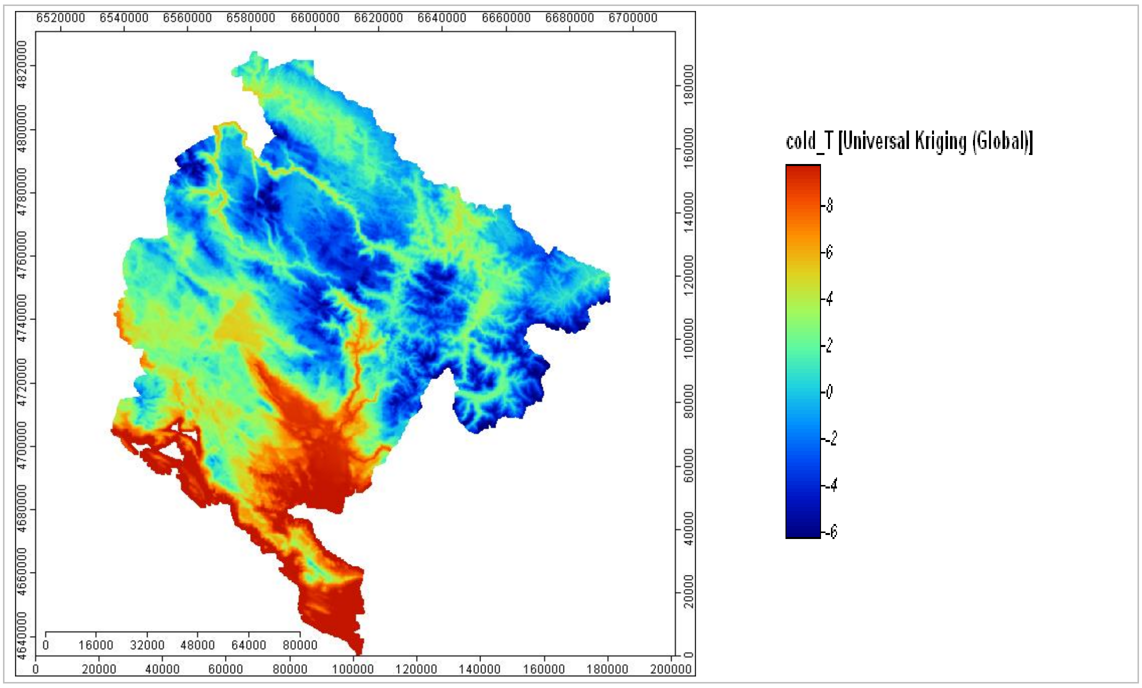
4.1.2.1 Climate data

Climate data in Montenegro is available as raster maps with a resolution of 100m based on the climate stations in Figure 2. Although finer resolutions are generally recommended this data had to be used for forest site mapping in Montenegro (cf. chapter 5.2.1).



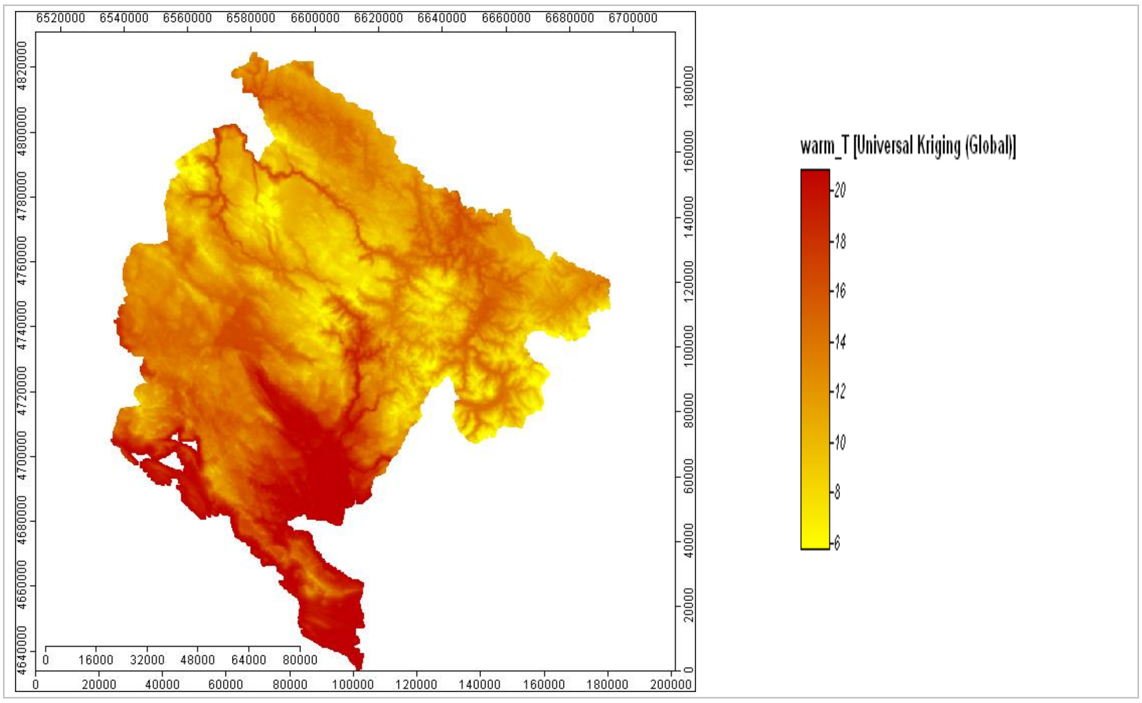
Source: M. Ivanov, Institute of Hydrometeorology and Seismology, Montenegro

Figure 2. Location of the climate stations draped over the DEM



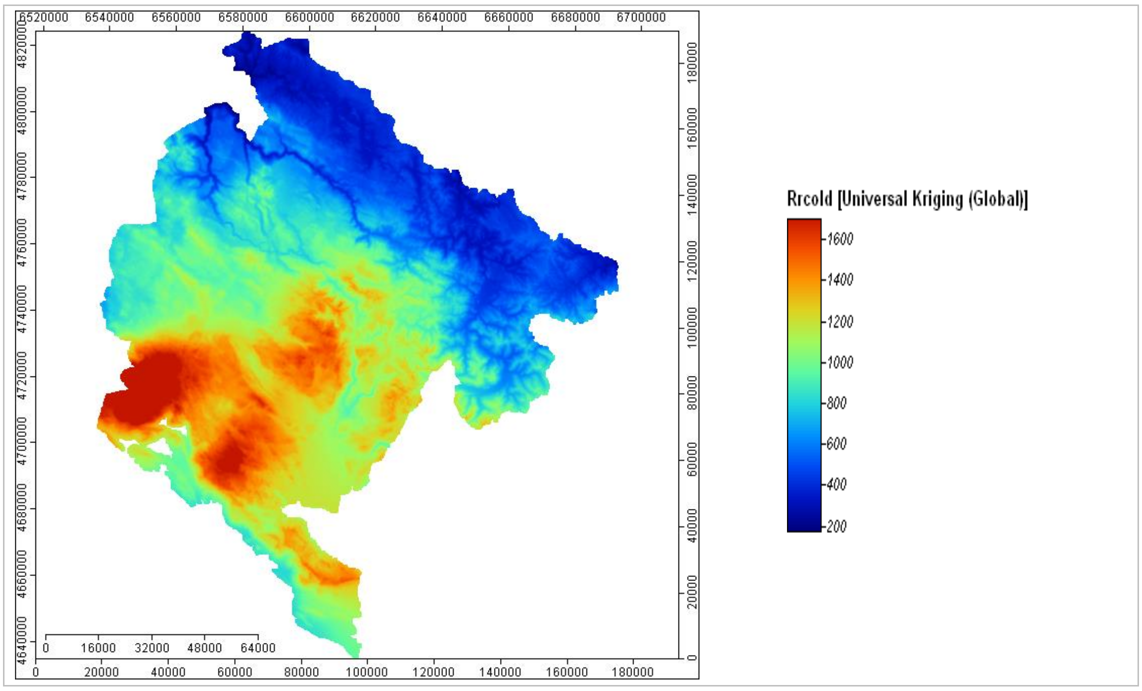
Source: M. Ivanov, Institute of Hydrometeorology and Seismology, Montenegro

Figure 3. Daily temperature averaged for the cold season October-March



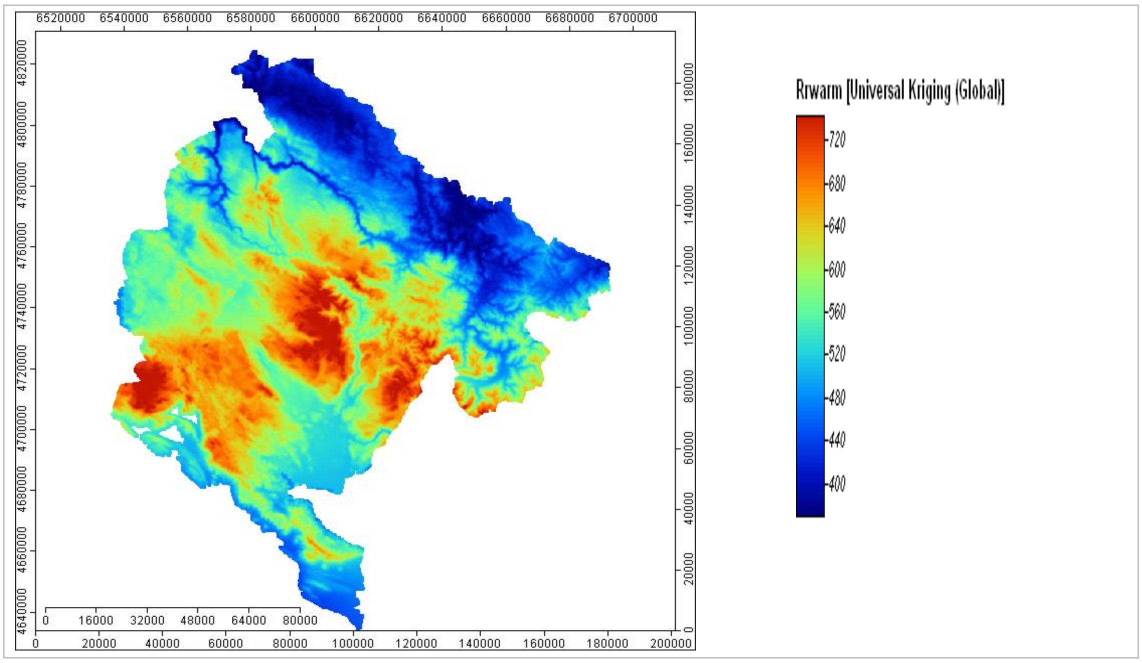
Source: M. Ivanov, Institute of Hydrometeorology and Seismology, Montenegro

Figure 4. Daily temperature averaged for the warm season April-September



Source: M. Ivanov, Institute of Hydrometeorology and Seismology, Montenegro

Figure 5. Daily precipitation averaged for the cold season October-March



Source: M. Ivanov, Institute of Hydrometeorology and Seismology, Montenegro

Figure 6. Daily precipitation averaged over the warm season April-September

4.1.2.2 Digital elevation model (DEM)

For the management unit survey during the project a DEM with a resolution of 2 m was available. With respect of the aim to map the whole country and due to some artifacts (cf. chapter 5.2.1) in the DEM the resolution was resampled to 10 m. On this level the DEM shows a good quality for site mapping.

4.1.2.3 Soil and parent material

A soil map containing some information on parent material was available at a scale of (1:50,000 for Montenegro. However, soil data regarding water balance and nutrient regime, necessary for forest site classification could only be estimated due to the coarse scale. Further information was available as reference soil profiles. These profiles were not available as GIS layers and georeferencing is not possible. Hence, this data was not available during the project.

4.1.3 Identification of test areas

Besides data acquisition an important step was to decide about the number and the location of the test areas in Montenegro. With the local partners we decided to select management units (MU; defined regions for a common forest management plan) to be the spatial representation of the test areas. Because these are also used as planning units in forestry which is the main application of the methods developed in this project. The forestry administration divided the country´s forest area in management units to organize inventory and planning (see Fig 7). Two MUs were selected based on the following criteria discussed at the Kick-off meeting:

- The Forest Management Plan revision was planned for 2015 – which should provide synergetic effects regarding field work on site (WP 1) and vegetation assessment (WP 2)
- Representative regarding geology, climate and landscape formations

- Homogeneity of the soil conditions within each MU
- A Diversity of vegetation types and tree species compositions

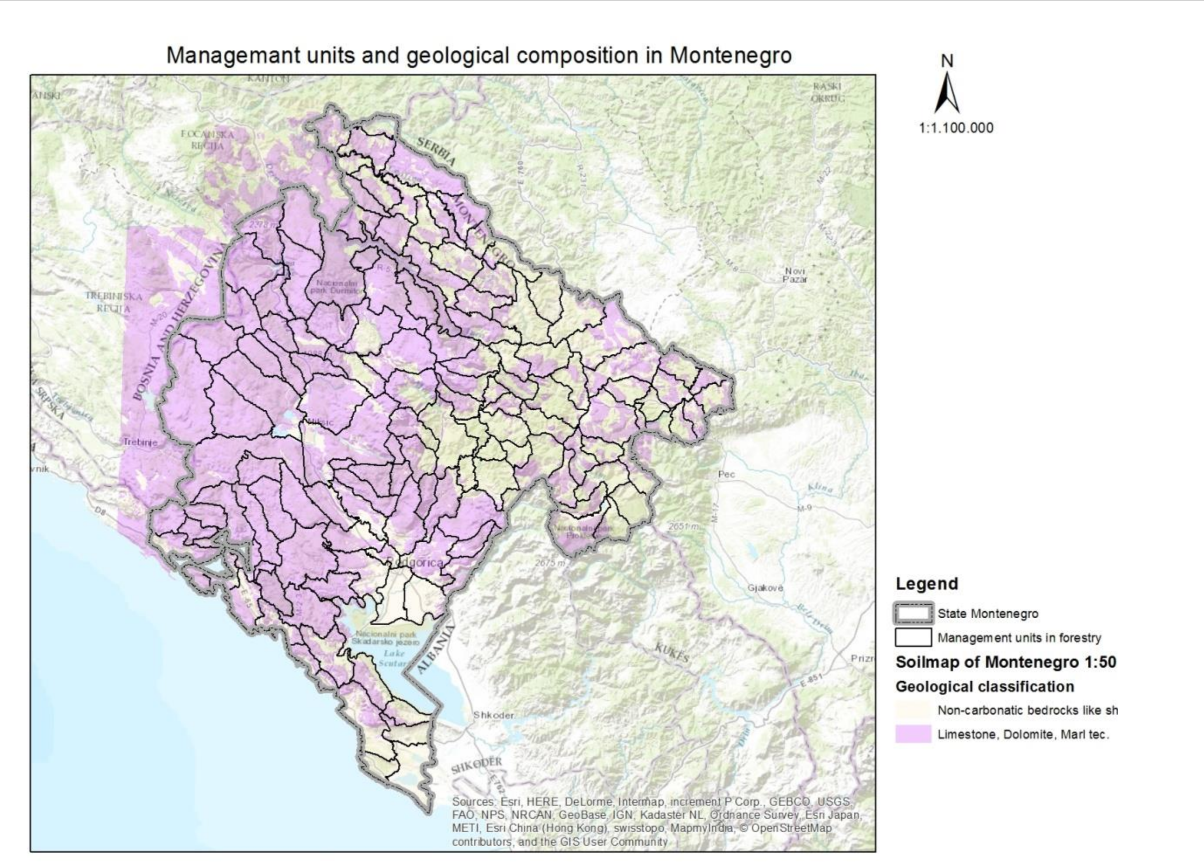


Figure 7. Management units and geological composition in Montenegro (bedrock in the soilmap of Montenegro (1.50.000): lilac: calcerous bedrock like dolomite or limestone; green: non-calcerous bedrocks like shist, sandstone, clay etc.)

Only two management units were in the pipeline to be inventoried in 2014 and 2015 and were homogenous regarding the soil conditions, but with a diversity in the vegetation. The management units (MU) selected as test areas were Štitovo (1541) and Bjelasica (1101).

4.1.3.1 MU „Bjelasica“

4.1.3.1.1 Study region

The MU Bjelasica (1101) is situated in the middle-east of Montenegro near the border to Serbia in the administrative district of Bijelo Polje including a small area of Berane in the southern part of the municipality of Bijelo Polje, on the left side of the river Lim, on the northern side of mountain Bjelasica (Figure 8). The total area under forest management comprises 9205 hectares. 5248 ha are forested, of which high forests having semi-natural tree species composition (i.e., resulting from natural regeneration) cover 82%.

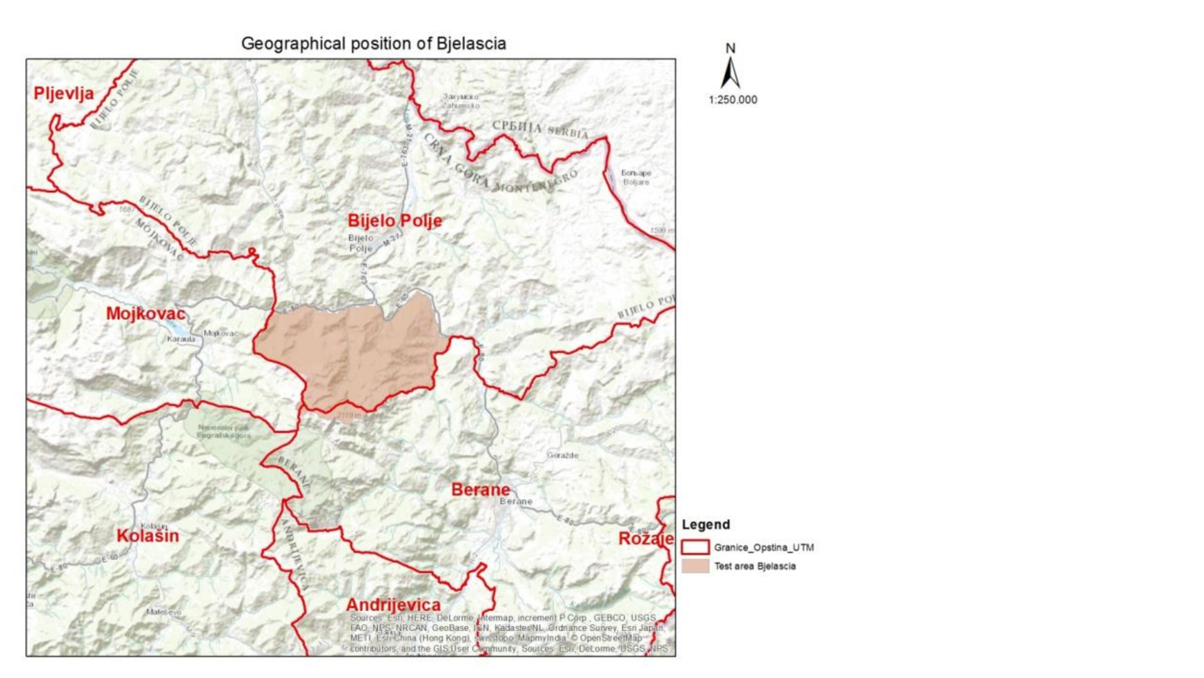


Figure 8. Administrative position of MU Bjelascia

4.1.3.1.2 Geology and Soil

The geology is very diverse. At lower altitudes predominantly shale and sandstone occur. At higher altitudes carbonate-silicate bedrock prevails. The main characteristics of this area are moderately steep to steep slopes. 53% of forest area is located on a moderately steep slopes (11-20^{o}) and 43% on steep slopes (21-30^{o}). The MU is located at the northern slopes of Bijelasica Mountain, therefore the prevailing exposure of the terrain is north (N, NE and NW comprise 77% of the Management unit "Bjelasica"). The lowest point is 585 m NN, the highest elevation reaches 1850 m NN. Many springs and streams have deeply incised their riverbeds. Between the water courses are ridges, mostly running from south to north.

The soil map of Montenegro describes the pedological situation as Rendzina over hard limestone in small patches surrounded by Brown Soil on carbonate-silicate bedrock and a few places with Ranker on sandstone in the highest mountains. On the slopes Brown Soil was dominating on shist or sandstone. In furthest Northwest alluvial sediments were common (Figure 9).

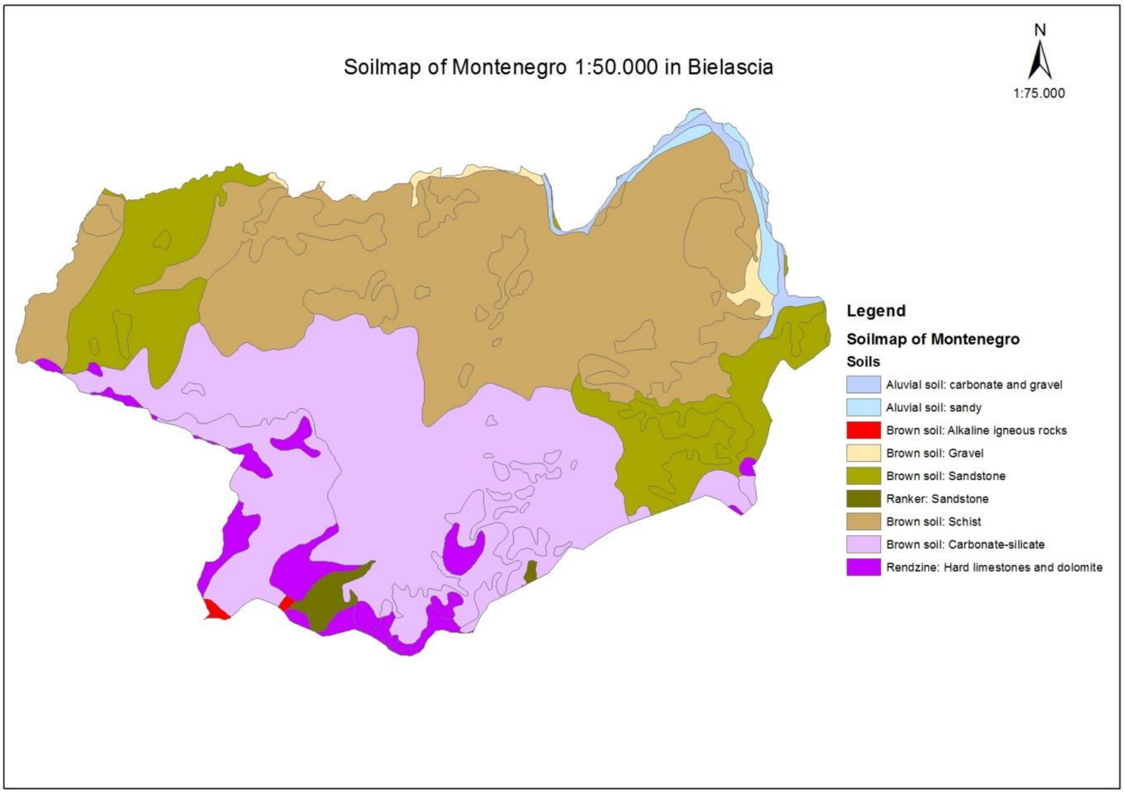


Figure 9. Soils of the test area Bjelascia based on the soil map of Montenegro (1:50.000)

4.1.3.1.3 Climate

The climate of the MU Bijelasica was characterized by the data from the climatic station Bijelo Polje. It is characterized by its location on the inland side of the mountain ranges, i.e. as more continental ("Illyric"). Because of the high altitude (montane zone) there are no arid months.

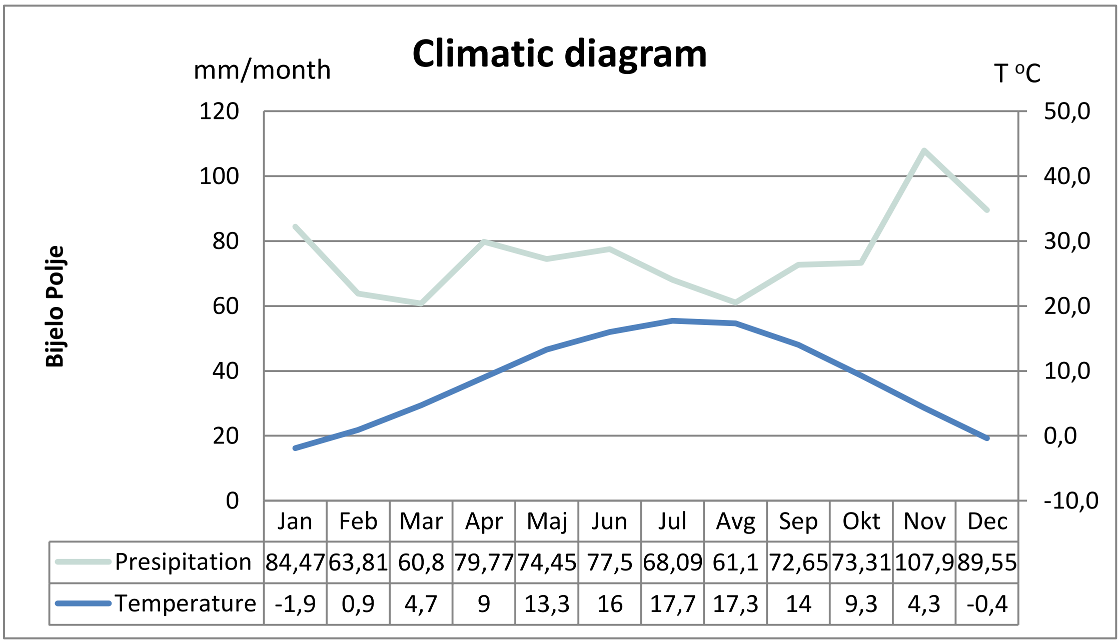


Figure 10. Annual course of temperature and precipitation of the climatic station Bijelo Polje (570 m NN)

Based on the measured values of the climatic station Bijelo Polje the temperature was modelled for the altitudes between 620 and 1719 m NN:

- The mean annual air temperature at 620 m is 8.7 ° C, and at 1719 m is 3,3° C.
- At 620 m a.s.l. the duration of the vegetation period is about 230 days (Formayer, 2007). There the growing season usually begins around March 19 and ends November 15. For every 100 m increase in altitude vegetation period shortens for 11.5 days. On the basis of legality can be concluded that the length of the vegetation period of 1300 m a.s.l. lasts about 165 days, and at the upper limit of the studied zone at 1700 m a.s.l. only 126 days.
- Measured temperature data from climatic reference station were used to model the regional variability including elevational differences. These calculations were based on a temperature lapse rates of 0,65° C (in summer and spring), 0,52 ° C (in autumn) and 0,35 ° C (in winter) per 100 m altitude (Milosavljević, 1988).
- The amplitude of monthly mean temperature is 20.2 ° C at 591 m and 18.2 ° C at 1467 m a.s.l. That means with increasing altitude continentality decreases. The temperature amplitude of monthly mean temperatures during the growing season is at all altitudes between 9.8 and 10.7 ° C. The annual precipitation was modeled according to changes in elevation, it ranged below 800 mm and exceeded 1600 mm at the highest plots.

Table 1. Monthly mean temperature in the MU of Bijelasica, modeled for different elevations

T°C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
900m	-2,89	-0,09	3,71	8,01	12,31	15,01	16,71	16,31	13,01	8,31	3,31	-1,39	7,71
1100m	-3,99	-1,19	2,61	6,91	11,21	13,91	15,61	15,21	11,91	7,21	2,21	-2,49	6,61
1300m	-5,09	-2,29	1,51	5,81	10,11	12,81	14,51	14,11	10,81	6,11	1,11	-3,59	5,51
1500m	-6,19	-3,39	0,41	4,71	9,01	11,71	13,41	13,01	9,71	5,01	0,01	-4,69	4,41
1700m	-7,29	-4,49	-0,69	3,61	7,91	10,61	12,31	11,91	8,61	3,91	-1,09	-5,79	3,31

Table 2. Monthly mean precipitation for the period 1961-1990, Bijelo Polje (mm/month)

Bijelo Polje	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Precipitation (mm)	84,5	63,8	60,8	79,8	74,5	77,5	68,1	61,1	72,7	73,3	108	89,6	913,7

4.1.3.1.4 Vegetation

In the highlands Illyrian-Dinaric altimontane beech-, fir-beech- and Illyrian-west Balkan montane spruce forests occurred. On the slopes on shist and sandstone were Dinaric beech forest and West Moesian herb-rich sessile oak forests were common (Figure 11).

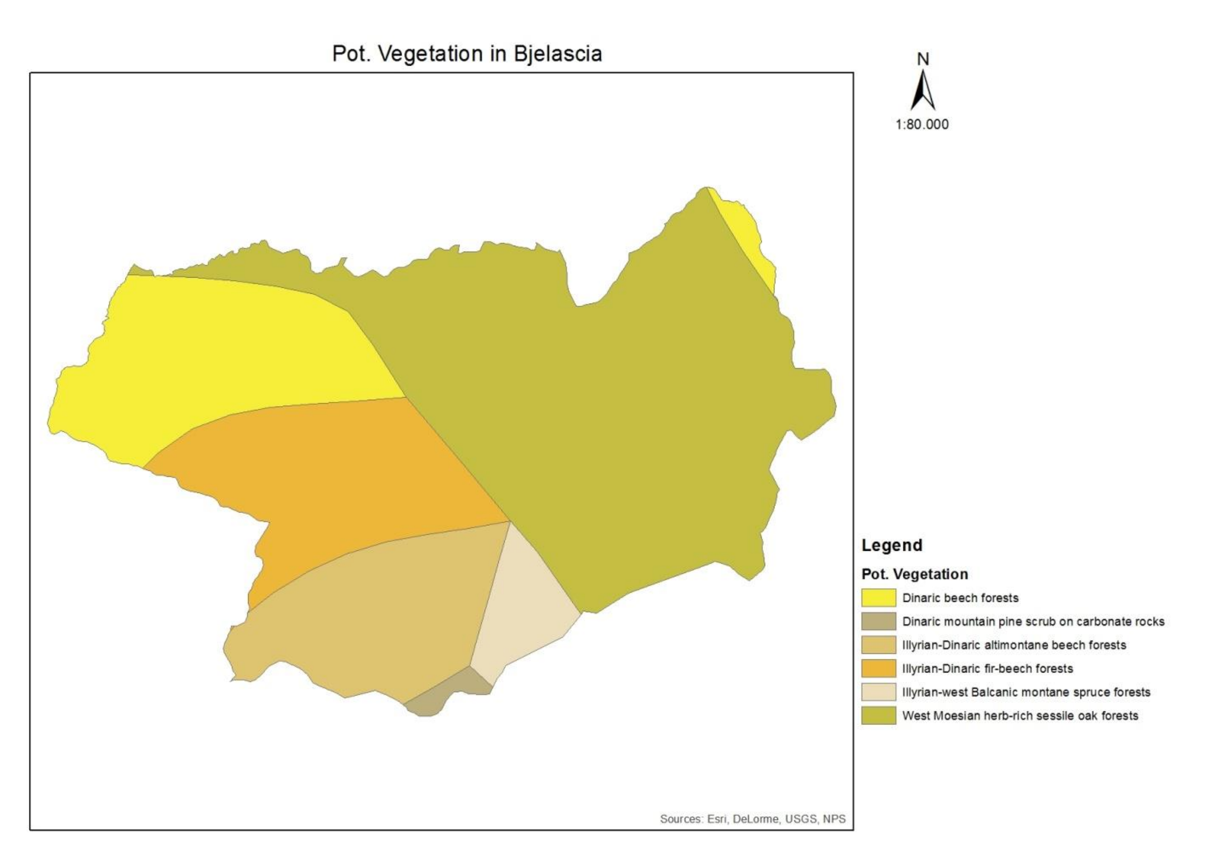


Figure 11. Potential natural forest vegetation of MU Bjelasica based on the European Map (Bohn et al. 2000)

4.1.3.2 MU Štitovo (1541)

4.1.3.2.1 Study region

The MU „Štitovo“ is located northeast of Danilovgrad and extends from 19°12’18’’ to 19°16′32′ eastern longitude and from 42°33’35’’ to 42°45’46’’ northern latitude (Figure 12). It belongs to the municipality of Danilovgrad and leans on to the border of the municipality of Niksic and Kolasin . The management unit „Štitovo“ covers an area of 2471.20 ha. The most common forest types are formed by *Pinus heldreichii* (1087,5 ha = 56,34%), *Fagus sylvatica* (419,50 ha = 21,73%), and *Fagus sylvatica* mixed with *Abies alba* (412,50 ha = 21,37%). The mean timber volume is 79,1 m^3/ha.

The lowest point of this unit is located at 1400 meters above sea level (Vodni do), and highest point at 2124 meters (Kurozeb). The forest area can be classified into three altitudinal zones, i.e. between 1401 and 1600 m a.s.l. (1589 ha = 64%); between 1601 and 1800 m NN (659 ha = 27 %), and above 1800 m NN (223 ha = 9 %).

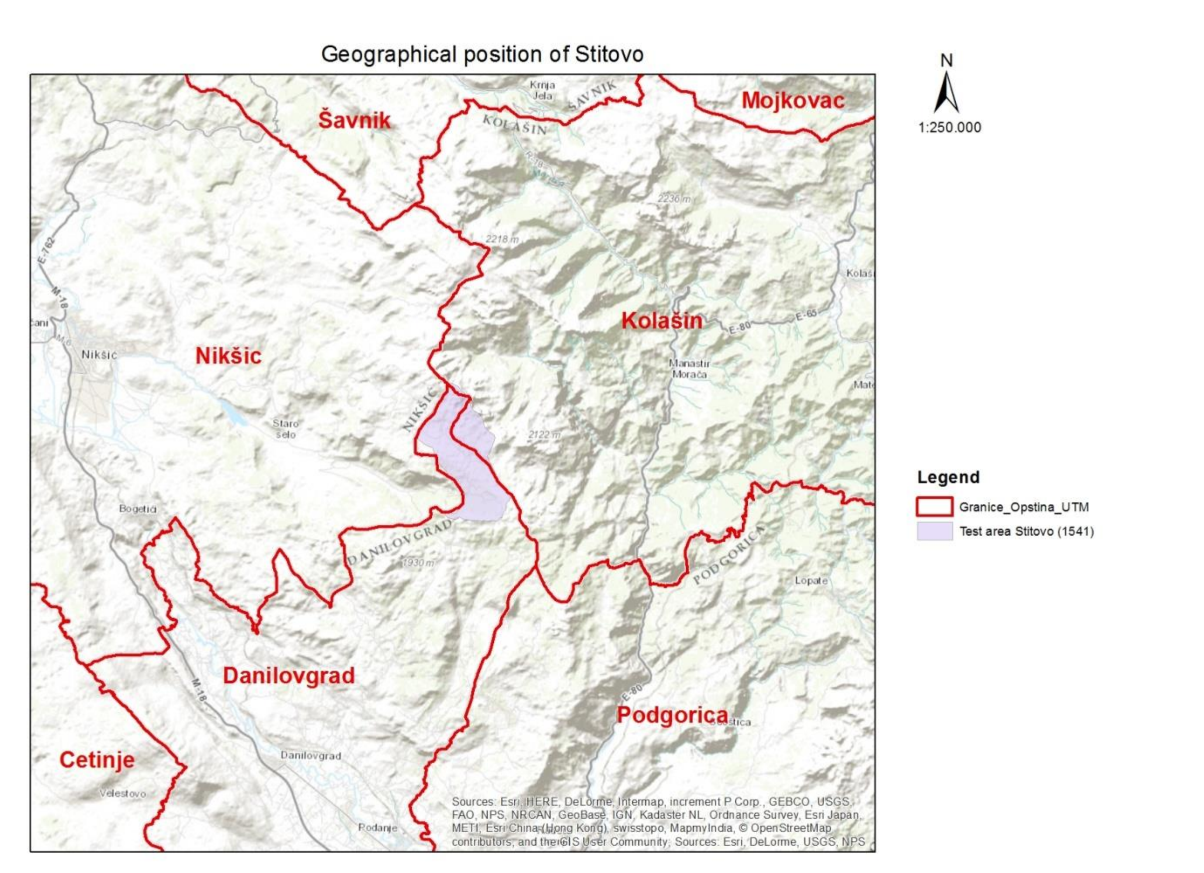


Figure 12. Administrative position of MU Štitovo

4.1.3.2.2 Geology and soil

The geology of the area is mainly formed by limestone with all phenomena of typical karst: karst valleys, sinkholes, caverns, gorges. There is no above-ground stream or river. Several small sources of drinking water (Rakočica, Studenac and Vodni do) can be found. The area belongs to the geomorphological branch Niksić field, as the largest karst field in Montenegro. The soils are organo-mineral calcareous black soil and Brown soil on limestone.

The soils were locally shallow with dolomite rocks without soil cover at the surface (Figure 13).

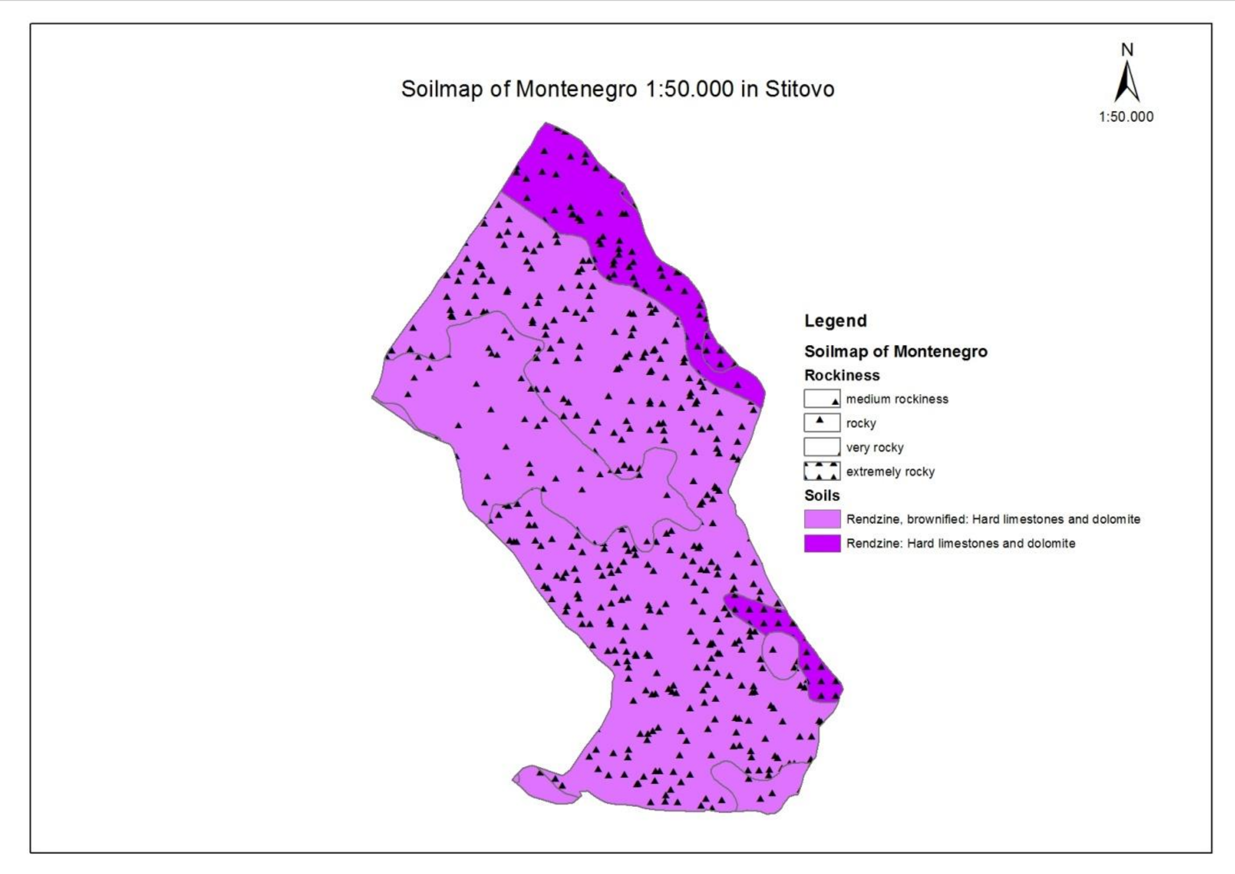


Figure 13. Soils of the MU Štitovo based on the soil map of Montenegro (1:50.000)

4.1.3.2.3 Climate

The climate of the plots was modelled, based on the measured values (1961-1990) of the Institute for Hydrology and Meteorology of Montenegro for the climatic station in Nikšić (Fig. 12). The mean annual air temperature in this unit is 11°C, mean annual precipitation 1982 mm, the mean relative humidity 71%.

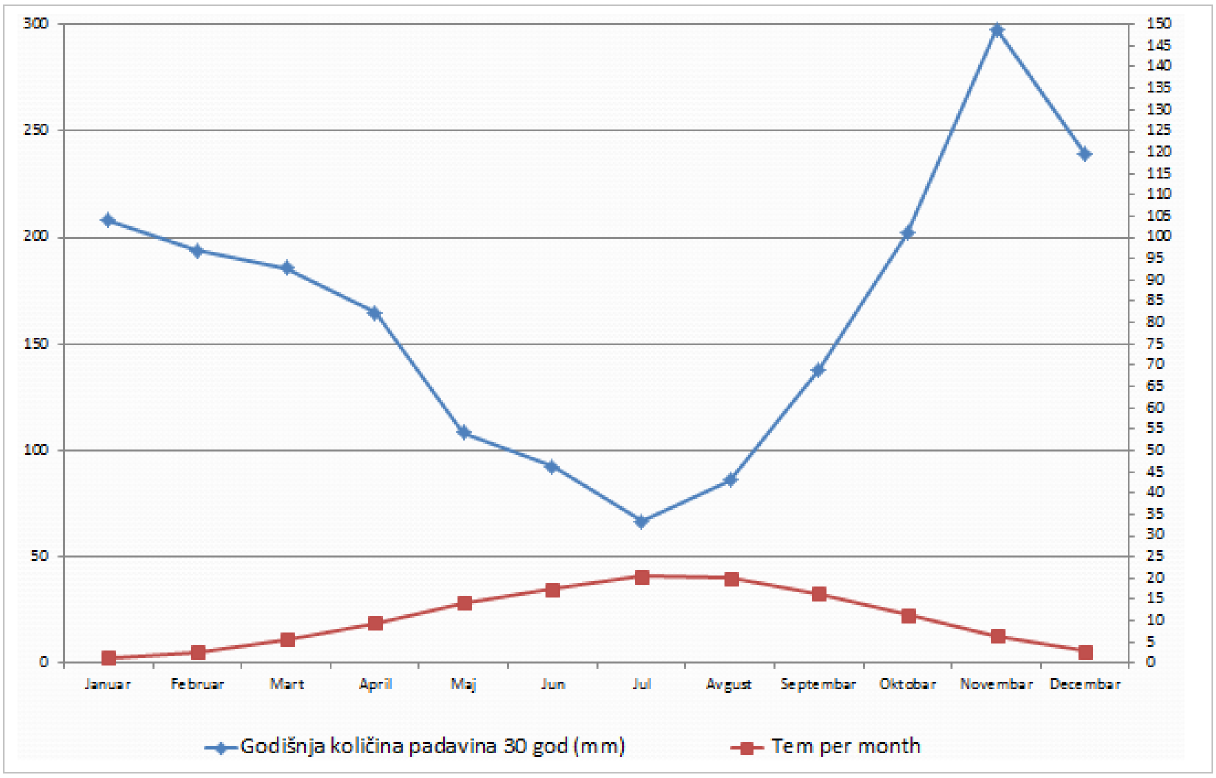


Figure 14. Annual course of temperature and precipitation of the climatic station Nikšić (600 m a.s.l.)

The measured temperature data at Nikšić were used as reference. Elevational differences for the individual plots were based on temperature lapse rates of 0,65° C (in summer and spring), 0,52 °C (in autumn) and 0,35 ° C (in winter) per 100 m altitude (Milosavljević, 1988).

The precipitation data were calculated based on the existing measurements (climatic stations) and interpolation by elevation.

The PET was calculated using the formula of Turc (1961) for different time periods (summer season, annual). Based on the average values, there is not semiarid month. However, during extreme years there is not enough rainfall and humidity during the vegetation period (15. April- 15. October), and particularly on shallow soils the conditions for tree growth are rather unfavorable.

4.1.3.2.4 Vegetation

The map of the potential natural forest vegetation zones of Europe showed two units: In the northern and eastern part of the area Illyrian-dinaric altimontane beach forest, in the south and west Illyrian-dinaric fir- beach forest (Figure 15).

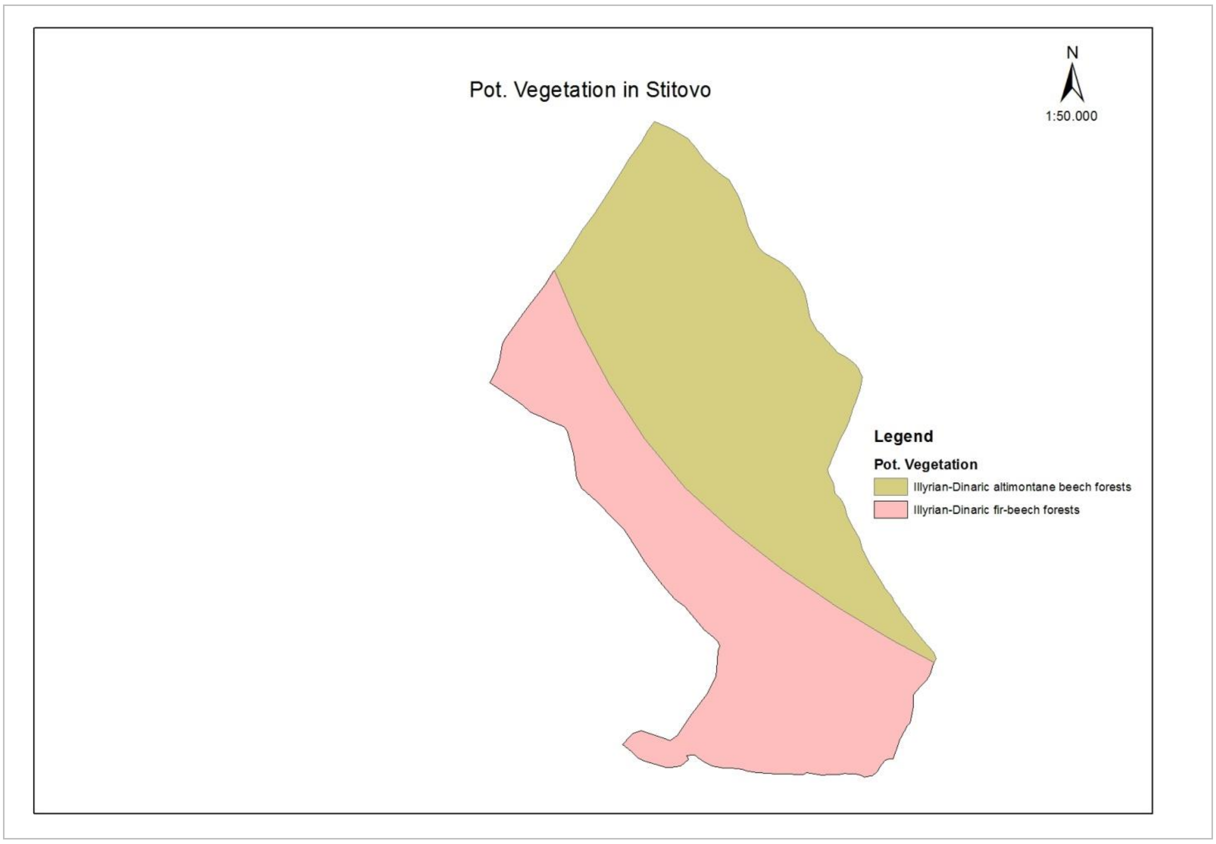


Figure 15. Potential natural forest vegetation of the test area Štitovo based on the European Map (Bohn et al. 2000)

4.2 Method development I: Data Preparation, Sampling Design and general concept

4.2.1 Background on Forest Site Mapping

The major aim of developing FoSiM (Forest Site Mapping) is to provide an efficient and reliable concept for forest site mapping with special focus on sparse data. The system should be simple and applicable by non-scientific staff.

Minimum data requirements are a digital elevation model of 10m resolution, average summer precipitation and temperature. Soil or parent material maps are recommended but not required.

The FoSiM concept is based on the recommendations of the German working group on forest mapping „AG Standortskartierung in der Arbeitsgemeinschaft Forsteinrichtung [Forstliche Standortskartierung, 6. Auflage, 2003]" of the German forest planning agencies.

ForSiM is an integrated concept comprising the

- selection of representative sampling locations
- preparation of initial concept maps
- integration of soil and vegetation field survey data
- efficient spatial prediction

By analogy with most common forest site mapping approaches the most crucial point is a detailed landscape segmentation approach. This is based on the existing and relevant environmental covariates and conducted according to the guidelines of the German working group on forest mapping. This landscape segmentation forms the basis for the concept map, the sampling design, the field work and the final forest site map (Figure 16).

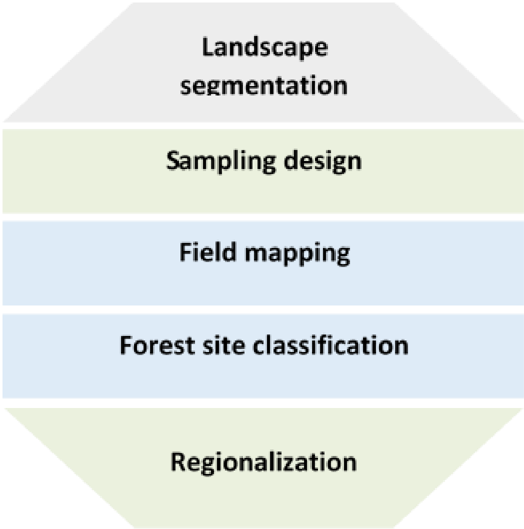


Figure 16. General concept and workflow of the FoSiM approach

The relevant soil properties required in FoSiM are reduced to the fundamental properties required. The following properties are crucial:

- water balance
  - available field capacity in the root zone
- base saturation
- pH values in different depth

The DEM as well as the climate data has to be in grid format with spatial resolutions around 10m.

The forest site type results from climate, soil and terrain conditions

- climate and terrain determine the growing zone
- climate, soil and terrain determine the water balance
- soil and vegetation determine the nutrient regime

The growing zone changes locally based on terrain position and regionally based on elevation and the geographical location. In FoSiM the growing zones is factored in by the altitude zone and the differentiation in sunlit and shaded terrain.

Both the nutrient regime and the water balance level are influenced by the environmental conditions. The most important factor are:

- available water capacity
- precipitation
- evapotranspiration
- terrain position and slope
- vegetation

The nutrient regime is a complex measure and thus not easy to determine with respect to forest site mapping. It is characterized by parent material, the weathering regime, vegetation, water fluxes and climate. Relevant datasets are

- Soil and parent material maps
- Soil survey data
- Vegetation survey data

4.2.2 Development of a concept map

A concept map which can be used as a basis for sampling design and mapping should comprise all relevant data to provide a system of landscape units which should be as homogeneous as possible regarding their site characteristics.

A concept map for forest site mapping should thus include terrain structures, a climate zoning as well as basic information on soil properties. The specific content has to be adjusted according to the available basis data.

4.2.2.1 Parent material

The first level of the concept map in FoSiM consists of information from the soil map. The spoil map is classified according to the parent material properties to derive differences in base saturation. The following classes have been aggregated based on the [ABR_GEO] data column:

- SH, SHk: Shist
- Psh: Sandstone
- C: Hard Limestone and dolomite
- Ks: Calcerous material

4.2.2.2 Elevation zones

A growing zones describes locations with a similar thermal regime. These have to be differentiated in horizontal and vertical differences. Locally, it is differentiated by terrain position and solar insolation, regionally be the elevation gradient and the geographical location.

In this project we use the elevation zones of the Orjen consisting of the following 5 climate zones:

Table 3. Climate zones of the the Orjen

Climate zone	**Altitude [m o. NN]**
eumediterran	0 - 400
supramediterran	400 - 1100
oromediterran	1100 - 1450
altimediterran	1450 - 1700
kryomediterran	> 1700

4.2.2.3 Landform classification

Terrain position and landform classes are typically used in soil and site mapping schemes. They describe characteristic and complex areas. Regarding the local climate conditions and growing zones the differentiation between sunlit and shaded areas is most important. It is based on the total solar insolation between May 15 and September 15. Three classes have been derived:

- Sunlit 925 – 2000 kWh/m²
- Intermediate 825 - 925 kWh/m²
- Shaded 0 - 825 kWh/m²

Several additional landform classes are important for the water balance. In FoSiM we use the terrain segmentation based on the works of Yokohama et al. (2002) and Stepinski und Jasiewicz (2011). This approach classifies the zenith and nadir angles to the closest visible peak and pit found in eight radial directions around a pixel (Figure 17) to determine so called geomorphons (Figure 18). The geomorphons are then aggregated to landform units (Figure 19).

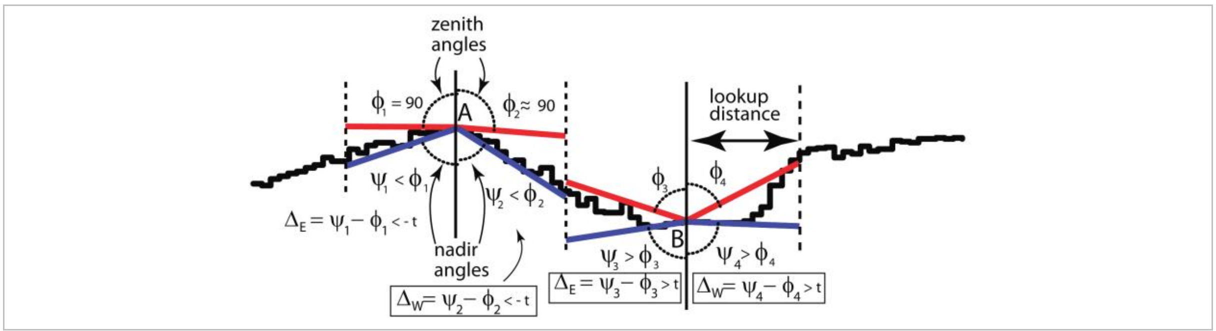


Figure 17. Basic concept of landform analysis using zenith and nadir angles. Stepinski and Jasiewicz (2011)

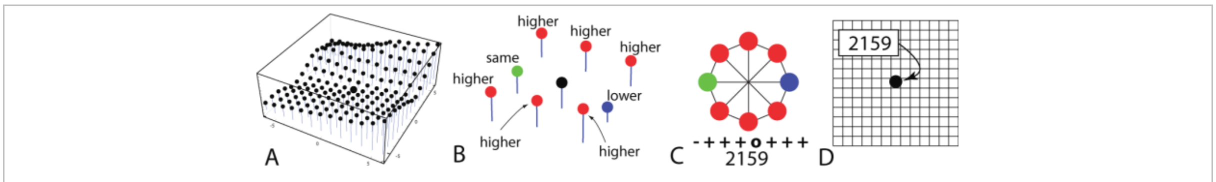


Figure 18. Aggregation of viewing angles to geomorphons. Stepinski and Jasiewicz (2011)

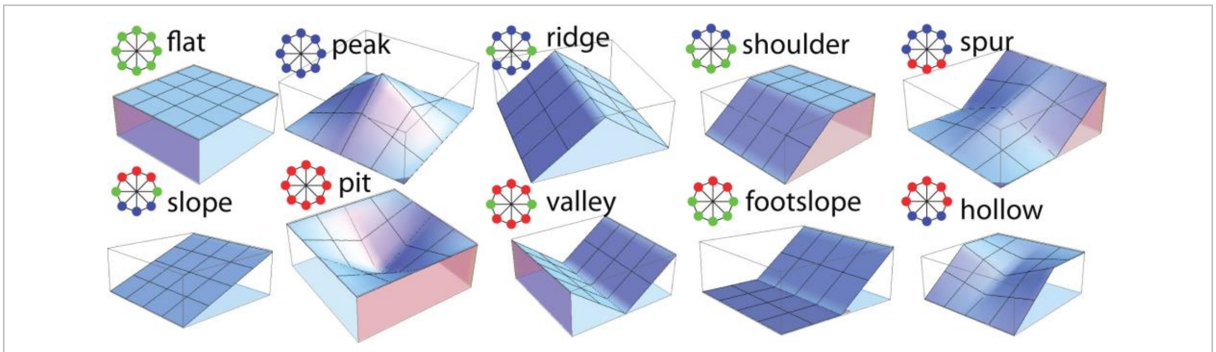


Figure 19. Classified landform units according to the geomorphins (Stepinski and Jasiewicz (2011))

The following classes were aggregated according to the common soil and site mapping schemes:

- peak
- ridge
- shoulder
- spur + slope
- hollow
- foot slope
- pit + valley

A further layer included is slope. Spur and foot slope are subdivided in areas <= 30° and > 30°. This results in:

- peak (200)
- ridge (300)
- shoulder (400)
- spur + slope <= 30° (560)
- spur + slope > 30° (564)
- hollow <= 30° (700)
- hollow > 30° (704 / 740)
- foot slope <= 30° (800)
- foot slope > 30° (804 / 840)
- pit + valley (900)

4.2.2.4 Complexity of the concept map

Combining the 10 resulting terrain classes with the solar insolation classes the concept map contains 30 different terrain units. Including the parent material classes based on the soil map this sums up to 30 units for Štitovo (1 parent material class) and 60 units for Bielasicia (2 parent material classes).

4.2.3 Sampling Design

Sampling design focusses covering the feature space – i.e., to ensure that all base saturation classes, all altitude levels and solar insolation classes as well as landform units are covered. The second aim is to reduce travel time since the area is not well accessible.

To achieve both aims a sampling scheme based on non-overlapping 500*500m patches was developed. The general scheme is a stratified random sampling approach and works as follows:

```
for each base saturation class
   for each altitude level
       for each solar insolation class
           select the patch comprising all landform units with equal
           probability/area
               sample each landform unit randomly
```

The analysis is based on the concept map. The selection of the patches is done in Microsoft Excel (Figure 20) and the random sampling is done using a GIS. Each combination should be samples more than once to estimate the variance.

	Spaltenbeschrift 750-800_1		750-800_2		750-800_3		800-850_1		800-850_2		800-850_3	
Zeilenbeschriftur	Anzahl von Geom_s	Summe von Hectar	Anzahl von Geom_s	Summe von Hectar	Anzahl von Geom_s	Summe von Hectar	Anzahl von Geom_s	Summe von Hectar	Anzahl von Geom_s	Summe von Hectar	Anzahl von Geom_s	Summe von Hectar
0											1	0,113
4					1	0,015					3	0,2
5	6	0,934	6	1,153	5	1,644	7	1,776	7	2,154	8	2,474
6	7	0,529	2	0,045	6	1,736	9	3,252	8	1,125	8	3,884
7	6	6,654	5	0,899	7	1,99	7	1,568	6	0,753	6	2,325
8	8	9,416	7	2,536	10	5,121	2	0,118	6	0,365	2	0,09
9	9	8,187	5	3,084	8	2,857	5	0,577	6	1,862	8	1,768
10	7	3,857	7	2,004	9	5,549	6	1,42	7	3,028	8	2,647
11	8	1,07	8	2,588	9	9,756					1	0,013
24									1	0,186	3	0,28
25							7	0,344	7	1,846	10	4,316
26							8	2,657	6	3,044	9	9,028
27							9	10,648	7	3,275	9	10,247
28					2	0,022	8	8,637	8	4,247	10	11,323
29							9	2,886	8	5,019	9	16,687
30							7	2,258	6	3,824	8	18,507
31	1	0,016	4	1,162	7	11,855	3	0,989	4	1,995	6	8,524
32	3	0,162	4	0,647	6	3,965						
46							3	0,131	1	0,019	3	0,615
47							7	6,468	6	3,379	9	11,551
48							7	4,986	6	3,892	7	15,743
49							2	0,304	4	4,312	5	20,273
50	5	0,12	1	0,051	5	1,453	5	2,36	7	3,012	6	17,689
51	5	0,351	6	2,16	8	18,102	4	0,428	5	0,551	7	3,043
52	6	0,888	7	2,373	8	10,344						
66									1	0,012	3	0,061
67							8	2,572	7	2,633	8	13,265
68							6	1,428	4	1,898	7	21,396
69							1	0,023	6	1,154	9	23,645
70	2	0,051	6	0,726	9	7,288	3	0,42	8	0,66	8	15,606
71	3	0,231	4	0,699	8	23,868						
72	7	1,209	7	1,265	9	15,694						
86							6	1,027	4	0,899	8	11,113
87							8	3,023	7	2,912	8	18,702
88							3	0,264	6	1,31	9	23,203

Figure 20. Pivot table (subset) used to derive the sampling patches

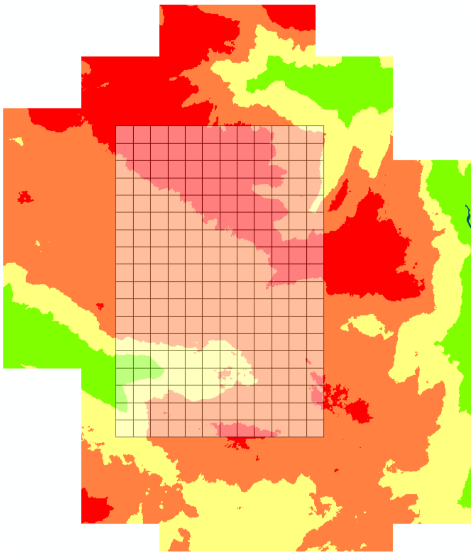


Figure 21. Patch sampling structure in Štitovo

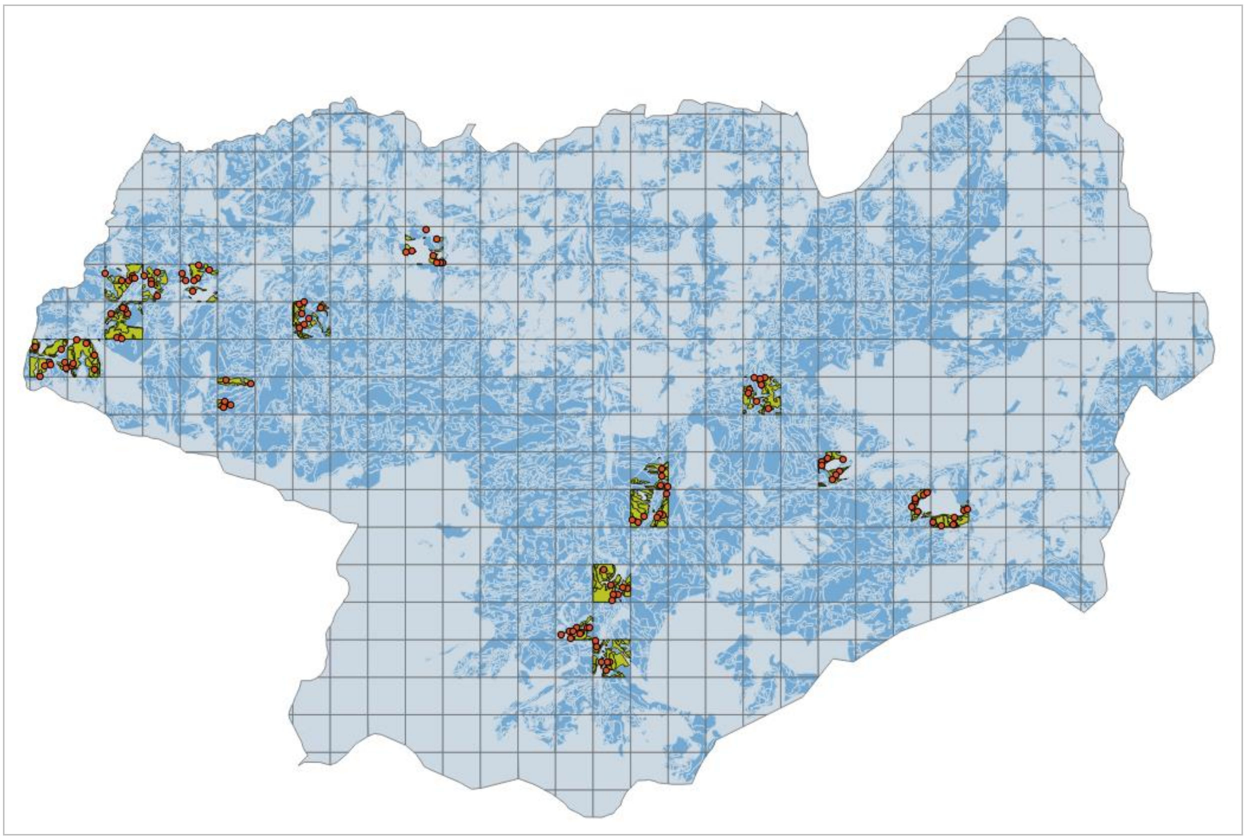


Figure 22. Sampling locations in Bjelascia (repeated samples are not shown)

4.2.4 Field Survey

The two Montenegrin doctoral candidates were trained in the field and tested the methodologies in the field in 2014. Based on their preliminary results, the sampling design was revised and updated for the second vegetation season (2015), where it was successfully implemented on 271 plots.

4.2.4.1 Vegetation

On selected sample plots, relevés were recorded using the modified Braun-Blanquet-scale (van der Maarel 1979), and were used to describe and classify the forest types. Data were recorded from a nested plot formed by a vegetation rectangle and an adjacent soil profile (Figure 23). Plot size was 100 m^2, representing homogenous site conditions.

The sample points were located in the field using handheld GPS receivers. At each sample point the following parameters were recorded: Location and landform, terrain form, slope, aspect, curvature, elevation a.s.l., terrain position, humus layer thickness (L, Of, Oh), soil horizons (FAO/KA5), soil texture, stone content, humus content, lime content, root penetration, bulk density, pH-Value (in water). Within the sampling plot, the soil auger/soil pit was positioned in the southern left corner of the vegetation plot (which is oriented towards north). Climatic parameters were not measured in the field, they were modeled and attributed to each plot using existing climatic data from climatic stations.

The structure of the vegetation was described by three layers: (1) Ground vegetation layer (height < 1 m), (2) Shrub layer (height 1-5 m), (3) Tree layer (height > 5 m). As first step the total cover of each layer was estimated. All vascular plant species were listed for each layer. The vegetation for each layer was recorded using the modified Braun-Blanquet-scale (van der Maarel (1979).

Table 4). For numerical analyses this scale was transformed into a rank scale with a range from 0 to 9.

Figure 23. Design of plots

Table 4. Modified Braun-Blanquet-scale (Mueller-Dombois & Ellenberg 1974, van der Maarel 1979)

	Description
R	<1% cover of the total plot area, 1-3 individuals/plot
+	<1% cover of the total plot area, 4-10 individuals/plot
1	1-5% cover of the total plot area, 10-50 individuals/plot
2m	1-5% cover of the total plot area, >50 individuals/plot
2a	5-15% cover of the total plot area, abundant (>50 individuals/plot)
2b	16-25% cover of the total plot area, abundant
3	26-50% cover of the total plot area, abundant (small clumps)
4	51-75% cover of the total area of the plot, abundant (extensive matts/clumps)
5	76-100% cover of the total area, abundant (continuous cover)

The sample plots were grouped to define the forest types on a floristic base. Principally two classification methods were available: The own relevés were (1) related to already described forest communities from adjacent regions and countries of the Balkan region; (2) classified using numerical methods (clustering). The latter approach was started, but could not be completed during this project. Applying ordination techniques the relations between species, forest types and site factors were detected, using the program "Vegan" which is implemented in "R" (methods and results not shown in this report).

4.2.4.2 Soil

Soil is surveyed with a minimal dataset in mind. The approach follows Caspari and Schack-Kirchner (2008). Relevant data are:

Site:

- GPS coordinates
- Elevation
- Terrain position
- Date
- ID
- Geographic name
- Stone cover at surface in 10 % steps
- Percentage of karstic area in 10 % steps (if applicable)
- Soil type

Profile:

- Name of the horizon
- Horizon depth
- Soil texture
- Stone content in 10% steps
- Stone type
- Humus content
- Soil color (Munsell)
- Bulk density
- (at least) one pH measurement in 0 - 60 cm
- (at least) one pH measurement in 60-100 cm

4.3 Method development II: Classification of sites

The concept for the forest site classification as implemented in FoSiM are adapted to the available data and the geographic situation in Montenegro. To describe a forest site type information on climate, vegetation and soil is required. Figure 24 shows the general relations between environmental conditions and forest site type.

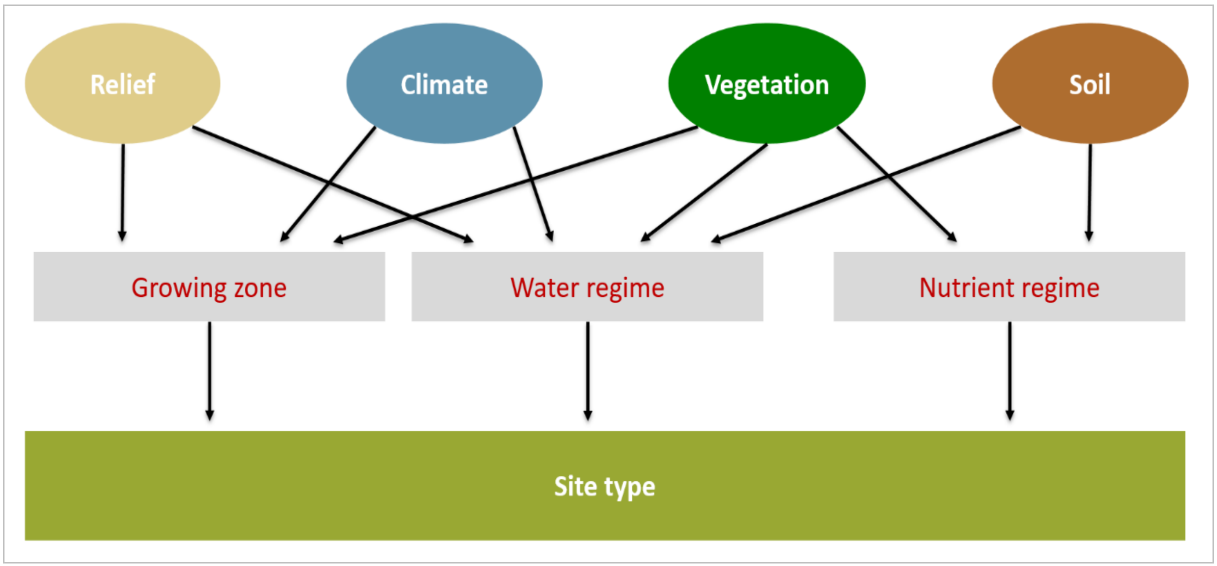


Figure 24. Forest site type and environmental conditions [simplified from: Forstliche Standortskartierung Hessen, Abb. 29, S. 285]

4.3.1 Site analysis

Vegetation patterns are principally caused by the primary site factors nutrients, temperature and water, and their spatial and temporal patterns. The trophic conditions (nutrient regime) are shaped by geology and soil parameters. The temperature regime is formed by the macroclimatic conditions which are modified by local topography. The water supply depends both from soil and climatic factors.

The following chapters describe the approach developed in this project for site classification and regionalization based on the concept map, the field survey data as well as additional relevant and classified basis data.

4.3.2 Precipitation in summer

For Montenegro precipitation in FoSiM is classified as described in Table 5:

Table 5. Precipitation classes using for site mapping

RRwarm [mm]	Precipitation classes
<300	1
300 - 450	2
450 - 600	3
600 - 750	4
> 750	5

4.3.3 Available water capacity

Available water capacity (AWC) is derived for each horizon based on soil texture, stone content, bulk density and humus content. The AWC is derived based on existing transfer functions (Figure 25, Table 6).

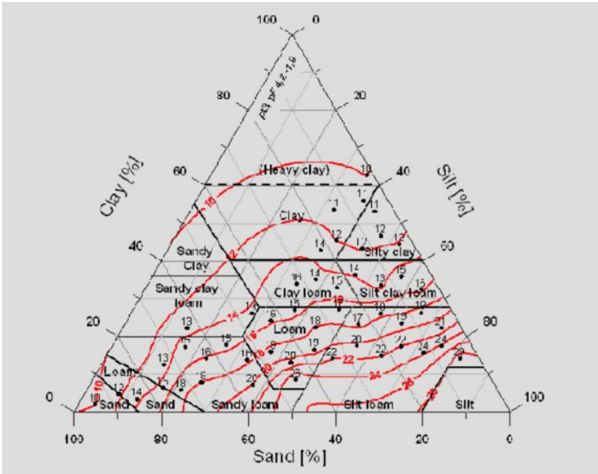


Figure 25. Diagramm to derive the available water capacity based on soil texture. http://www.lgb-rlp.de/fileadmin/cd2009/images/content/bodenuebersichtkarte/Diagramme_pt300.pdf

Table 6. Water capacity for 10 cm depth based on soil texture.

heavy clay	9
sandy clay	11
clay	12
silty clay	12
sandy clay loam	13
clay loam	15
silty clay loam	15
sand	11
loam sand	15
sandy loam	18
loam	19
silty loam	22
silt	29

The values shown in Table 6 are corrected by stone content and summed up for the entire profile according to the flowing functions:

$$AWC_{horizon} = (AWC_{tab} * \text{stone content } [\%] / 100) * \text{depth } [dm]$$

$$AWC_{profile} = AWC_{horizon\_n1} + AWC_{horizon\_n2} + ... AWC_{horizon\_n}$$

To classify the AWC aiming to characterize the water regime FoSiM uses the following classes for Montenegro:

Table 7. AWC classes

AWC [mm]	AWC classes
1 - 10	1
10 - 25	2
25 - 45	3
45 - 65	4
65 - 95	5
95 - 130	6
> 130	7

4.3.4 Soil Water Balance Level

To derive the relevant soil water balance level (WBL) the AWC has to be adjusted according to the climate and terrain position. The classification is based on a system of tables (Table 8).

Table 8. Transformation matrix to determine WBL based on AWC mit Hilfe der Reliefelemente und der Sonneneinstrahlung [nFK > 45mm]

nFK	Geom	Reliefeinheit	sun	mid	sha	sun	mid	sha	sun	mid	sha
> 130	560	spur and slope: slope < 30°	7	7	8	8	8	9	9	9	9
> 130	564	spur and slope: slope > 30°	6	7	8	7	8	9	9	9	9
> 130	400	shoulder	6	6	7	7	7	8	9	9	9
> 130	200	peak	6	6	7	7	7	8	9	9	9
> 130	300	ridge	6	6	7	7	7	8	9	9	9
> 130	700	hollow; slope < 30°	7	8	8	8	9	9	9	9	9
> 130	740	hollow; slope > 30°	6	7	8	7	8	9	9	9	9
> 130	800	footslope; slope < 30°	7	8	8	8	9	9	9	9	9
> 130	804	footslope; slope > 30°	7	8	8	8	9	9	9	9	9
> 130	900	valley	8	8	9	9	9	9	9	9	9
95 - 130	560	spur and slope: slope < 30°	6	6	7	7	7	8	9	9	9
95 - 130	564	spur and slope: slope > 30°	5	6	7	6	7	8	8	9	9
95 - 130	400	shoulder	5	5	6	6	6	7	8	9	9
95 - 130	200	peak	5	5	6	6	6	7	8	9	9
95 - 130	300	ridge	5	5	6	6	6	7	8	9	9
95 - 130	700	hollow; slope < 30°	6	7	7	7	8	8	9	9	9
95 - 130	740	hollow; slope > 30°	5	6	7	6	7	8	8	9	9
95 - 130	800	footslope; slope < 30°	6	7	7	7	8	8	9	9	9
95 - 130	804	footslope; slope > 30°	6	7	7	7	8	8	8	9	9
95 - 130	900	valley	7	7	8	8	8	8	9	9	9
65 - 95	560	spur and slope: slope < 30°	5	5	6	6	6	7	8	8	8
65 - 95	564	spur and slope: slope > 30°	4	5	6	5	6	7	7	8	8
65 - 95	400	shoulder	4	4	5	5	5	6	7	8	8
65 - 95	200	peak	4	4	5	5	5	6	7	8	8
65 - 95	300	ridge	4	4	5	5	5	6	7	8	8
65 - 95	700	hollow; slope < 30°	5	6	6	6	7	7	8	8	9
65 - 95	740	hollow; slope > 30°	4	5	6	5	6	7	7	8	8
65 - 95	800	footslope; slope < 30°	5	6	6	6	7	7	8	8	9
65 - 95	804	footslope; slope > 30°	5	6	6	6	7	7	7	8	8
65 - 95	900	valley	6	6	7	7	7	7	8	8	9

65 - 95	560	spur and slope: slope < 30°	5	5	6	6	6	7	8	8	8
65 - 95	564	spur and slope: slope > 30°	4	5	6	5	6	7	7	8	8
65 - 95	400	shoulder	4	4	5	5	5	6	7	8	8
65 - 95	200	peak	4	4	5	5	5	6	7	8	8
65 - 95	300	ridge	4	4	5	5	5	6	7	8	8
65 - 95	700	hollow; slope < 30°	5	6	6	6	7	7	8	8	9
65 - 95	740	hollow; slope > 30°	4	5	6	5	6	7	7	8	8
65 - 95	800	footslope; slope < 30°	5	6	6	6	7	7	8	8	9
65 - 95	804	footslope; slope > 30°	5	6	6	6	7	7	7	8	8
65 - 95	900	valley	6	6	7	7	7	7	8	8	9
25-45	560	spur and slope: slope < 30°	3	3	4	4	4	5	5	6	6
25-45	564	spur and slope: slope > 30°	2	3	4	3	4	5	5	6	6
25-45	400	shoulder	2	2	3	3	3	4	4	5	6
25-45	200	peak	2	2	3	3	3	4	4	5	6
25-45	300	ridge	2	2	3	3	3	4	5	6	6
25-45	700	hollow; slope < 30°	3	4	4	4	5	5	6	6	7
25-45	740	hollow; slope > 30°	2	3	4	3	4	5	5	5	6
25-45	800	footslope; slope < 30°	3	4	4	4	5	5	6	6	7
25-45	804	footslope; slope > 30°	3	4	4	4	5	5	5	6	6
25-45	900	valley	4	4	5	5	5	5	6	7	7
10-25	560	spur and slope: slope < 30°	2	2	3	3	3	4	4	5	5
10-25	564	spur and slope: slope > 30°	1	2	3	2	3	4	3	4	5
10-25	400	shoulder	1	2	2	2	2	3	3	4	5
10-25	200	peak	1	1	2	2	2	3	3	4	5
10-25	300	ridge	1	2	2	2	2	3	3	4	5
10-25	700	hollow; slope < 30°	2	2	3	3	4	4	4	5	5
10-25	740	hollow; slope > 30°	1	2	3	2	3	4	4	4	5
10-25	800	footslope; slope < 30°	2	3	3	3	4	4	5	5	6
10-25	804	footslope; slope > 30°	2	3	3	3	4	4	4	5	6
10-25	900	valley	3	3	4	4	4	4	5	5	6
<10	560	spur and slope: slope < 30°	1	1	2	2	2	3	3	4	4
<10	564	spur and slope: slope > 30°	1	1	2	1	2	3	2	3	4
<10	400	shoulder	1	1	1	1	1	2	2	3	4
<10	200	peak	1	1	1	1	1	2	2	3	4
<10	300	ridge	1	1	1	1	1	2	2	3	4
<10	700	hollow; slope < 30°	1	1	2	2	3	3	3	4	4
<10	740	hollow; slope > 30°	1	1	2	1	2	3	3	3	4
<10	800	footslope; slope < 30°	1	2	2	2	3	3	4	4	5
<10	804	footslope; slope > 30°	2	2	2	3	3	3	3	4	5
<10	900	valley	2	2	3	3	3	3	4	4	5

4.3.5 Water regime

The water regime is shaped by the climatic component (climatic water balance) and the soil acting as buffer (in form of the Available Soil Water Storage Capacity, (AWC) (Allen et al. 1998).

The Climatic Water Balance (CWB) was calculated for given time periods based on data from precipitation (P, in mm) and potential evapotranspiration (ET_{pot}, in mm). (Allen et al. 1998):

$$CWB = P - ET_{pot}$$

Precipitation data are available from climatic stations. For specific sample plots, they have to be adjusted in a similar way as it was mentioned for the temperature data. It should be mentioned, that an exclusion of uncertain precipitation data does not provide a solution, because they are essential for the water balance.

Evaporation is normally included as potential evapotranspiration (ET_{pot}) (Allen et al. 1998). It depends from many factors; because most parameters are not available for each plot, the most complete formula to calculate evapotranspiration, the physical Penman-Montheith-formula, cannot be applied. Instead of that the simplified approach based on Turc´s method which includes air temperature and solar irradiation (Turc 1963) can be used (also in this project):

$$ETpot_{Turc} = 0,013*(T_{ave}/T_{ave}+15)*(Rs+50)$$

T_{ave} = average temperature (^{o}C), Rs = solar insolation (g calori./cm^2);

λ = latent heat of vaporisation (λ=2,26476 MJ/Kg);

Solar insolation was calculated following Frank & Lee (1966).

Available Soil Water Storage Capacity (AWC) was calculated from texture, stone content and soil depth, following Arbeitskreis Standortskartierung in der Arbeitsgemeinschaft Forsteinrichtung (2016):

$$AWC_{horizon} = (AWC_{tab} * (1\text{-stone.c}[\%]/100)) * \text{depth [dm]}$$

$$AWC_{profile} = AWC_{horizon\_n1} + AWC_{horizon\_n2} + \ldots AWC_{horizon\_n}$$

4.3.6 Temperature regime

Temperature has two functions: (1) It limits the vegetation period, low temperatures can cause frost damage. (2) Temperature is related to water loss by evapotranspiration.

Plant growth depends from the temperature regime of a site during the course of the year. **Low temperature** can cause chilling effects (for tropical plants), frost damage (including frost drought) at tree lines. Therefore for site classification, absolute minimum temperatures, length and severity of winter period are important.

High temperature results in a decrease of photosynthesis and an increase heat respiration and finally death. Additionally, high temperature leads to increased evapotranspiration which can cause shortage of water supply, drought stress and beyond the wilting point of a plant finally its death. Therefore for site classification, absolute maximum temperatures, and length and severity of periods with high temperatures are important.

Optimum temperature for photosynthesis and growth is species-specific, in the majority of plants it ranges between 5 and 30^{o} C. At the climatic tree lines it seems that not photosynthesis, but plant growth limits growth: Growing season air temperature at the tree line is ca. 6.6 °C (Hoch & Körner 2012, Körner 2003). Therefore for site classification, the length of vegetation period is an important factor for plant growth.

For optimum plant growth, the temperature sum during the vegetation period may be a relevant indicator. Example: Under continental climate, tree line is higher because of less cloud cover, higher irradiation, therefore warmer days (Ellenberg & Leuschner 2011).

For practical applications, the temperature patterns for each sample plots can be modeled by using the data of the nearby climatic stations, and interpolations, e.g. by geostatistical methods (Samaras et al. 2014). If only one climatic station is available, linear extrapolation using known elevational temperature lapse rates can be performed.

4.3.7 Nutrient regime

Nutrient regime is crucial for plant growth and is driven by chemical and bio-chemical processes in soils. Data available to characterize the nutrient regime are

- soilmap of Montenegro (1:50.000)

- pH values in different soil depth (field survey data)
- vegetation survey data (field survey data)

Estimators to classify nutrient regime are:

- Trophic level
- pH values in different soil depth
- parent material of the soil map 1:50.000

Trophic data were derived from the pH values (in H_2O) of soil horizons which were measured during the field work. The pH-values were related to the base saturation following Fuštić & Đuretić (2000). Six trophic classes were defined (see Figure 26).

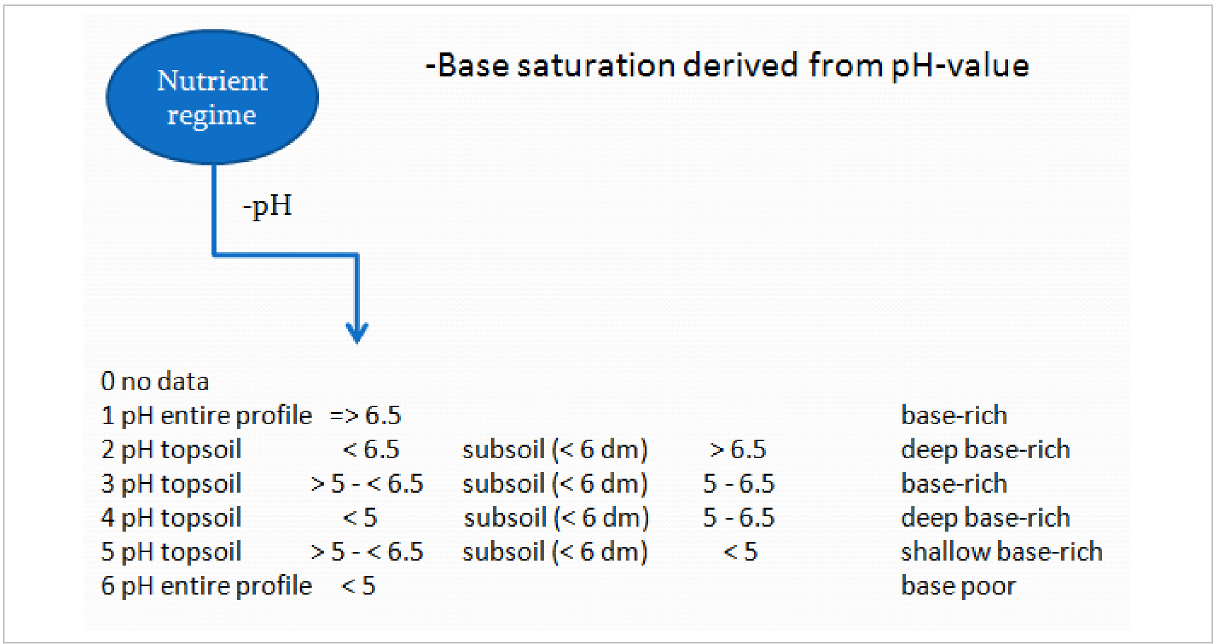


Figure 26. Nutrient regime

4.3.8 Decision matrix to classify the nutrient regime

The decision matrix to classify the nutrient regime is shown in Table 9 and the classification matrix for base saturation is presented in Figure 27.

Table 9: Decision matrix to classify the nutrient regime

Classes	Properties		
	Parent material (soil map)		
0	NA		
1	high:	base-rich	(e.g. limestone)
2	intermediate:	base-poor to base-rich	(e.g. silt)
3	low:	base-poor	(e.g. weathered sandstone)
	Base delivery potential for horizons		

0	no horizon with > 25 % stone content for base rich parent material or > 50 stone content for base poor parent material			
1	high: base rich parent material, stone content > 25 % (e.g. limestone)			
2	intermediate: base-poor to base-rich parent material, stone content > 50 % (e.g. silt)			
3	low : base-poor parent material, stone content > 50 % (e.g. weathered sandstone)			
	pH value for different depth intervals			
0	NA	topsoil pH value	subsoil pH value	
1	entire profile	=>6.5		base rich
2	topsoil	< 6.5	> 6.5	deep base rich
3	entire profile	5 - 6.5		base rich
4	topsoil	<5	5 - 6.5	deep base rich
5	topsoil	5 - 6.5	< 5	shallow base rich
6	entire profile	< 5		base poor
	Trophic level based on vegetation survey			
0	NA			
1	Eutrophic			
2	Mesotrophic			
3	Oligotrophic			

coarse fraktion	< 50 %	> 50 % alkanality of bedrock		
pH class		high	medium	less
1	rich	rich	rich-medium	rich-medium
2	rich-medium	rich-medium	rich-medium	medium
3	medium	rich-medium	medium	medium
4	medium	medium	medium	medium - poor
5	medium - poor	medium	medium - poor	medium - poor
6	poor	medium - poor	medium - poor	poor

Figure 27. Classification matrix for base saturation

4.3.9 Classification of parent material classes of the soil map 1:50.000

Table 10 shows the classification of the parent material classes with respect to trophy of the soil map 1:50.000 as used in FoSiM for Montenegro.

Table 10. Classification of the parent material classes of the soil map 1:50.000

GEO_ENG	Base classification	km²
Alkaline igneous rocks	1	342

Andesits	1	40
Carbonate (drobine)	1	292
Carbonate-silicate	2	1.253
Clay	1	0,3
Clay to ilite	1	27
Conglomerates	2	11
Diabase	1	22
Dolimites to hard limestones and dolomites	1	82
Dolomites	1	110
Flysh	2	979
Gravel	2	174
Gravel, conglomerates	2	1,7
Hard limestones and dolomite	1	8.424
Hard limestones and dolomites to dolimtes	1	88
Hard limestones and dolomites to hornstones	1	44
Hard limestones and dolomites; gravell	1	1,4
Hard limestones and dolomites; marl	1	2,3
Hornstone	2	10
Illite	1	2,0
Illite, clay	1	16
Illite, marl	2	32
Illite-sandstone	2	38
Keratophyre	1	0,7
Marl	1	68
Marl to conglomerate	1	7,5
Marl to hard limestones and dolomites	1	151
Metamorph	2	0,1
Mixed carbonate rocks	2	11
Pliocene formation	2	7,0
Quartzite	3	45
Relict tera rossa	2	80
Sandstone	2	1.183
Sandstone, gravel	2	19
Sandstone, shisht, (glinci)	2	62
Sandstone, shist	2	222
Sandstone, stone clay	2	8,1
Schist	2	753
Serpentin to hard limestones and dolomites	1	2,2
Serpentines	1	0,3
Soft limestones	1	225
Soft limestones to gravel	1	1,9
Standstone, stone clay	2	0,2

(Empty)	0	1.280
Summary		16.116

4.4 Method development III: Classification of forest types

4.4.1 Relevance

Until now, the knowledge of the vegetation types of Montenegro is incomplete, and their site demands and distribution limits under natural conditions is poor. Montenegro has a long-lasting land use history, which influenced the species composition, the community structure, of species and vegetation units and their distribution limits under natural conditions, i.e. under exclusion of human influence. The existing maps of the potential natural forest vegetation are general and of low precision, the distribution limits often follow topographical contour lines (Bohn et al. 2003; Horvat et al. 1974).

Montenegro in future will need a transparent and complete compilation of habitats, quantifying classification and mapping of forest sites, and science-based relation of tree species to sites. This basic knowledge will necessary for international reporting, nature conservation, and site-adapted forest management and timber production. Because of these demands, a method was developed for to provide a comprehensive description and mapping of actual existing vegetation patterns, of the sites, and of the pnV occurring under natural conditions. Such information also provides the base for modelling future climate scenarios (Hickler et al. 2012).

Based on the methods for a criteria-based plot selection, and a conceptual framework to record relevant site information for the temperature, water and nutrient regime, the vegetation parameters were recorded, and combined with the site information.

4.4.2 Vegetation analysis: Classification and ordination of forest types

Two case study regions were selected in form of the two forest management units (MU) “Bielasica” (by Milan Gazdić) and “Štitovo” (by Srdjan Pejović). In these two study regions, the site characteristics and the forest vegetation were inventoried.

The soils could be characterized based on Fuštić & Đuretić (2000) and own field data.

Only few existing climatic stations provided climatic reference data for the calculation of the local climate of each sample plot. Because of the complex mountain topography with windward and leeward sides, big differences between the few available climatic stations can be recognized. Therefore the macroclimatic most similar station was used as reference (Bjelopolje for Bjelasica; Niksić for Štitovo), having different lapse rates for temperature and precipitation. For the precipitation rates it must be assumed, that they increase in relating to altitude. Data of the precipitation gradients were not available. Therefore existing knowledge from adjacent countries, mainly from Serbia, was used (Milosavljević, 1988): Measured temperature data from climatic reference stations were used to model the regional variability including elevational differences. These calculations were based on a temperature lapse rates of 0,65^{o} C (in summer and spring), 0,52^{o} C (in autumn) and 0,35^{o} C (in winter) per 100 m altitude (Milosavljević 1988).

The actual distribution patterns of the forest trees were related to the relevant site factors. The results illustrate how the scientific base could be provided to construct the ecological limits of the most important tree species and the related forest types. Other initially planned applications, including the analysis of site suitability and productivity, could not be performed.

4.4.3 Construction of potential natural forest vegetation

The potential natural distribution of the dominant tree species, and related with them the forest communities, was derived from analyses of the actual distribution of the tree species. The following assumptions were made:

The climax tree species beech (*Fagus sylvatica*) and Fir (*Abies alba*) are not limited by competition through other tree species, but by abiotic site factors (Ellenberg and Leuschner 2010). This allows direct conclusions with respect to their ecological niches under natural conditions.

Light-demanding tree species, namely pines (*Pinus heldreichii*) and other pioneers, are limited by competition of shade-creating canopy trees, and not by abiotic site factors, at least locally or in the region. On sites where beech and fir can grow light-demanding tree species can occur as pioneers after disturbance (e.,g., fire, clearcut); in the climax forest they can be a minor species, or completely absent.

The tree species distribution as most important component of the potential natural forest vegetation was related to the most important site factors, and the potential distribution was constructed based on these ecological assumptions described before.

4.5 Site productivity and species suitability assessment

The assessment of site productivity in the DBU project was envisaged as one of the working activities of both the WP 1 and WP 2. Few factors influenced the delay of this working activity. A manifold of challenges resulting from the organization of project activities at the beginning of the project influenced the late start for this analysis. Furthermore, there was a certain delay of the necessary data delivery and a country-wide Digital Elevation Model, which caused a late start of this analysis, which is still ongoing. The site productivity and site suitability assessment[2] in Montenegro is being carried out within one of the doctoral theses within the project, which has an overall aim to identify from existing literature the decision-making criteria for tree species selection suitable to the site, to categorize them and to identify their priorities. The output is a set of recommendations for tree species selection suitable to the site, also according to the priorizition of forest functions. In a second stage, the aim is to demonstrate the implementation of the identified decision-making criteria through the example of Montenegro. This will be done through (a) analysis of tree species performance in relation to site conditions and ecological thresholds within the recognized decision-making criteria; and (b) analysis of tree species distribution under current and climate change conditions and development of a scientific basis for recommendation of tree species selection suitable to the site for Montenegro.

The following data available from the project will be prospectively used for this study:

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[2] The assessment of site productivity and site suitability is carried out within the dissertation of the doctoral candidate Sofche Spasikova. The analyses of this thesis will be carried out on the entire area of Montenegro. The doctoral theses of Srdjan Pejovic, and Milan Gazdic encompass analyses of site conditions for the two test areas in the project, MU Štitovo and MU Bjelasica respectively.

- Climatic data (temperature, precipitation) for estimating growing zones and climatic water balance; climate projections for Montenegro for simulating future distribution of tree species
- Digital Elevation Model (DEM) for the description of topography and estimation of energy resources, like solar radiation and correction of the estimated climatic water balance.
- Geological and soil data to estimate nutrient availability and site productivity

Vegetation and forest inventory data about tree species occurrence and distribution, available from the Forest Management Plans (FMP) and the National Forest Inventory (NFI).

4.6 Case studies: Regionalization of site characteristics

All data from the field survey have to be regionalized to produce the final forest site map. The basis for the regionalization are the precipitation in summer (RRWarm), total insolation and landform units.

4.6.1 Water balance level

In a first step the AWC values determined after the field survey using the transfer functions were transformed into WBL values. Table 11shows the results for Bjelasica,

Table 12 for Štitovo. The median (fields marked in green) was used if possible to minimize the influence of outliers.

Table 11: Frequency of the WBL classes in Bielscia in relation to RRwarm, landform unit [Geom] and total insolation [TI]

		Ti =1								Ti=2								Ti=3								total
Rrwarm	Geom	1	2	3	4	5	6	7	Sum	1	2	3	4	5	6	7	Sum	1	2	3	4	5	6	7	Sum	
300-450	200																				1		1		2	2
	300				2				2			1	1		1		3				1	1		1	3	8
	400													1			1			1	1	1	1		4	5
	560			1	1	1	1		4			1			2	2	5			1	2		3	1	7	16
	564		1	1	2	3	1	1	9			1	3	1		1	6					2		1	3	18
	700			1		2			3				2				2			1			1	1	3	8
	740			1	3		1		5			2	1		1		4				1	1		2	4	13
	800				1	2			3				1	2			3					2			2	8
	900			2	1	1			4			1					1									5
	Sum		1	6	10	9	3	1	30			6	8	4	4	3	25			3	6	7	6	6	28	83
Rrwarm	Geom	1	2	3	4	5	6	7	Sum	1	2	3	4	5	6	7	Sum	1	2	3	4	5	6	7	Sum	
450-600	200																					1			1	1
	300	1							1											1		1			2	3
	400																			1		1			2	2
	560			3	2	1			6	2	1	1	2	1			7			1	1	2		1	5	18
	564	1	2	1	1		1		6	1	1			1	1	1	5			2				1	3	14
	700		1	1	2	1			5			3					3			2	1		1		4	12
	740				2				2			1				1	2	1		1		1			3	7
	800			1	2				3			1		2			3	1			1			1	3	9
	900	1		1	1				3		1				1	1	3		1	1					2	8
	Sum	3	3	7	10	2	1		26	3	3	6	2	4	2	3	23	2	1	9	3	6	1	3	25	74
total		3	4	13	20	11	4	1	56	3	3	12	10	8	6	6	48	2	1	12	9	13	7	9	53	157

Table 12. Frequency of the WBL classes in Štitovo in relation to RRwarm, landform unit [Geom] and total insolation [TI]

	Ti=1							Ti=2							Ti=3								total
Geom	3	4	5	6	7	9	Sum	3	4	5	6	7	8	Sum	2	3	4	5	6	7	8	Sum	
200															1	1			1			3	3
300		1					1									3		1				4	5
400		1	1				2		2					2	7	2	1					10	14
560		1		1			2			4	1		1	6		16	13	7		2	1	39	47
564		1	1				2	2	1		1			4	3	1						4	10
700		1	1				2		1	3	3			7		10	5		6	2	1	24	33
704	1			1			2					1		1			1	2				3	6
800			1			1	2			4				4			6	5		1		12	18
804			1	1			2			1				1		1						1	4
900			1		1		2			1				1			3	3				6	9
total	1	5	6	3	1	1	17	2	4	13	5	1	1	26	11	34	29	18	7	5	2	106	149

In the case of insufficient sample sizes to determine the median the total insolation was skipped in the analysis. A final classification table can be extracted which can be joined to the polygons of the concept map. Table 13 and Table 14 show the transfer tables for Bjelasica and Štitovo. Figure 28 and Figure 29 show the regionalized WBL for Bjelasica and Štitovo.

Table 13. Transfer table of WBL, Bjelasica

	Geom	Ti=1	Ti=2	Ti=3
300-450	200	5	5	5
	300	4	4	5
	400	5	5	5
	560	5	6	6
	564	5	4	5
	700	5	4	6
	740	4	4	6
	800	5	5	5
	900	4	3	3
450-600	200	5	5	5
	300	4	4	4
	400	4	4	4
	560	4	3	5
	564	3	5	3
	700	4	3	4
	740	4	5	3
	800	4	5	4
	900	3	6	3

Table 14. Transfer table of WBL, Štitovo

Geom	Ti=1	Ti=2	Ti=3
200	4	4	3
300	4	4	3
400	4	4	2
560	5	5	4
564	4	4	2
700	5	5	4
704	5	5	5
800	5	5	5
804	5	5	5
900	6	5	5

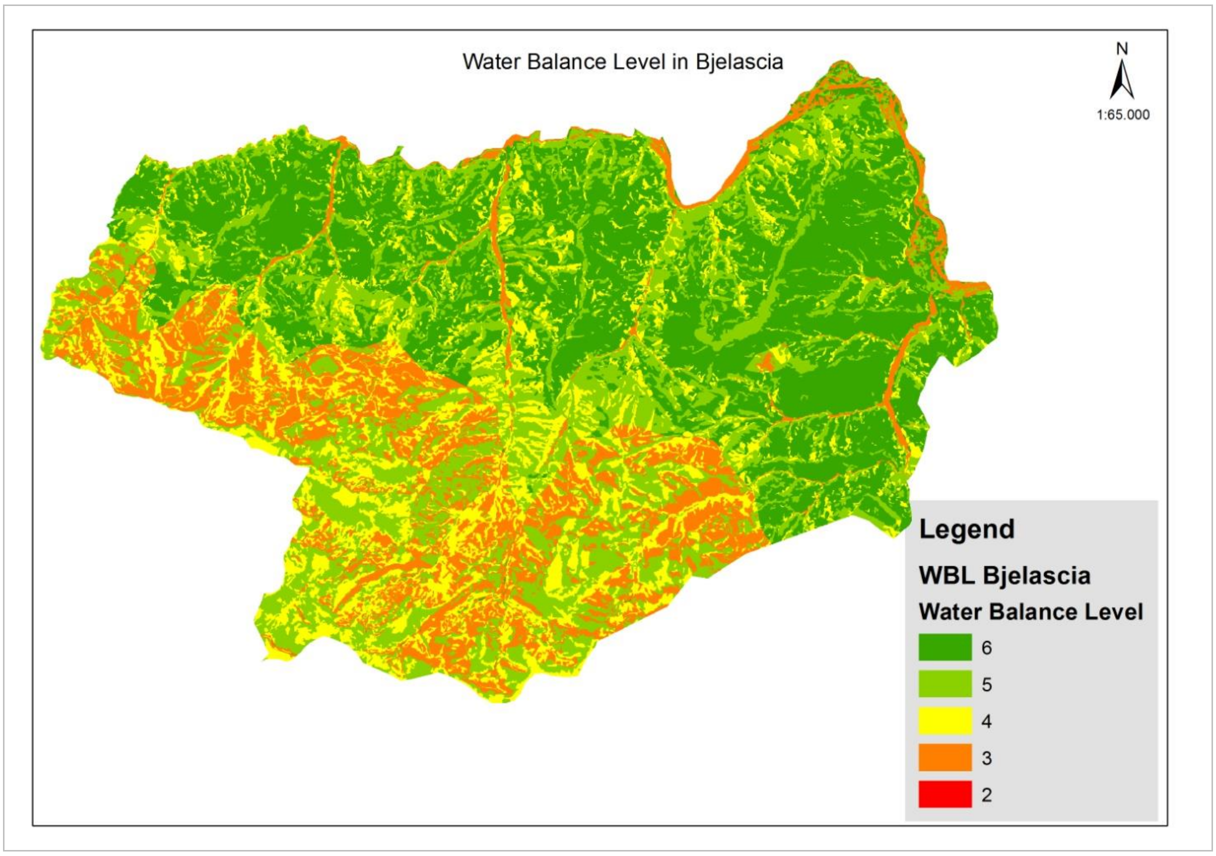


Figure 28. WBL in Bjelasica

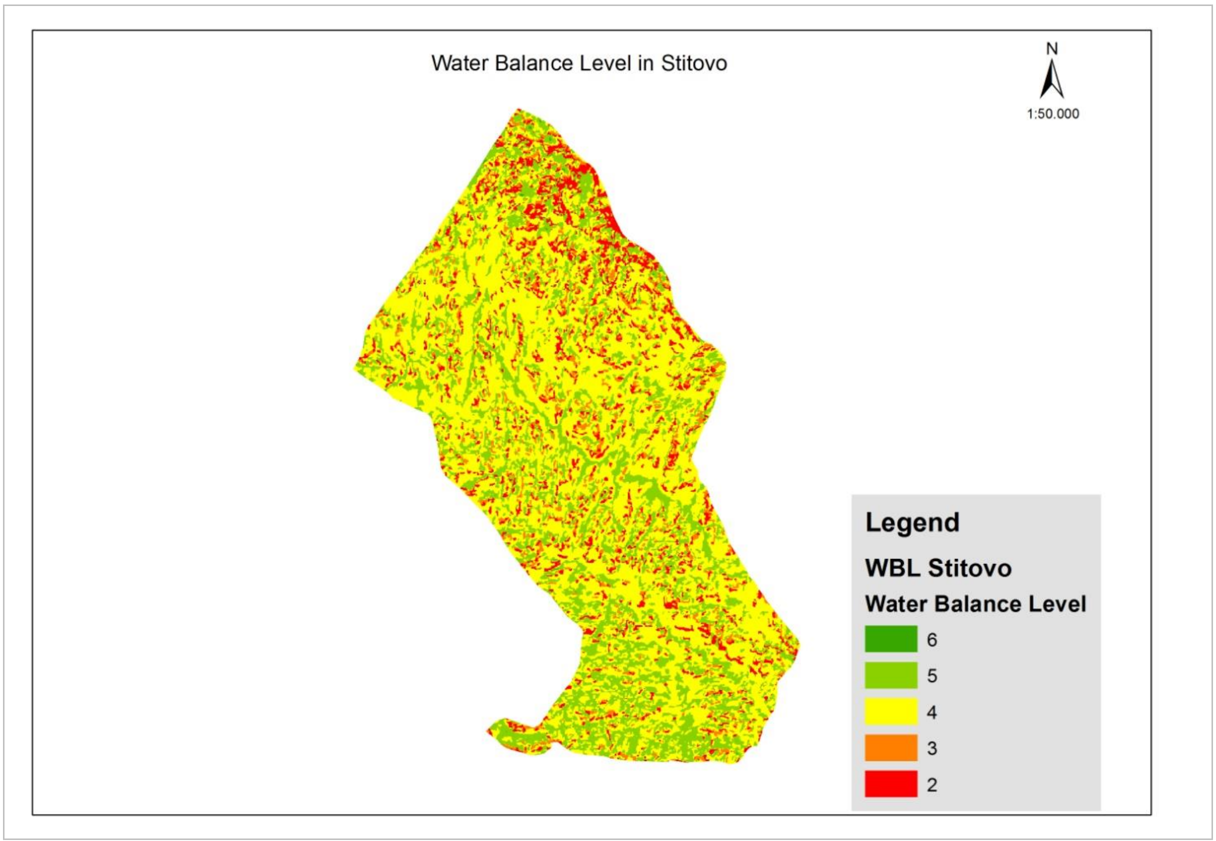


Figure 29. WBL in Štitovo

4.6.2 Nutrient regime

To regionalize the base saturation information of the soil map as well as the landform units is required (Table 15).

Table 15. Frequency of the base saturation classes in relation to landform unit and parent material in Bielscia [ri = rich, ri-me = rich to medium, med = medium, poor = poor]

Geo	GEOM	rich	ri-me	med	me-po	poor	Total
Ks	200				1		1
	300			2	1	2	5
	400				1	1	2
	560	1	3	5	1	6	16
	564	2	3	6		2	13
	700		2	2	1	3	8
	740		2	3			5
	800			4		2	6
	900			3		1	4
	Summe	3	10	25	5	17	60
Psh	200					1	1
	300			1		1	2
	400				1		1
	560			4		2	6
	564			6		1	7
	700		1	4		1	6
	740		1	5			6
	800			5			5
	900			3			3
	Summe		2	28	1	6	37
SHk	200			1			1
	300			3		1	4
	400			2		2	4
	560			6	6		12
	564		1	3	6	2	12
	700			3		3	6
	740		1	7	1		9
	800			4		2	6
	900		2	3	1		6
	Summe		4	32	14	10	60
	Total	3	16	85	20	33	157

The final site map is a result of an overlay of the WBL and base saturation regionalization. Additionally, a temperature layer is added to account for differences in growing zones. The final results are shown in Figure 30 and Figure 31 for Bjelasica and Figure 32 and Figure 33 for Štitovo.

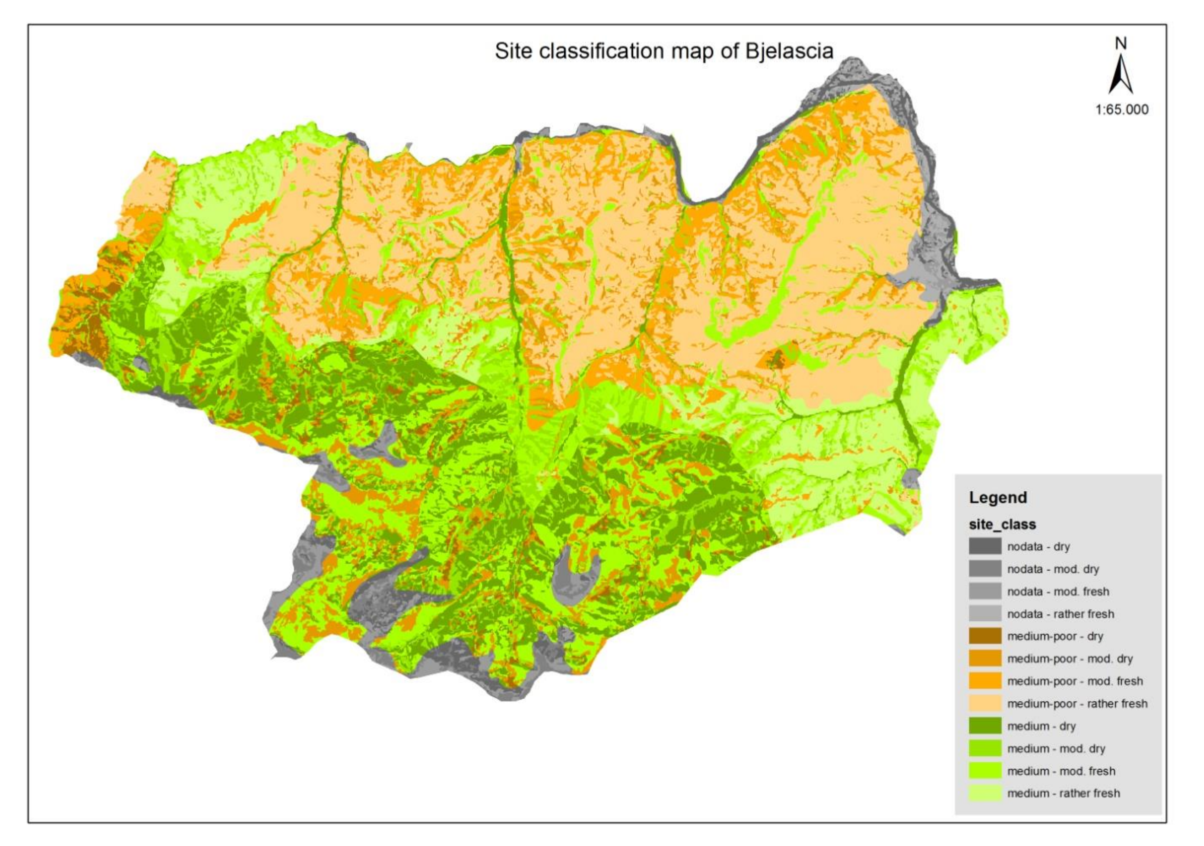


Figure 30. Sitemap of Bjelasica

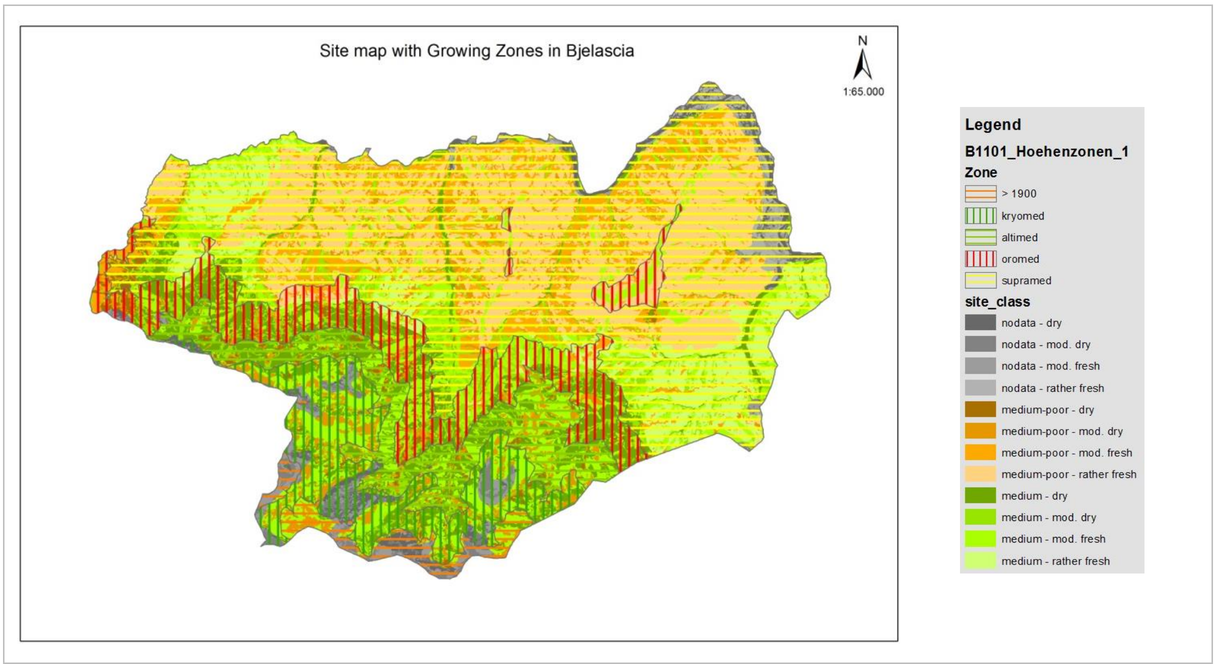


Figure 31. Sitemap of Bjelasica with growing zones

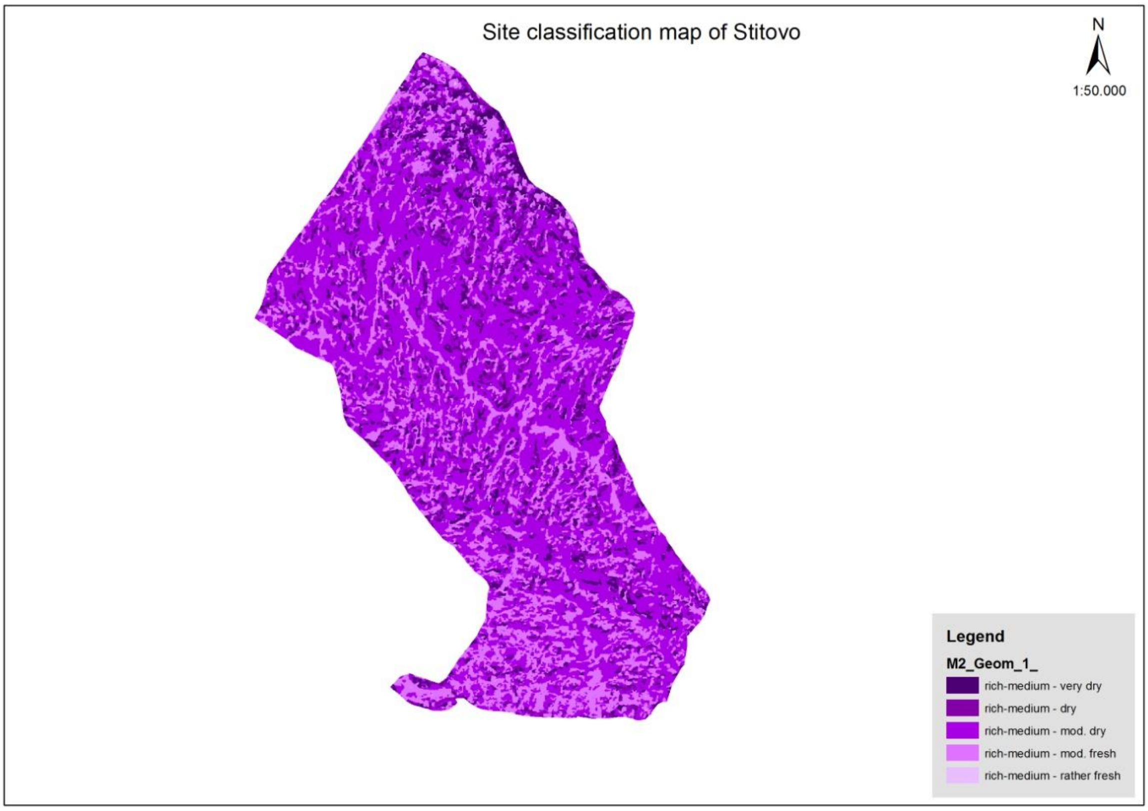


Figure 32. Sitemap of Štitovo

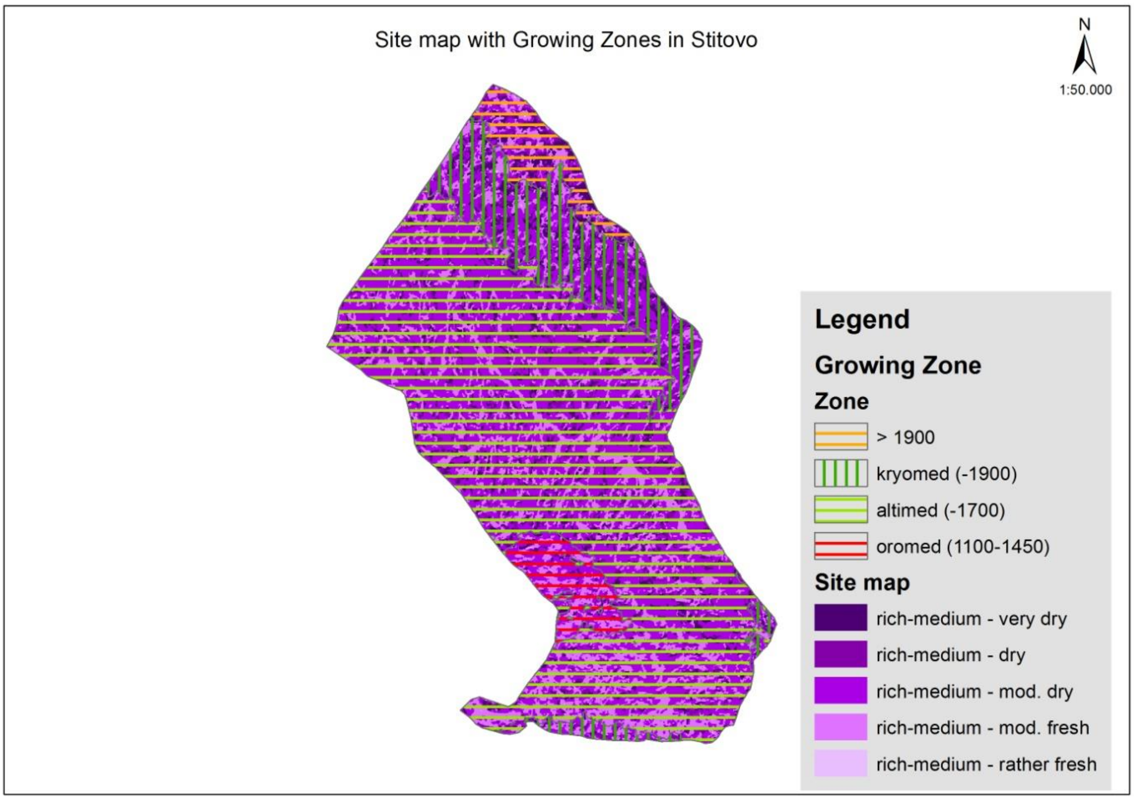


Figure 33. Sitemap of Štitovo with growing zones

4.7 Case studies: Regionalization of forest types

4.7.1 Actual forest flora

The sampling provided an overview of the actual vegetation. The actual vegetation and site factors were sampled on 161 plots in MU Bjelasica and 120 plots in MU Štitovo. In total they contained nearly 200 vascular plant taxa (chapter 10, Appendix 3).

4.7.2 Actual distribution of tree species

4.7.2.1 MU Bjelasica

The actual distribution of the main tree species beech, fir, and Hop hornbeam (*Ostrya carpinifolia*) was related to the actual site conditions. Based on the complete species composition, forest types could be described.

The **climatic water balance** of sample plots in Bijelasica was mainly influenced by elevation (models of precipitation and temperature follow elevation) and elevation combined with exposition and inclination (= irradiation) (potential evapotranspiration after Turc 1961). It could be shown, that

- beech is able to grow on all sites (Figure 34)
- fir is absent when precipitation is less than 900 mm per year (Figure 35)
- spruce can become dominant when precipitation exceeds 1400 mm per year, i.e., in high altitudes. It is absent on plots with precipitation <900 mm per year (Figure 36)
- Hop hornbeam (*Ostrya carpinifolia)* occurs on plots with low precipitation (< 1200 mm per/year) combined with high evapotranspiration (< 3,5 mm/per day daring the year) (Figure 37).
-

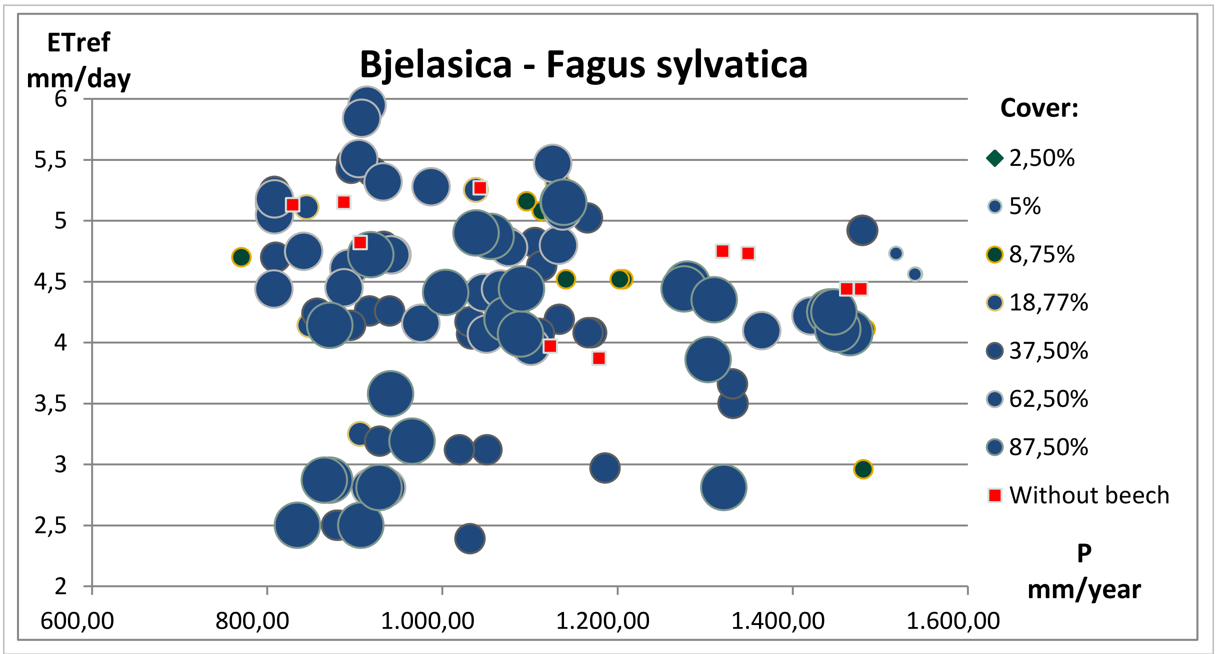


Figure 34. Occurrence and coverage of Fagus sylvatica in relation to potential evapotranspiration (ETref) and precipitation.

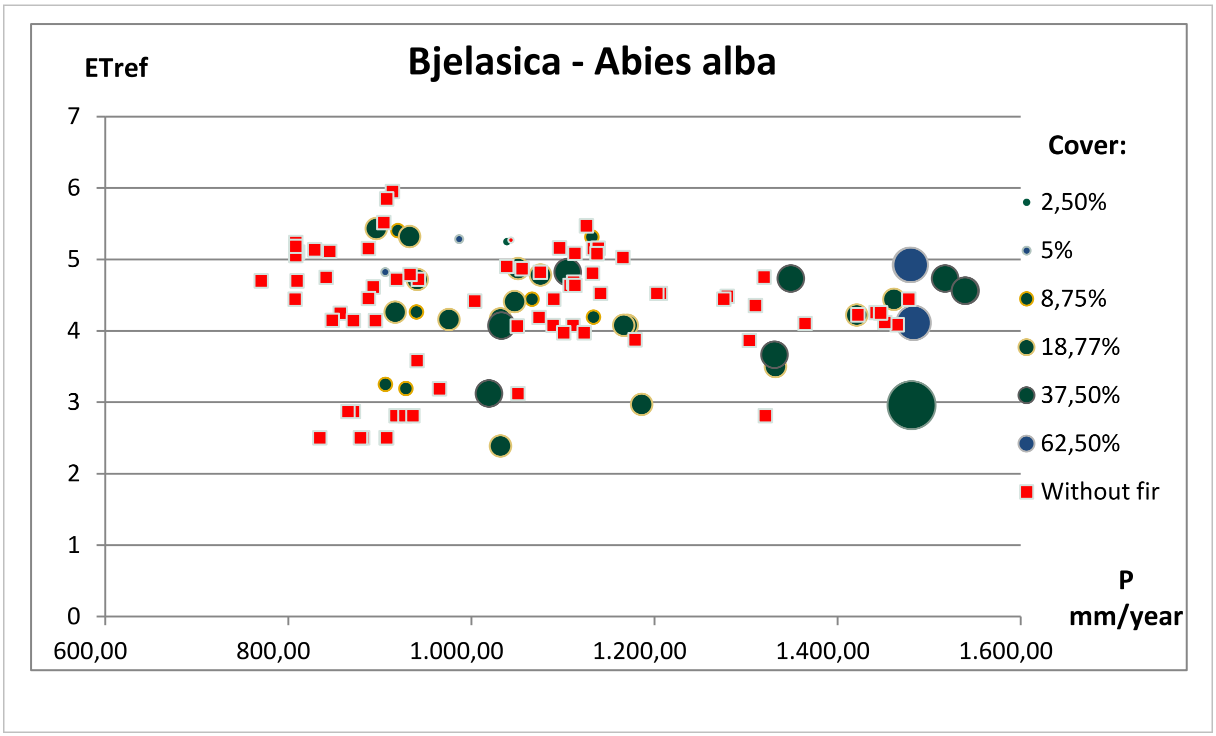


Figure 35. Occurrence and coverage of *Abies alba* in relation to potential evapotranspiration (ETref) and precipitation.

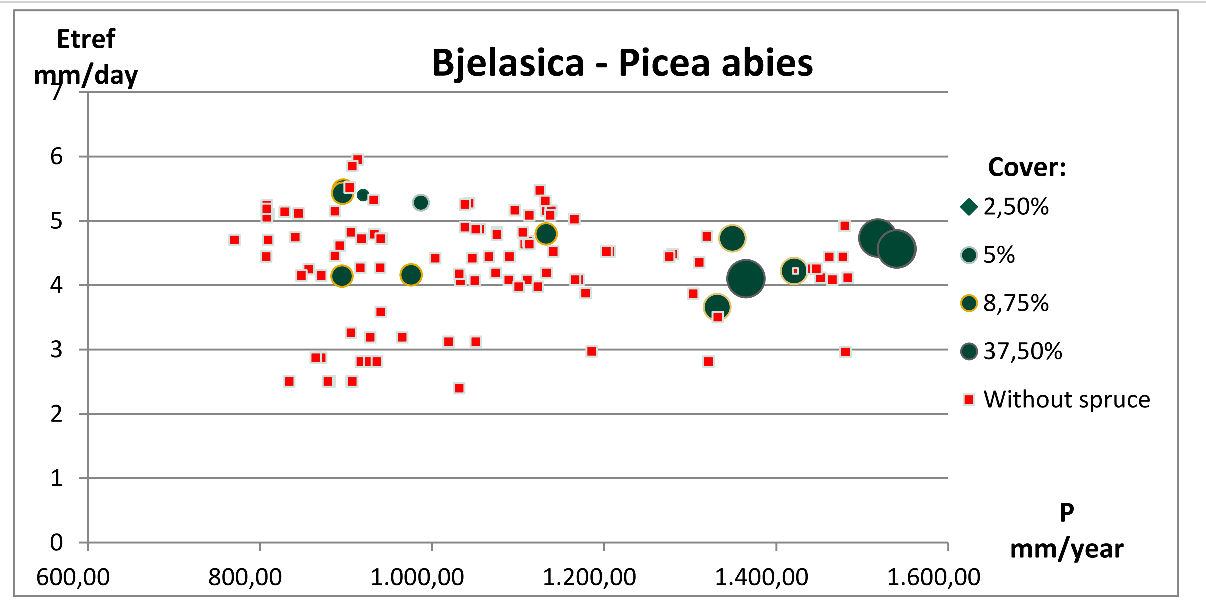


Figure 36. Occurrence and coverage of *Picea abies* in relation to potential evapotranspiration (ETref) and precipitation.

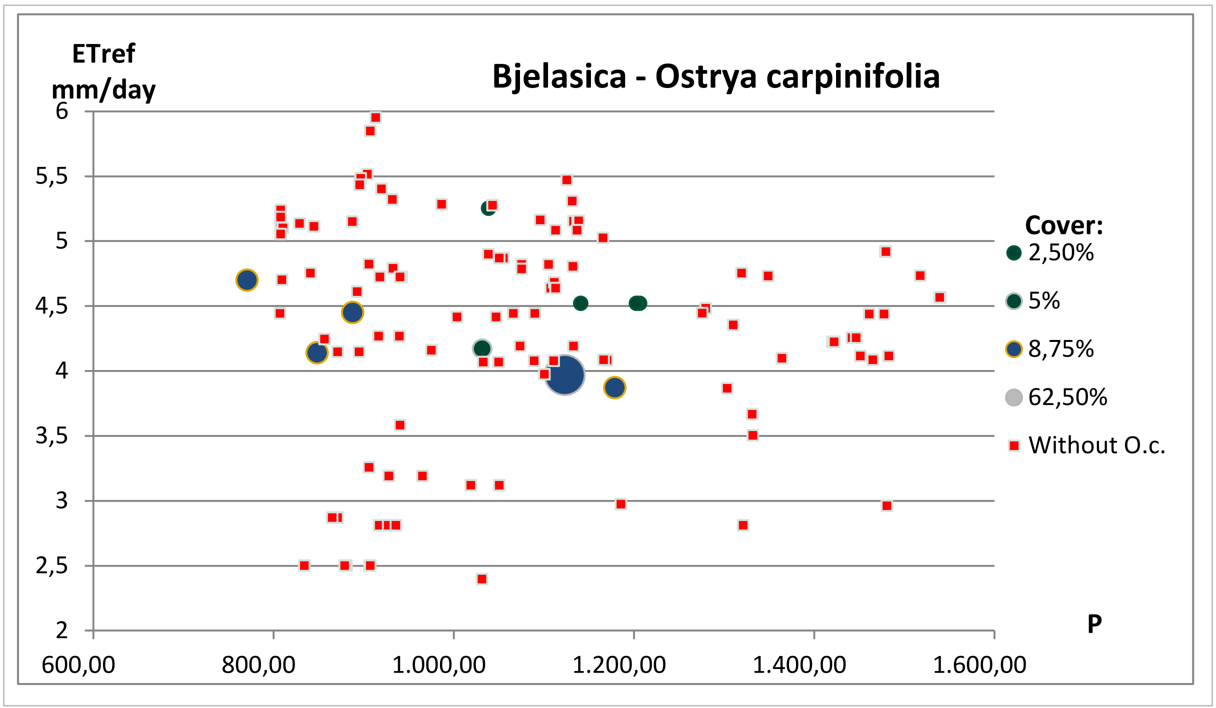


Figure 37. Occurrence and coverage of *Ostrya carpinifolia* in relation to potential evapotranspiration (ETref) and precipitation

The climatic water balance is modified by the soil water storage capacity. This interacts with the climatic water balance. For the occurrence of fir could be shown (Figure 35), that (1) increased positive climatic water balance is related to increased cover of fir in the canopy; above an annual climatic water balance of 600 mm, fir can become a dominant tree species; (2) fir is absent on shallow soils combined with low climatic water balance, i.e., dry sites; (3) fir is absent on many plots which are within the ecological envelope of fir. That means, that human influence must have removed fir from these stands. They bear the potential for fir under natural conditions, but also under improved silvicultural management.

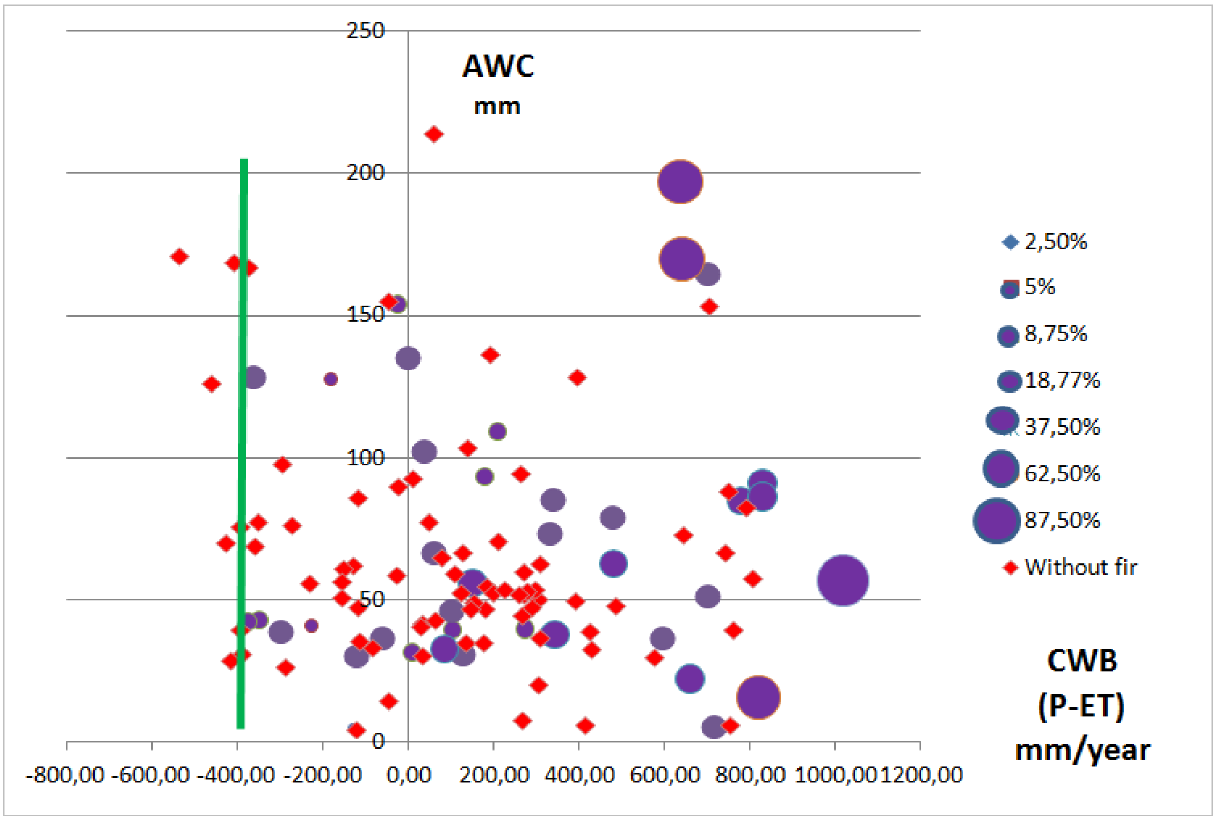


Figure 38. Relation between AWC (available soil water storage capacity), CWB (Climatic water balance) during the summer period and distribution of *Abies alba* in in the canopy MU "Bjelasica".

4.7.2.2 MU Štitovo

The actual distribution of the main tree species beech, fir, Balkan Pine (*Pinus heldreichii)* was related to the actual site conditions.

The climatic water balance of sample plots in Štitovo was mainly influenced by elevation (models of precipitation and temperature follow mainly elevation) and elevation combined with exposition and inclination (= irradiation) for the calculation of the potential evapotranspiration after Turc (1961). It could be shown, that

- High evapotranspiration and shallow soil limit beech (and fir), therefore creating the spatial niche for the light-demanding *Pinus heldreichii* (Figure 39)
- *Pinus heldreichii* is not limited by lack of water, but excluded by competition. On moist sites, beech and fir would predominate, but *Pinus heldreichii* can also grow, if the shade-creating climax species are removed after severe distrubance, e.g., logging or fire (Figure 40). That means in in the climax forest Balkan Pine can be only a minor species (temporal successional relict species), or completely absent.

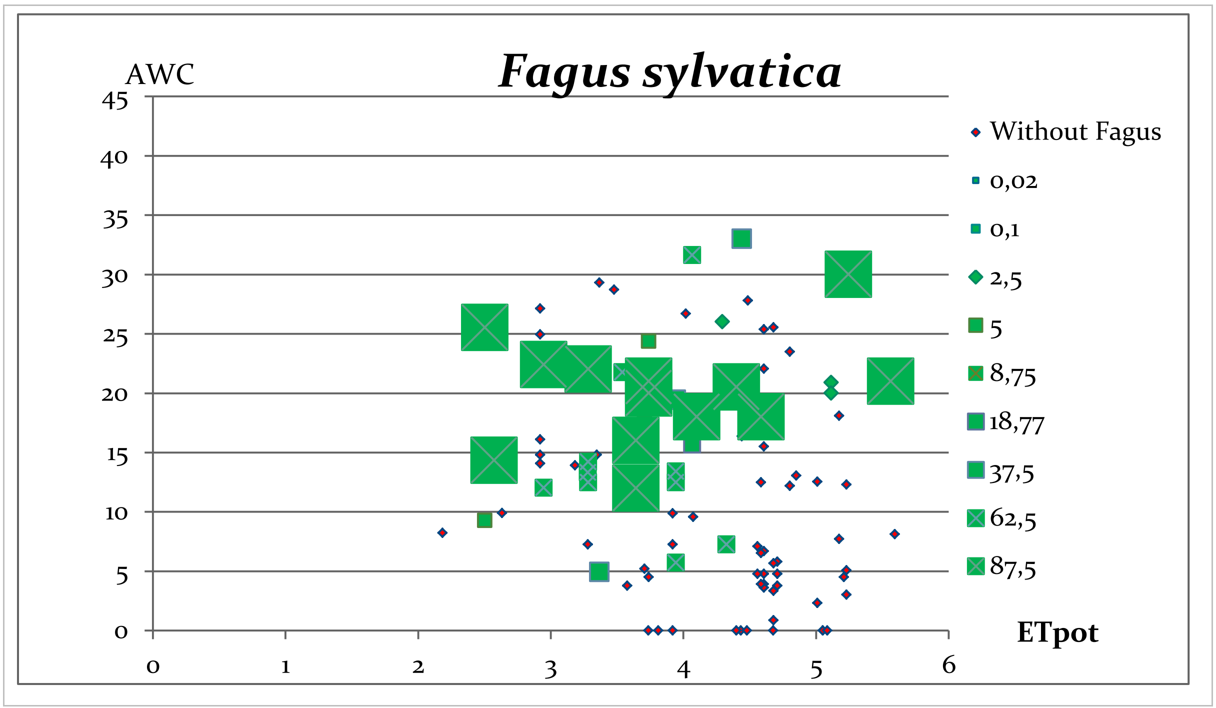


Figure 39. Drought limit of Beech (*Fagus sylvatica*) at MU Štitovo. High evapotranspiration and shallow soil limit beech.

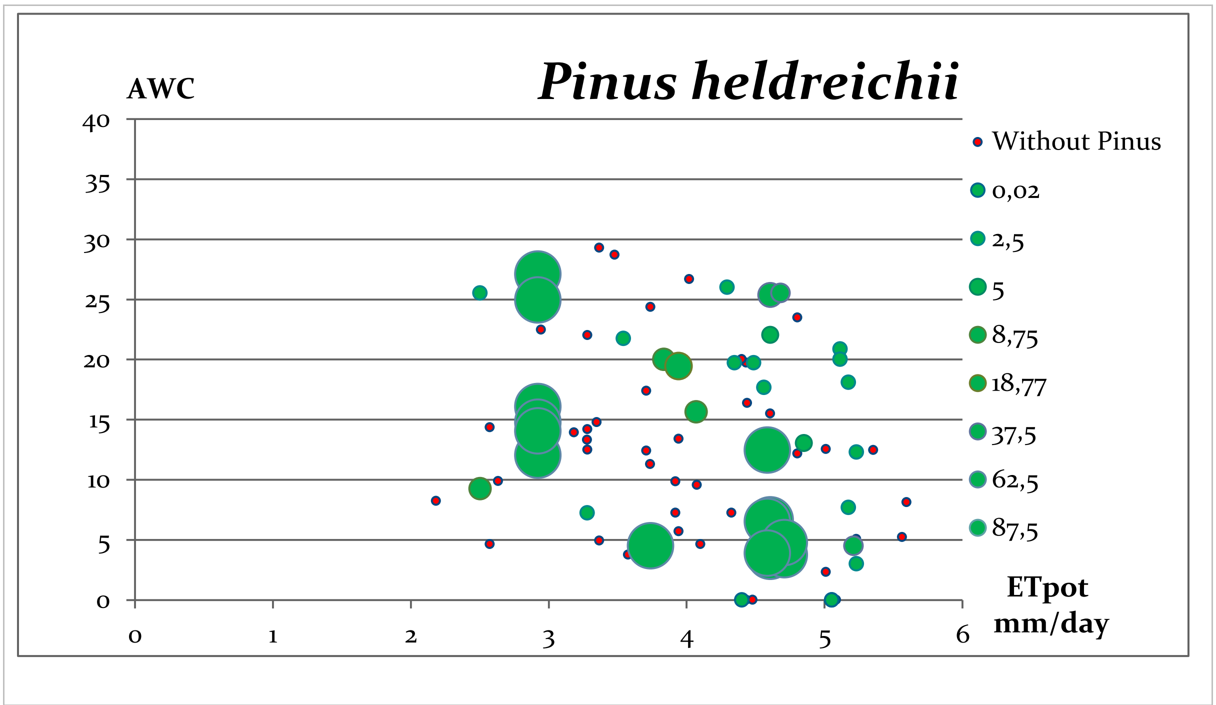


Figure 40. Distribution of Pine (*Pinus heldreichii*) at MU Štitovo. Pinus heldreichii is not limited by site factor water, but excluded by competition. On moist sites it can be a temporal component in form of a successional relict species.

4.7.3 Actual forest types

4.7.3.1 MU Bjelasica

The actual flora and vegetation of Bjelasica was described based on 161 sample plots (relevés and site factors). From 13 (representative soil profiles) sample plots physical and chemical soil properties were analyzed. The forests are commercial production forests which means extraction of firewood and timber.

Following the Serbian classification (Tomić, 2004) these forest types were distinguished:

1. Abieti-Fagenion moesiacae

General characteristics of the habitat:

- Elevation: 800 to 1800 m;
- Mean annual temperature: 5-8°C (year), 10-14°C (vegetation period);
- Mean annual precipitation: 1100-2800 mm (per year);
- Soil: deep, acidic, brown soils, pH 4,5-5,5 (in water);
- Floristic composition: *Fagus sylvatica, Abies alba, Picea abies, Acer pseudoplatanus, Sorbus aucuparia, Lonicera nigra, Mycelis muralis, Galium odoratum, Aremonia agrimonioides, Fragaria vesca, Rubus hirtus, Epilobium montanum, Geranium robertianum, Dryopteris filix-mas, Prenanthes purpurea, Viola reichenbachiana, Oxalis acetosella, Athyrium filix-femina, Daphne blagayana, Anemone nemorosa, Galium rotundifolium, Lamium galeobdolon, Veronica officinalis, Allium ursinum.*

2. Luzulo-Fagenion moesiacae

- Elevation_: 800-1600 m;
- Slope: 20°-40°;
- Soil: shallow, very acidic soil with a low pH values;
- Floristic composition: *Luzula luzuloides, Fagus moesiaca, Veronica officinalis, Mycelis muralis, Festuca drymeia, Viola reichenbachiana, Dryopteris filix-mas, Galium odoratum*.

3. Fagenion sylvaticae submontanum

- Elevation: 500-1300m;
- Soil: brown soil on silicate parent material;
- Floristic composition: *Fagus sylvatica, Carpinus betulus, Prunus avium, Acer campestre, Acer pseudoplatanus, Corylus avellana, Pyrus pyraster, Sambucus nigra, Rosa sp., Fragaria vesca, Rubus hirtus, Dryopteris filix-mas, Mycelis muralis, Allium ursinum, Hedera helix, Geranium robertianum, Geum urbanum, Poa nemoralis, Helleborus odorus, Athyrium filix-femina, Anemone nemorosa.*

4. Ostryo-Fagenion moesiacae

- Elevation: 850-1000 m;
- Soil: shallow;
- Slope: steep.
- Floristic composition: *Ostrya carpinifolia, Fagus sylvatica, Quercus petraea, Q. cerris, Lonicera nigra, Sesleria rigida, Sesleria argentea, Veronica officinalis, Vaccinium myrtillus*.

4.7.3.2 MU Štitovo

Three vegetation types were identified, based on the dominating tree species: Beech forest („Fagetum montanum") which includes stands with pure beech and beech-fir-mixed forest; Pine forest ("Pinetum heldreichii mediterraneo-montanum"); and subalpine Juniper shrubland (Juniperetum nanae-intermediae).

***Fagetum montanum* (51 plots)**

Wide-spread, typical species in Štitovo beech and beech-fir-forests were *Fagus silvatica, Prenanthes purpurea, Anemone nemorosa, Dryopteris filix-mas, Epilobium angustifolium, Lamium galeobdolon, Veronica urticifolia, Veronica officinalis, Viola reichenbachiana, Epilobium montanum.*

***Pinetum heldreichii mediterraneo-montanum* (37 plots)**

The pine tree species *Pinus heldreichii* Christ. can be regarded as a Tertiary relict and subendemic species of the western part of the Balkan Peninsula. The community dominated by that tree is wide-spread in the mountains around Niksic (Štitovo, Maganik and Prekornica). The *Pinetum heldreichii mediterraneo-montanum forests in Štitovo* are exposed to strong anthropogenic pressures including fire.

Wide-spread, typical taxa in Štitovo pine forests were *Pinus heldreichii, Juniperus nana, Dianthus petraeus, Sorbus aria, Hieracium_sp, Hieracium tomentosum, Arctostaphylos uva-ursi, Potentilla erecta, Coronilla coronata, Asperula scutellaris, Galium lucidum, Gentiana asclepiadea, Hieracium pavichii , Veratrum album.*

Towards east there is a gradual transition to the „Pinetum heldreichii bertiscum" Blač 1959 in the Komova and Prokletija region (Blečić and Lakušić 1970)

Juniperetum nanae-intermediae shrubland (22 plots)

The vegetation with mountain juniper (*Juniperetum nanae-intermediae*) occurs at high altitudes in the subalpine zone from Slovenia to Macedonia and Montenegro. This vegetation type was first described under the name Juniperetum nanae-intermediae (Jovanović, 1953). In Štitovo it was sampled at high altitudes between 1500 and 2100 m a.s.l..

Wide-spread, typical taxa of this subalpine shrubland in Štitovo pine forests were *Juniperus nana, Lonicera formanekiana, Potentilla erecta, Hieracium_sp, Hieracium tomentosum, Sorbus aria, Coronilla coronata, Asperula scutellaris, Galium lucidum, Veratrum album.*

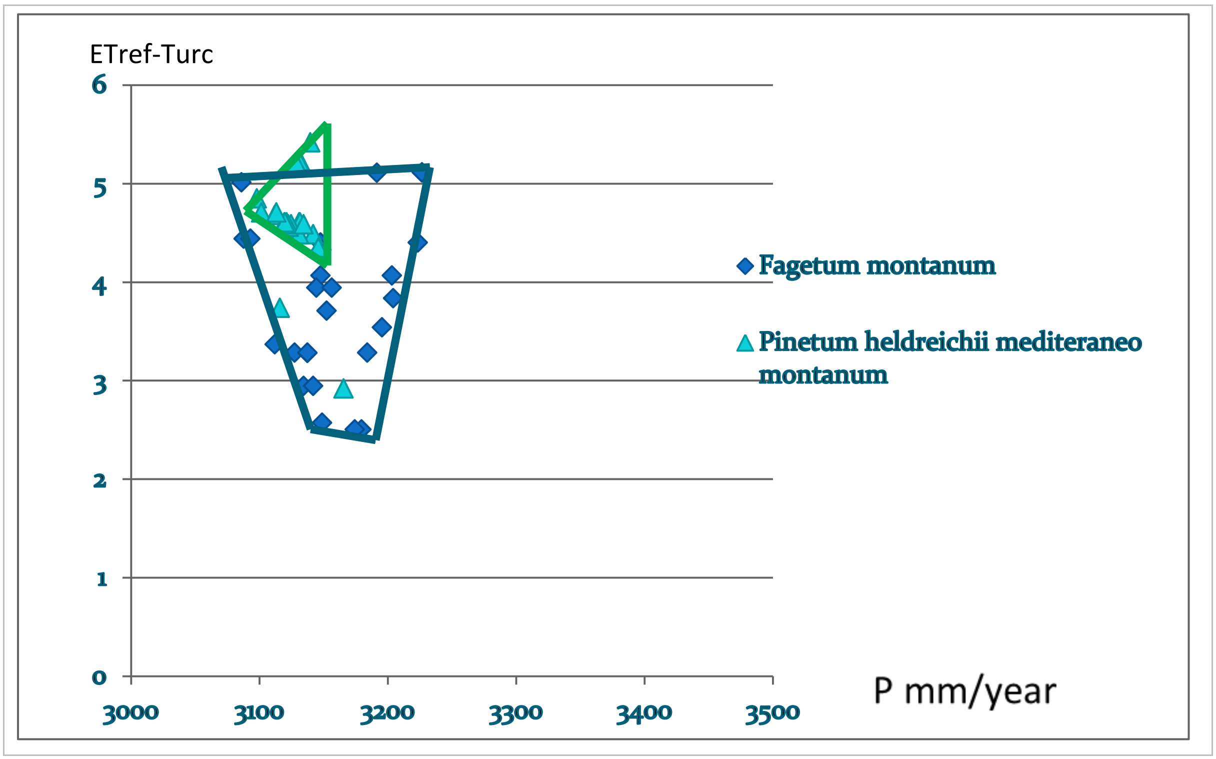


Figure 41. Distribution of beech- and pine-dominated forest types in MU Štitovo in relation to ET_{pot} and Precipitation. It seems that under higher precipitation pine is not occurring (outcompeted by beech). The large range of the site factors precipitation and potential evapotranspiration indicates, that soil water storage capacity (AWC) is another relevant factor.

4.7.4 Application of method to construct the potential natural forest vegetation

The information of the actual distribution of a certain species, e.g., a tree species, and their site parameters (on sample plots) allows us to identify its physiological and ecological amplitude, and the limits of its occurrence. If forest inventory data would be available, additional conclusions could be drawn of their growth and production potential. In a similar way, the description and mapping of plant communities, e.g., forest types, could be performed by relating the forest type identified for a near-natural sample plot with the site data.

4.7.4.1 Potential natural distribution of tree species

From the actual distribution of selected tree species, conclusions can be drawn with respect to their occurrence under potential natural conditions. For the 2 case studies in Bjelasica and Štitovo it could be shown, that within these management units clear ecological limits for the tree species can be detected. It could be shown, that

- The climax tree species beech (*Fagus sylvatica*) and Fir (*Abies alba*) are not limited by competition through other tree species, but by abiotic site factors (Ellenberg and Leuschner 2010). This allows direct conclusions with respect to their ecological niches under natural conditions.
- Light-demanding tree species, namely pines (*Pinus heldreichii*) and other pioneers, are limited by competition of shade-creating canopy trees, and not by abiotic site factors, at least locally or in the region. On sites where beech and fir can grow light-demanding tree species can occur as pio-

neers after disturbance (e.,g., fire, clearcut); in the climax forest they can be a minor species, or completely absent.

- High evapotranspiration and shallow soil limit beech (and fir), therefore creating the spatial niche for the light-demanding trees, in Štitovo *Pinus heldreichii*.

Because these findings derive from case studies designed for a method development, they need to be confirmed and enlarged by further studies. Based on the existing knowledge of these tree species, more site factors and their interrelation in form of indices have to be included in the analyses.

4.7.4.2 Potential natural distribution of forest types

The construction of the potential natural distribution of the forest types needs the identification of the existing forest type and the relevant site factors for each sample plot.

Forest types can depend from the influence of the tree species composition, which could be man-made. An example: The ground flora under a man-made oak or spruce forest which replaces potential natural beech forest is very different (different influences of the canopy).

Therefore construction of the potential natural model of the occurrence of the tree species is the first crucial step for the construction of the pnV, because the tree species have a strong influence of the complete species composition. Sample plots assessed to be near-natural have the function to act as reference for vegetation-site-relationships, identifying the plant community limits in form of thresholds for abiotic site factors, and finally mapping.

4.7.4.3 Conclusion

For other regions under different climatic conditions the limiting site factors can change. For instance, drought may limit beech at low elevation, and temperature related factors at its upper limit. This affords separate analyses for the actual tree limits under the regional different climate (and soil) conditions. A stepwise procedure can be recommended:

- Identification of existing ecological limits of tree species, optimally under near-natural conditions
- Quantification of these limits in form of formulas describing the relation between the site factors
- Using thematic maps of site factors to relate them to the detected ecological limits of the tree species.
- The construction of the model of the pnV of the plant communities (forest types) principally follows the same procedure.

4.8 Work package 3 – Forest Ecological Geodatabase (FEGDB)

4.8.1 Background and objectives

The concept behind the development of a forest ecological geodatabase (FEGDB) is based on the idea of collecting all information that are relevant for Forestry, Ecology and Nature Protection in one place allowing an easy access and analysis for the decision making in forest management and as information for the environmental sector and an environmental monitoring.

Currently basic ecological information as exact soil maps, forest site maps and vegetation data are not existing. Data on biodiversity, endangered species, habitats, wildlife and nature protection is spread out in different institutions or organization, making their utilization very time and effort consuming.

Making all of the data available through one single database would allow each institution to use it whenever needed. For the Forestry sector access to data from the environmental and nature protection sector (such as habitats of endangered species, protected areas, biotopes etc.) are crucial for a modern sustainable forest management.

One other benefit of such a web based database or platform is that it provides a very easy approach for sharing forestry and nature protection relevant information with the public. With the proper user rights management and techniques it allows to collect and update the information from the interested public, NGOs, associations or any related governmental body, for example sightings of rare and endangered species. This information can then be directly saved in a central database and shared between all related institutions.

During the kick-off workshop (28.11.2013) the concept for achieving this goal was presented and accepted from all partners. It includes the following work steps:

- Work step 1: Evaluation of the current status regarding forestry and environment related geodata (already described in chapter 4.1.1)
- Work step 2: Assessment of GIS standards and web based geodatabases in the forest and environmental sector
- Work step 3: Design and development of a prototype for a forest ecological geodatabase (FEGDB)“

4.8.2 Work step 2: Assessment of GIS standards and web based geodatabases

All partner institutions were visited and interviewed about the existence, design and content of GI-systems respective spatial databases.

- Real Estate Agency: Desktop GIS is one of the main tools for the daily work. A central file data-storage exists which enables sharing of certain data types, but the data content is not related to forestry and environment.
- Ministry of Agriculture and Rural Development (MARD): The use of GIS is integral part of certain work processes for example in Forest Management Planning or Operational Planning. However the GIS is used decentralized on individual work stations. There is a central database containing information on forest management planning, which however is not on a server, and cannot be accessed by all relevant user remotely (like Forest district offices, MARD or the Forest Administration headquarter).
- Ministry of sustainable development and tourism (MSDT): Only a few work stations equipped with GIS exist. There is no central database and no central retrieval systems using spatial data.
- Institute for Hydrometeorology and Seismology (HMZCG): GIS and remote sensing software is available and used within the institute as one of their basic tools. However as the institute is not dealing with the respective topics, spatial data on biodiversity, nature conservation or forestry are not existing. A web-GIS is not existing.
- Environmental Protection Agency (EPAM): Individual GIS workstations are available at the agency. There is no central geodatabase with forest, vegetation or biodiversity information.

The survey showed:

- GIS workstations are available in each institution, but as individual desktop systems.

- With exception of REA and HMZCG the partners do not manage data in central geodatabases.
- Forest Management Plans are available in one database, but without link to spatial entities (FMU, Compartment, Sub-Compartments, Forest roads)
- A central geodatabase with forestry or nature protection related data is not – yet – available in MARD or MSDT
- Data sharing between Ministries and institutes is not possible.
- Data access for the public is not possible

4.8.3 Work Step 3: Design and development of a prototype for a Forest Ecological Geodatabase (FEGDB)

There was and is no central geodatabase in MARD, the Forest Administration or MSDT nor EPAM. As consequence a prototype of a web-based FEGDB using open source products was developed. It shall serve as a first framework and a show-case of a future integrated geo-portal of the Forest Administration or EPAM.

The draft concept for the geodatabase was already presented during the kick-off workshop in Podgorica. The concept and main content has been discussed that time and it was accepted by all partners. Figure 42 shows the main components of the system.

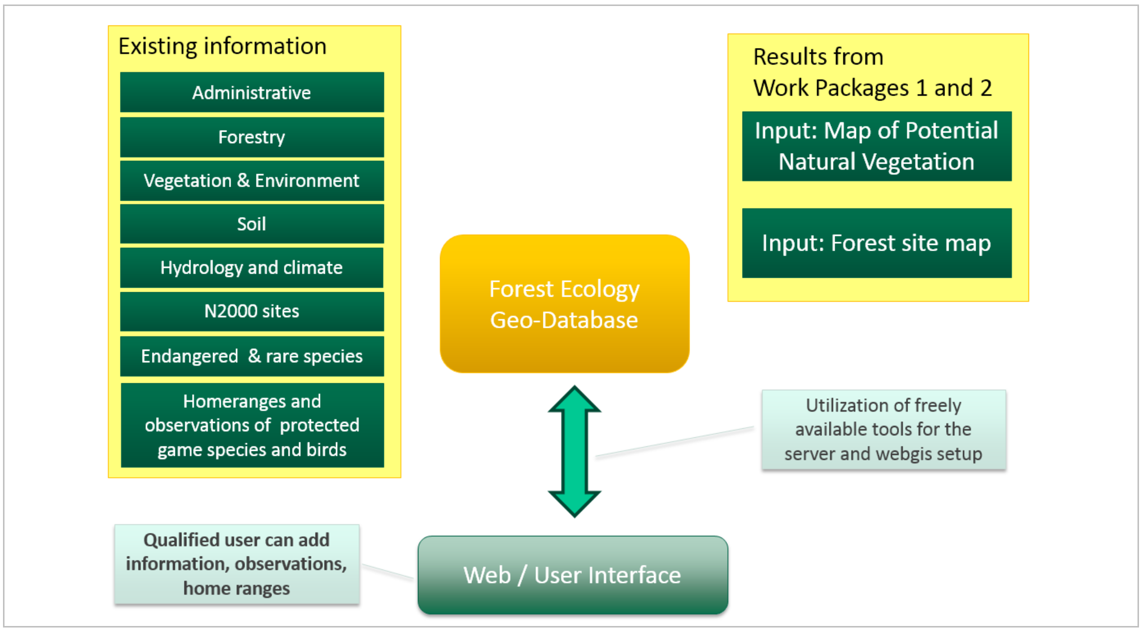


Figure 42. Concept of the Forest Ecology Geodatabase (FEGDB)

4.8.3.1 Information content

As previously described the necessity for such a geodatabase is to compile all available information related with forestry, ecology, biodiversity and nature protection. The main data input comes from the side of both ministries and their forestry- and environment related institutions in Montenegro. The second part of the data is project specific and would be incorporated in the geodatabase at the end of the project. These are the results of the first two work packages, namely the forest site map and map of potential natural forest vegetation of the study sites. The datasets of the prototype FEGDB can be seen following the link presented in the "User Guide for the Web GIS Platform" (see chapter 11, Appendix 4). Moreover the build in datasets are marked in the chapter 8, Appendix 1.

4.8.3.2 The Geodatabase

This is the central technical component of the system where all the spatial data are compiled. As a result of the discussions inside the project and during the kick-off meeting it was decided that the system would be based on freely available and open source technologies, which would reduce the implementation costs but allows upgrades and improvements in the future. The decision on which system the geodatabase would be set up, was based on that principle. According to previous experience and current state of the art technologies, it was decided to use a PostgreSQL database with PostGIS component. This system provides a relational database which can store all data and with the PostGIS component it supports spatial data as well.

The benefits of the system are as follows:

- Free of license fees
- Provides standard interfaces with most of the standard technologies used for setting up web-based platforms
- Updates of the system do not require a purchase of a new license
- It can be set up on one place and accessed locally and remotely.

4.8.3.3 Web Interface

The setup of the geodatabase in PostgreSQL is already a step forward into sharing the data between the different ministries and institutions. This however does not allow for a simple utilization of the data, especially for users that are not familiar with databases and GIS.

In order to make the system more user friendly, the data from the geodatabase can be presented, visualized and used on a web based system. Such a system allows to present the data in thematic maps online, and has a familiar look as nowadays the utilization of web-based mapping services (google maps, open street maps etc.) is wide spread.

A detailed description of the components will be made available to the partners from the Montenegrin institutions, with the intention of building up the system internally at one central place in Montenegro. Below we shortly give an overview of the key components in the system.

- Geoserver – is a server for sharing spatial data. It provides interoperability with a wide selection of platforms
- Openlayers - is an open source library used for displaying map and spatial data on web platforms
- Javascript – is a programming language used for development of web platforms. In this case it is used for customizing the GUI to fit the needs of the users

With the combination of these components the Web-GIS system provides the following functionalities:

- Storage of all data in one place
- Easy access to the data from different places simultaneously
- Access through a Web-GIS platform or directly in GIS as a WMS service
- Standardized format of the data
- Management of user accounts and rights
- Possibility to add and edit data

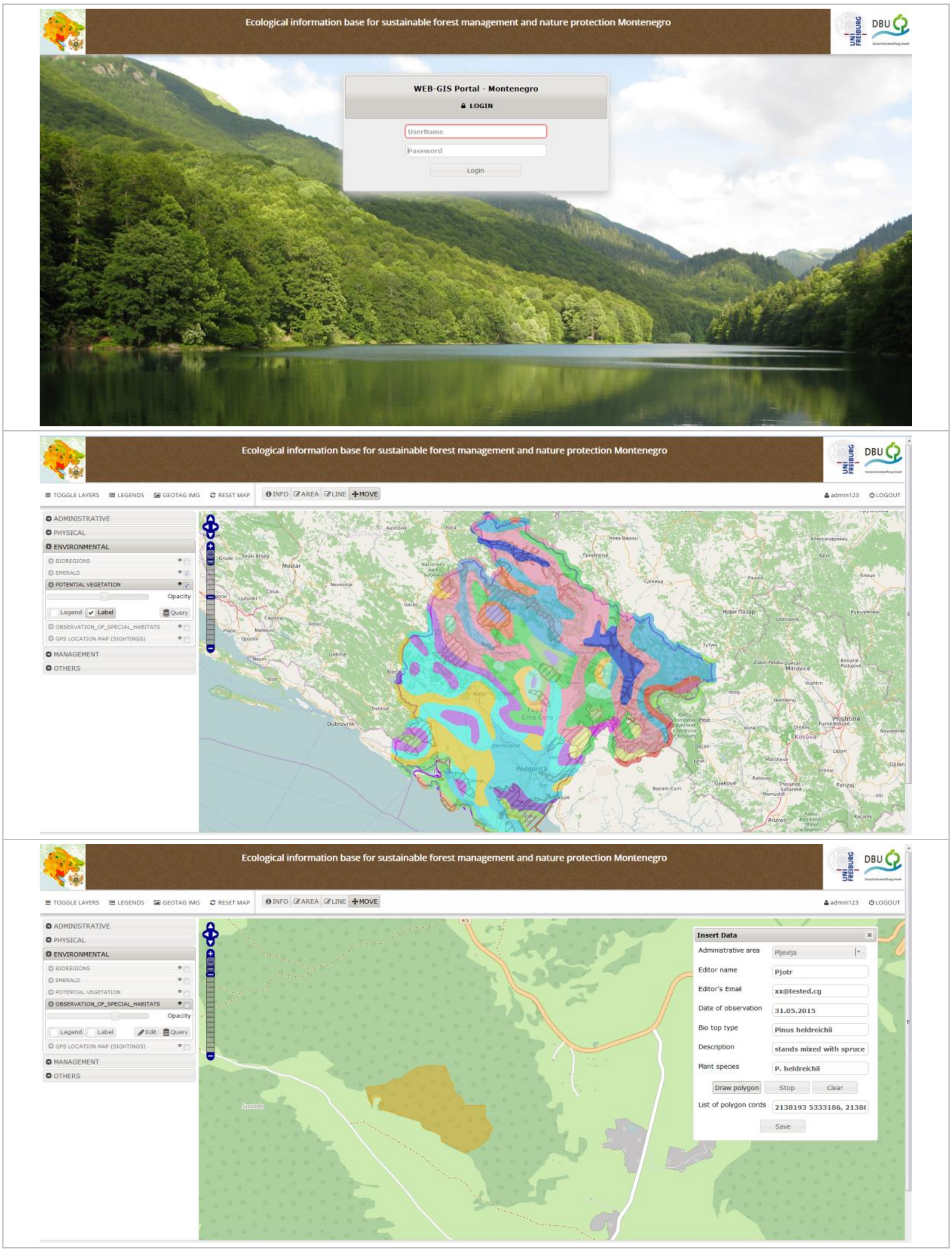


Figure 43. User interface of the Web-GIS platform: *1) Start page, 2) Example with European Vegetation Map. User can influence what information is combined. Labels can be used or transparency set. An attribute table can be opened or data of each layer element can be retrieved using the information button. 3) Two examples for the editing and addition of the database content are implemented. Here the definition of rare and endangered habitats is presented*.

The possibility to add and edit data is a crucial part of the system. This is designed in a way that not only users from inside the forestry and environmental sector can add data, but that it can be opened to the public as well.

It is a two phase process where the user can add point or polygon data (for example: sighting of brown bear) in a predefined dataset. This information will be than saved preliminary and controlled by an administrator. If this information satisfies the quality criteria it will be added to the central database and directly made accessible to all users.

Such systems are already functioning for a range of environmental and forestry topics. For example, mapping of lynx habitats in Germany (http://luchsmonitoring.luchsprojekt-harz.de/) or a wild boar information system (http://www.bayerischerbauernverband.de/sis).

The Web-GIS was developed and tested in the period prior to the workshop in Podgorica held on 23.-24.03.2015. During the workshop all functionalities were presented to the partners.

It can be accessed here: http://83.169.12.98/mne/login.php (Username for guests: guest123, Password: guest123).

For a first step UNIQUE will host and administrate the prototype of the geodatabase. As soon as MARD and MSDT have decided, how the system shall be used and where the host server and administration can be placed, the system will be moved to this respective institution. Potential institutions discussed are the Forest Administration or EPAM.

A "User Guide for the Web GIS Platform" was developed and is available as separate document attached to this report (see chapter 11, Appendix 4).

4.9 Work package 4: Concept for the use of the Forest Ecological Geodatabase as a module the Forest Information System (FIS)

4.9.1 Introduction

There have been two different approaches foreseen in the project outline how the information of the forest ecological geodatabase (FEGDB) can be used.

Approach 1: Web Based forest ecological geodatabase (FEGDB), which is freely accessible and provides interactive user interface

The development of such a Web-GIS component of the "forest ecological geodatabase" is described in chapter 4.8.3 The tool is flexible, allows easy access to the Forest Administration, the MARD, private forest owners, EPAM and the MSDT as well as relevant stakeholder dealing with biodiversity and nature conservation. However it is not fully integrated in a Forest Information System.

Approach 2**:** Connecting the forest ecological geodatabase as a module to the new planned "Forest Information System (FIS)". Target is that the new spatial information are fully integrated in the FIS and accessible from inside the system and not only via a separate website.

The task here was to draft a concept how the FEGDB can be integrated in the Forest Information system.

The concept work was planned in the following three steps:

- Work step 1: Assessment of the FIS and the status of development and implementation
- Work step 2: Assessment of the technical concept and design of the FIS for the existing components

- Work step 3: Proposal of a concept to connect FEGDB as a module of the FIS

One important deviation from the planned steps 2 and step 3 was necessary as the survey under step 1 (see chapter 4.9.2) showed that the planned new FIS is far away from being implemented. In result it was concluded to present the connection and integration for a theoretical and ideal design of the future FIS, that is presented in chapter 4.9.5. Instead of a full concept for the connection and integration a stepwise approach to establish a more comprehensive FIS based on the few existing components is presented in chapter 4.9.2.

4.9.2 Work Step 1: Assessment of the FIS status of development and implementation

The relevant partners, Forest Administration and MARD (CMU) have been interviewed in the workshop in March 2015 to assess the status of development and implementation of the FIS.

A comprehensive FIS was planned and a concept exists, but its implementation process is not fully developed (timeline, budget, software development, interface development, hardware, administration and maintenance structures) and the few existing software modules are not accessible to all users and not connected. A few but central components are existing:

- Forest database: Software "OSNOVA[3]" is used to compile Forest Management Plans. The database with all valid Forest Management plans and nearly 300.000 ha of forest exists as MS-Access database at the Forest Administration and CMU, but is not centrally stored and not centrally available.

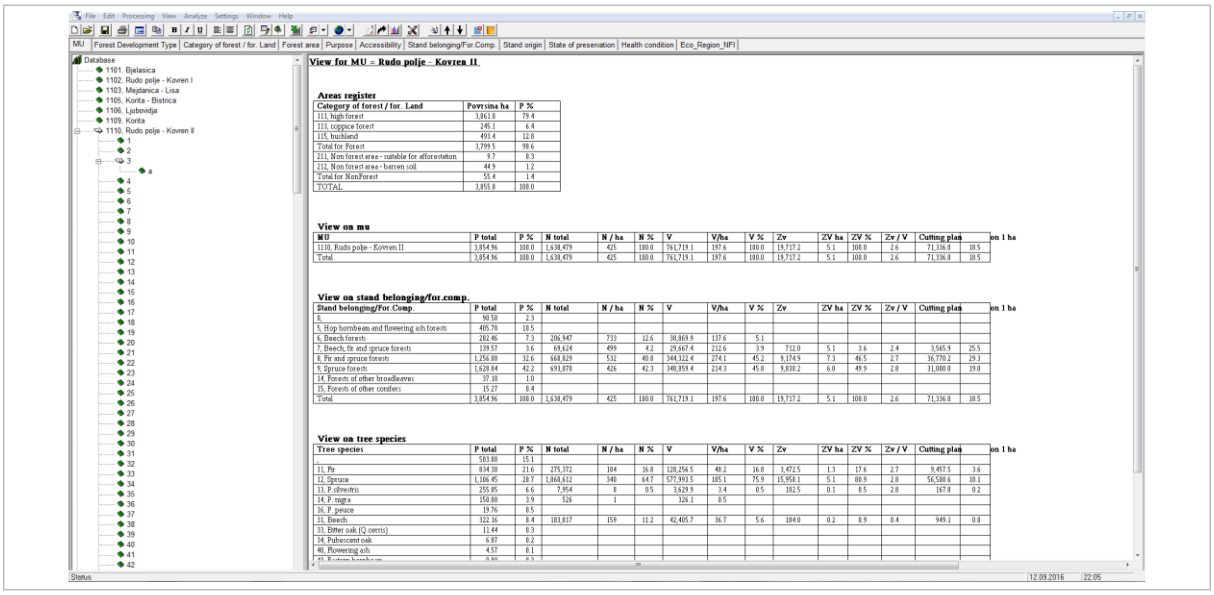


Figure 44. User interface of the software OSNOVA, which allows a utilization for forest sampling inventories, forest management planning and as a central forest database

- Software for Inventory and Forest Management planning: The software "OSNOVA" is also regularly used to perform the sampling inventory and the stand description during Forest Management Planning.

[3] Product of GREENFOR, Belgrade

- Geo-data of FMU, Compartments, forest stands are existing out of the forest management planning process, but are not managed in a geodatabase. An interface to the tabular data in the OS-NOVA system is technically possible but is not established.

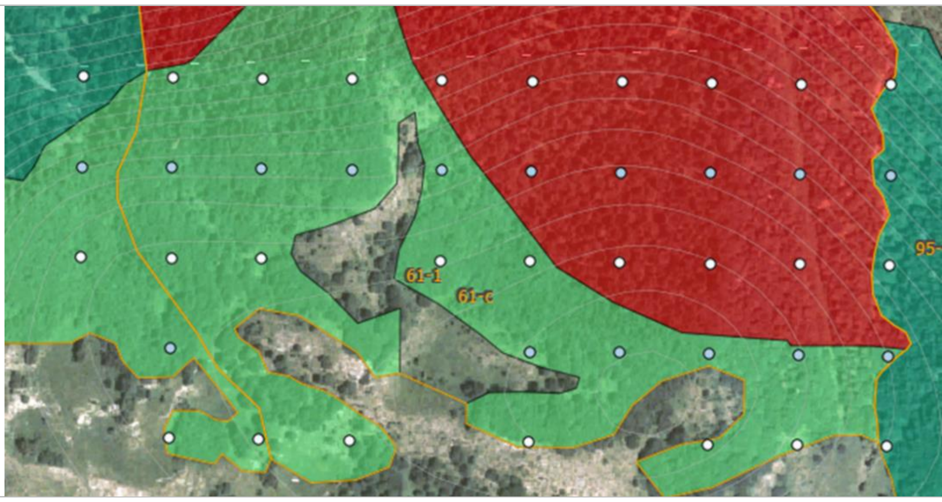


Figure 45. Forest map in a GIS format: It contains compartment and stand boundaries inside of each Management unit, forest roads. In addition the location of the forest inventory plots are shown here.

- Data retrieval from National Forest Inventory: “NFI[4]” Geodatabase and software to analyze the results of the National Forest Inventory

[4] Product of GREENFOR, Belgrade

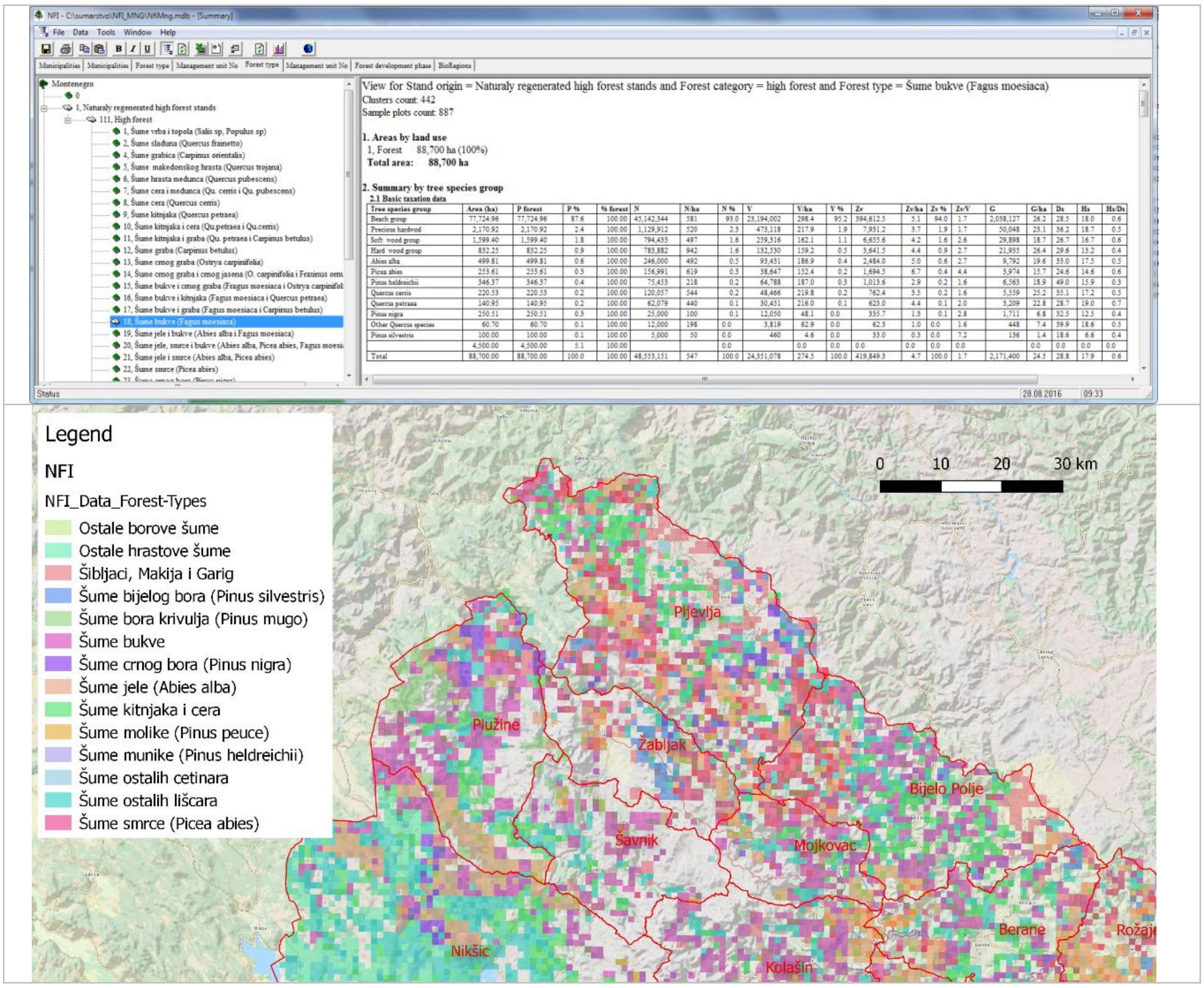


Figure 46. Retrieval software for the information of the National Forest inventory: Outputs are tables and maps

- Several other software modules are available mainly from GREENFOR, Belgrade and could be purchased and incorporated fast:
  - Software for operational plans and annual budget planning
  - Software module "Evid" for recording of harvesting and other silvicultural activities like planting or tending

Finally it can be stated that the existing FIS concept is only implemented to a very low extent at the moment. Therefore, it is not - yet - possible to define a technical solution for a connection between FEGDB and the FIS.

4.9.3 Work step 2: Assessment of the technical concept and design of the FIS for the existing components

As the step 2. Assessment of the technical concept and design of the FIS for the existing components could only be performed for the few and scattered existing modules of a future FIS, a prototype design of a comprehensive, but ideal FIS was presented, which reflects the typical functions and business processes of a state forest administration. The system was used to illustrate where and how the new information of the FEGDB could be located and retrieved in a future FIS for Montenegro.

4.9.4 Work step 3: Comprehensive structure of a Forest Information System for Montenegro

4.9.4.1 The design and technical layout of a modular Forest Information System (FIS)

A modern and comprehensive FIS for a typical public forest administration – as it is planned in Montenegro – can mostly not be realized in one software product. The systems are modular and consist of several software components and databases connected by interfaces with optimally standards for data exchange. Latter is recently more and more established in the EU countries, but also worldwide for spatial data. The European spatial data infrastructure (INSPIRE) is template for all western-Balkan states at the moment (INSPIRATION - Spatial Data Infrastructure in the Western Balkans project[5]) is will also lead to technical standards for spatial data exchange and accessibility.

In this FIS system the different user have access to all components relevant for their daily work and decision making via one general user-interface, which is often build up as web-portal. Here the integration of geo-data and tabular data is possible and leads to a web-GIS-portal. The following figure illustrates a web-GIS-portal. The example of this forest web-GIS portal is taken from the state of Sachsen, Germany[6].

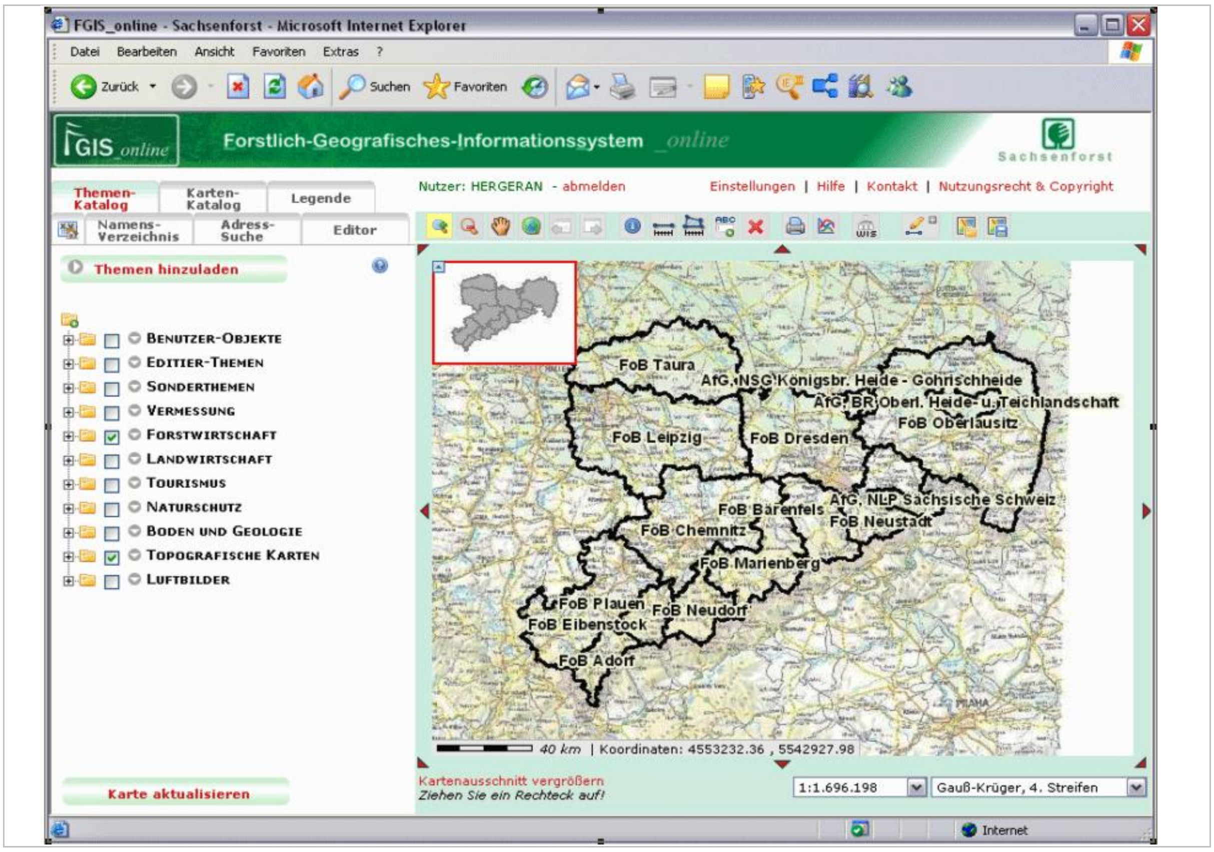


Figure 47. Example for a web-GIS-portal – potential central User interface for a modern FIS

[5] INSPIRATION - Spatial Data Infrastructure in the Western Balkans: http://www.gfa-group.de/web-archive/inspire/www.inspiration-westernbalkans.eu/index-2.html (retrieved 12.07.2016)

[6] Forest web-GIS portal from the state of Sachsen, Germany: Figure extracted from the following publication: Hergert and Kranz 2009

The next graph shows the modular system structure and the potential technical approach reflecting the organizational structure of the Forest Administration in Montenegro.

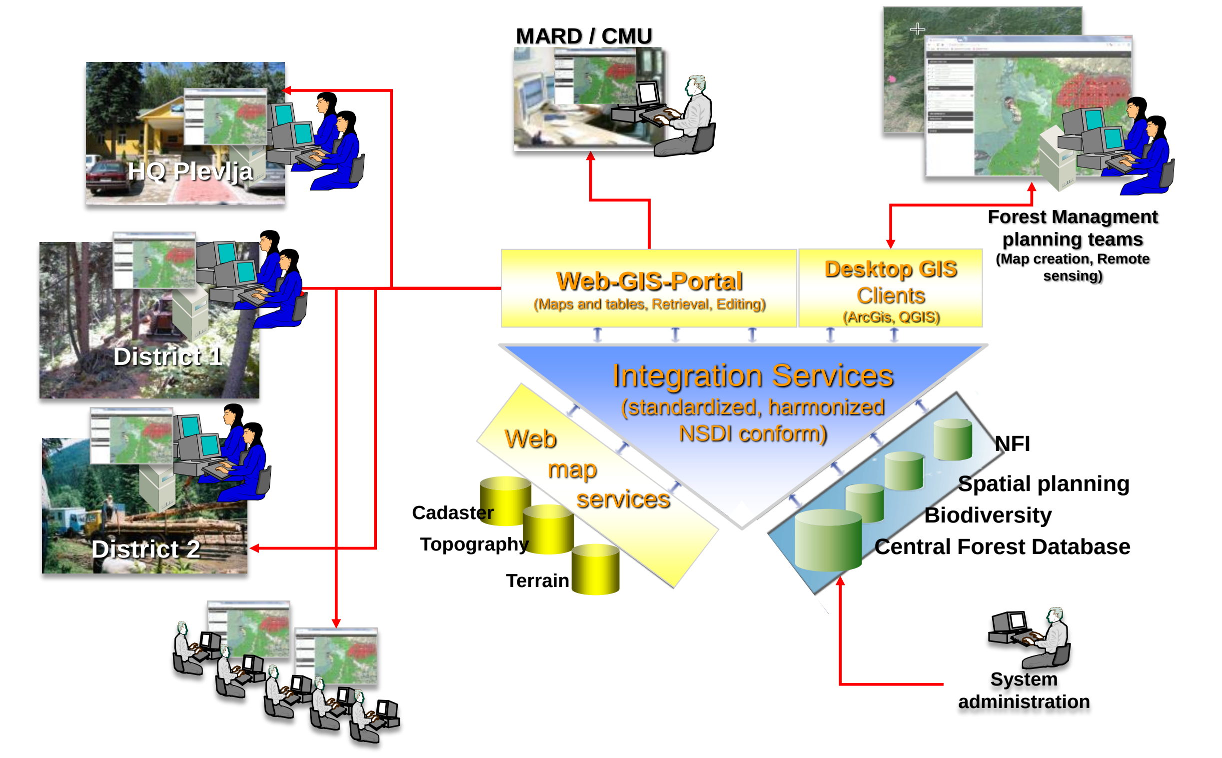


Figure 48. FIS system structure and outline for the Forest Administration in Montenegro

The following graph gives an overview of relevant software components and their interfaces. The components are grouped by the origin of the data managed. A central software component – as in all land use management systems – is a geodatabase describing and managing the basic units of forest management, the forest stands and their tree species.

The position of the three new information compiled in the FEGDB are highlighted. Technically all three components are geo-datasets (map-layer and geodatabases), which can be interfaced through the GI-window of the central web-portal.

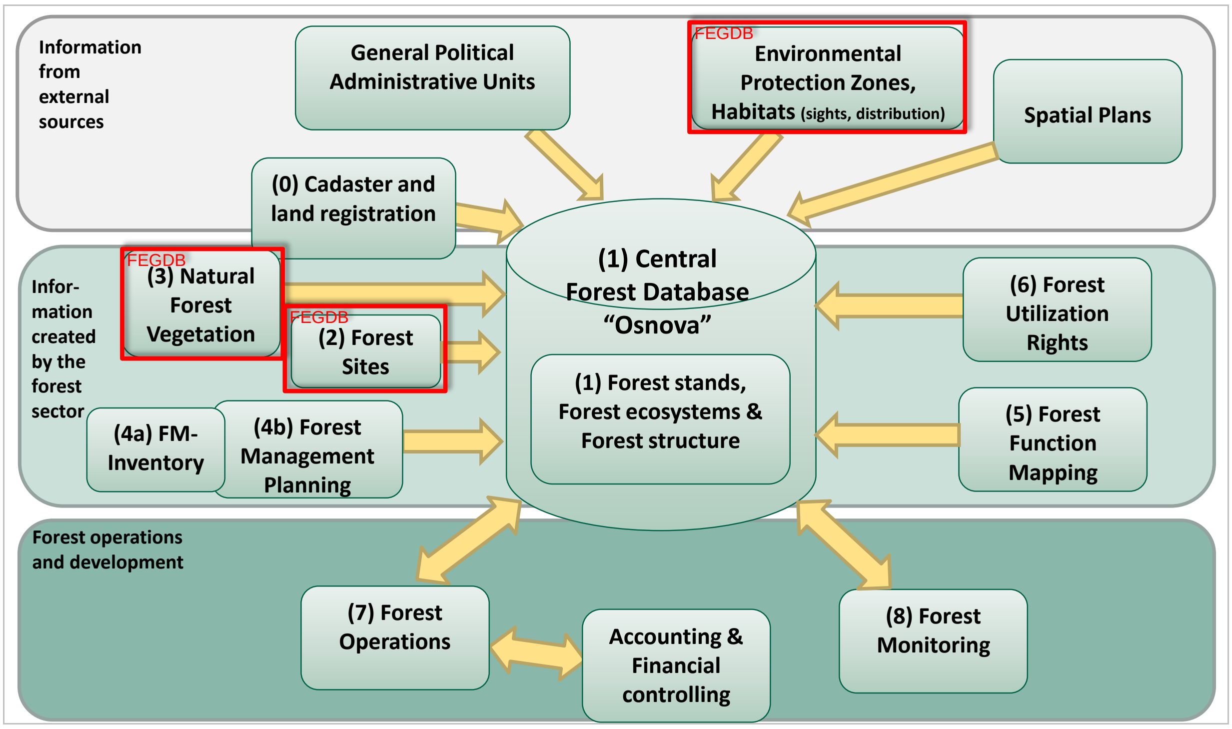


Figure 49. FIS – Modular structure of a comprehensive Forest Information and Monitoring System for Montenegro

4.9.4.2 Main Components of the Forest Information System (FIS)

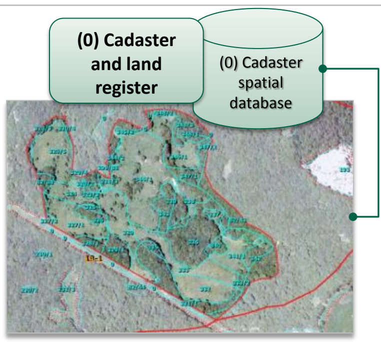
The following table presents the different software modules, respective datasets and functions. The components are ordered by their importance for the FIS logic driven by the needs of forest managers in a typical state forest administration.

Table 16. Software modules of a comprehensive FIS for Montenegro

Module 0: Cadaster and land registration

(0) Cadaster and Land Registration

- Location
- Parcel ID
- Ownership
  - Land use rights
- Land use classes



Purpose: Basic management and political and spatial planning information:

- Where is the forest located?
- Size / area of the forest?
- Who is owner?
- Who manages the forest?

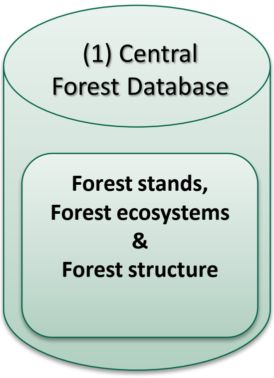
External data: All parcels covering forests

Internal data: All parcels managed by the specific forest administration / enterprise

Module 1: Forest and Forest Structure: Central Forest Database

(1) Central Forest (spatial) Database

- Forest stands
  - Stand description:
    - Forest type, Stand Layer, Species, Age, DBH, H, Vol, Increment, Quality, Assortments
  - Stand level planning:
    - Type of measure, Yield by species, planting, weeding, tending, work area, time line, frequency
- Roads
  - Main and secondary: Roads as Objects, length, status
  - Skidding roads
- Other support infrastructures (Offices, storage place, firelines)
- Management structures (Estates > FMU > Compartment > Stand)

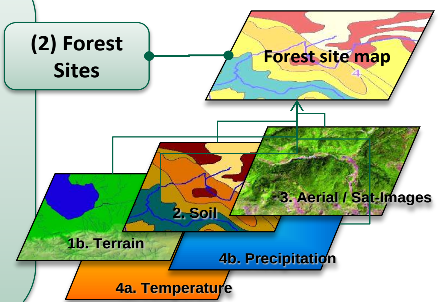


- Central internal information
- Central data base and module
- Contains the core forest management entities (Stands, tree species)

Module 2: Forest Site Map

(2) Forest Sites

- Soil conditions: Geology, soil type, water household, nutrients
- Climate conditions: Temperature, precipitation, snow, frost etc.
- Terrain conditions: Slope, aspect, terrain form
- Tree species risk and species suitability classes

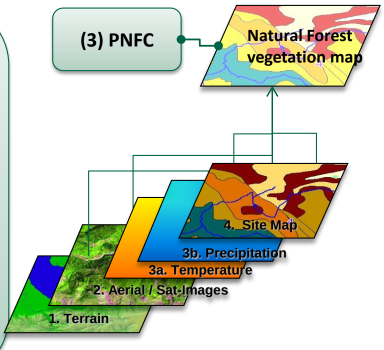


- New information from the FEGDB.
- Internal information created by the Forest sector
- As described in chapter 4.6 of a multisource mapping activity leading to basic ecological information and information on productivity (site index, risks, tree species suitability, terrain)

Module 3: Natural and Potential Forest Vegetation

(3) Potential Natural Forest Vegetation

- Potential Natural Forest Vegetation Communities
- Species list with data for abundance of the communities
- Differencation in species lists for regional units
- Typical terrain conditions and locations for occurrence (indicators: altitude, aspect, soil conditions, climate)
- Evaluation: Human influence, historical development, threats and endangerments

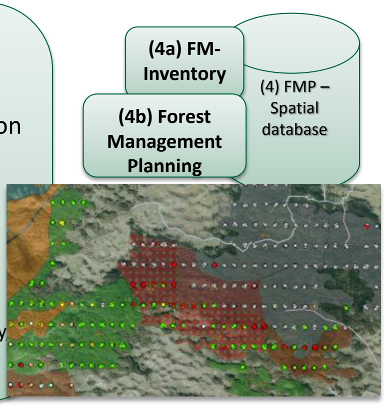


- First new information from the FEGDB
- Internal information based on a mix of external and internal sources on vegetation
- Result of the multisource mapping process described in chapter 4.7.4. presented in a geo-data layer and database
- After overlay or intersection with forest stand data used for management decisions like tree species selection and promotion, risk assessment, climate adaptation strategies.

Module 4 a: Forest Management Inventories & Planning

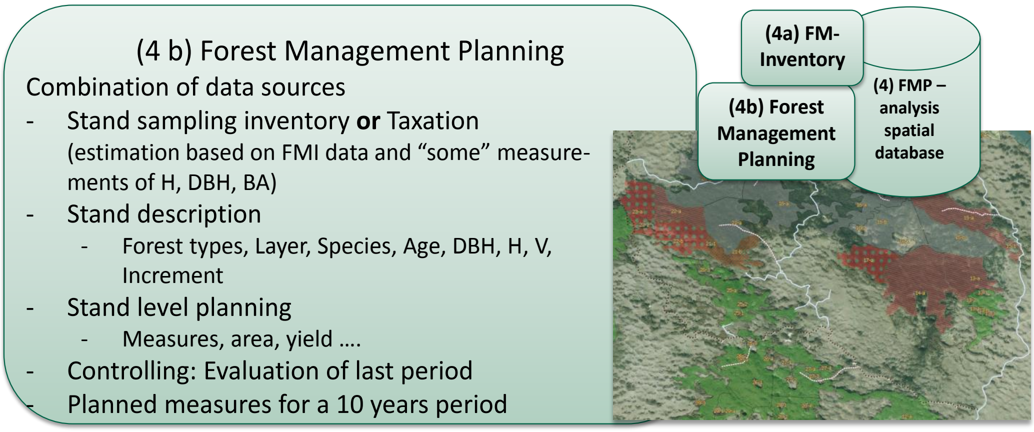
(4 a) Forest Management Inventories

- Statistical sound sampling inventory
  Combined with remote sensing based data collection
- Part of Forest Management Plannning process
- Smallest unit = Stand
- Data are used to describe stands
- Typical data collected:
  - Forest area
  - Forest Type & Species
  - Per forest type / species: Age, N, BA, V, Increment, mortality yield, tree quality, damages, dead wood
  - Site information, Ground vegetation



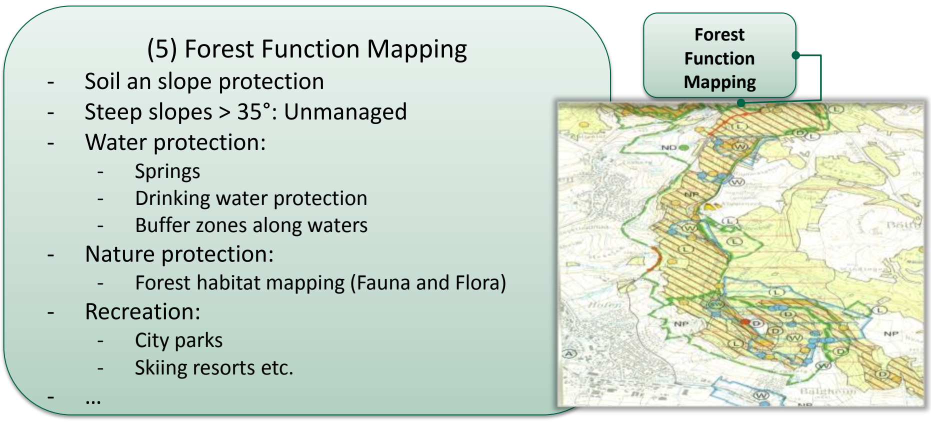
- Small unit: Forest Type / Species in a region / district
- Internal core information creation processes
- Special module and database for data collection, data analysis
- Interface to feed stand data to the Central Forest Database

Module 4 b: Forest Management Planning



- Internal information related with FMI Inventory
- Core spatial data creation process
- Special module to update stand data, update forest maps
- Update of the central forest database („Register“) on stand level and management unit level

Module 5: Forest Function Mapping

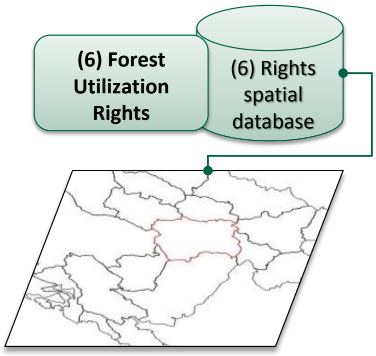


- Internal information
- Multi source mapping procedure using external and internal sources. Initially one time mapping project with mostly long validity, updated by spatial plans and forest management plans
- Elementary information for planning decisions in Forest Management Planning

Module 6: Forest Utilization Rights

(6) Forest Utilization Rights

- Fuel wood products: Fuel wood collection as local right
- Non-wood forest products: Concession or collection rights
- Hunting rights: Hunting areas
- Grazing rights: Local grazing rights
- Other forest utilization rights: ....

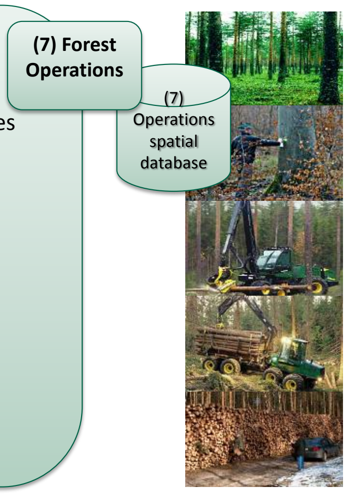


- Internal information
- Module also linked to land register (parcels)

Module 7: Forest Operations

(7) Forest Operations = activity monitoring

- Annual Operational Plan, Annual Budget Plan
  - Measures by stands, techniques, schedule, costs, revenues
- Records of implementation (EVID)
  - In general same structure as Operational Plan
  - Products:
    - Wood by species and assortment
    - NTFP
- Timber logistics
  - Log piles, transport, transport process and control
- Timber sales
  - Preparation of timber sales (wood assortments, piles, locations)
- Other forest operational items
  - Tending
  - Planting, weeding ...



- Internal management process in all forest enterprises or forest administrations.
- Based on FMP information and consisting of Operational Planning and Annual Budget plans as well as Activity recording functions
- Effect: Update of forest status (= activity based monitoring)

Module 8: Forest (Incidence) Monitoring

(8) Forest Monitoring = incidence / change monitoring

- Fire monitoring
  - By continous remote sensing
- Forest cover change: Succession and Illegal logging
  - By continous remote sensing
- Soil monitoring
  - by permanent monitoring plots
- Changes in the forest ecosystem (flora, fauna...)
  - Mixed approach:
    - By forest inventories PARTLY
    - By special inventories and monitoring (mainly fauna)
- Natural disturbances
  - Biotic disturbances: Insects, fungus, game, cattle
  - Abiotic disturbances: Storm, snow, avalanches

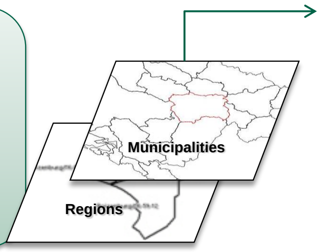
- Internal information
- Based on registration of incidences (storm, pests, fires): Recording and continuous update of forest status and central forest database
- Source: Monitoring by staff and support of remote sensing
- Multipurpose monitoring possible (combined with nature and environmental protection)

Modules managing external sources

- **General Political Administrative Units**

General Political Administrative Units

- Regions
- Municipalities
- Cities / Villages

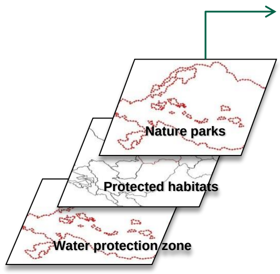


- External information: Land Registration Agency
- Boundaries of all levels of administrative units

- **Module: Environnemental Protection Zones and Habitats**

Protection Zones and Restrictions

- Nature protection zones: National parks, nature protection zone class 1-5
- Endangered habitats
- Environmental protection zones: Water, soil etc.
- Other existent protections or restrictions items: Military, etc.

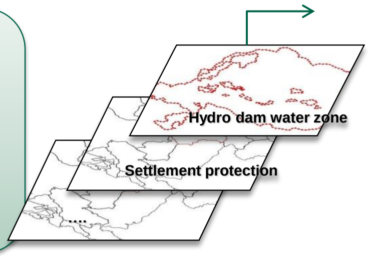


- External information from different institutions
- Zones boundaries and attributes
- Several geo-data layer

- **Module: Spatial Plans**

Spatial Plans

- Zonification related with forest area
- ...
- …



- External information
- Priority zones and planned land use from spatial planning

4.9.5 Work step 3: Proposal of a concept to connect the Forest Ecology Geodatabase (FEGDB) as a module of the FIS

As described in the introduction above (chapter 4.9.1) the planned new FIS is far away from being implemented. In result Instead of a full concept for the connection and integration it was agreed to draft a stepwise approach for the development and implementation of a more comprehensive FIS based on the few existing components.

Hereafter the stepwise development and implementation of the FIS concept is presented as a guideline for MARD and the Forest Administration. We have concentrated and limiting the concept to the existing software modules, a low cost approach, the incorporation of the new FEGDB and its web-GIS-portal. It can be described as a first phase to implement the comprehensive FIS described in chapter 4.9.4.

4.9.5.1 Step 1: Develop a web-GIS-portal for Forestry Information

- The FEGDB web-GIS-portal can be used as technical solution and a first component of a central FIS
- It – only – needs to add and compile the already available forest maps and related tabular data
- It also allows to add and present more of relevant external, secondary data: Topography, a digital terrain data as slope, aspect and contours or cadastral parcels. As most of the relevant institutions are project partners the data exchange can be organized inside the same team.
- The results of this project, the new site map, map of potential natural information as well as biodiversity, wildlife and nature protection related information are content from the start of the small, central FIS
- User rights for the forest administration staff and other groups in both related Ministries need to be defined

The following figures illustrates how this first component of a “Forest web-GIS-portal” could look like.

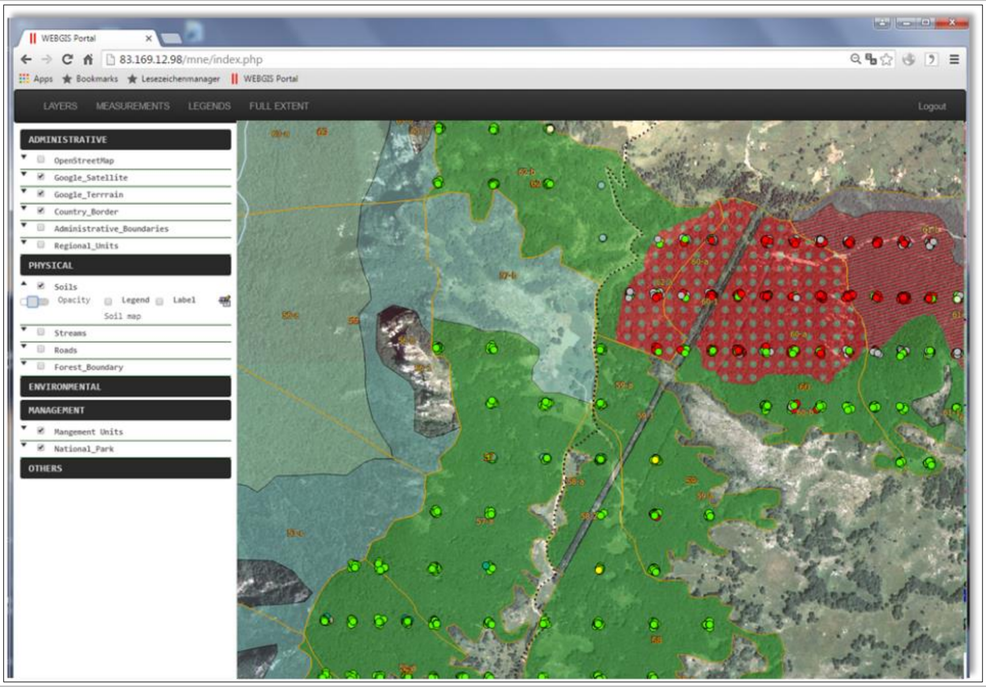


Figure 50. Idea of a web-GIS-portal for forestry information based on the FEGDB

4.9.5.2 Step 2: Establish OSNOVA as a Central Forest Database

- Setup OSNOVA in a central MS-SQL database system and run in on a central server. The technique is available, the software is used in the state forest enterprise "Vojvodinasume" in Serbia in this configuration.
- All valid Forest Management Plans of all Forest Management Units need to be loaded and regular updated in the central forest database. In result comprehensive forest information from more than 100 Management Units representing ca. 300,000 ha of state forest mostly situated in the northern part of Montenegro can be retrieved on all levels of the Forest Administration, in MARD and opened for the environmental sector (MSDT, EPAM).
- Develop OSNOVA as a spatial database: This step will allow to integrate the spatial forest data with its tabular data. Tree from sample plots have a position, sample plots are located on the map, stand can be presented and managed with its spatial extent and location, neighborhood can be analyzed and environmental conditions can be simply analyzed by overlaying or intersecting. Same options will occur for larger units like compartments or Management Units.

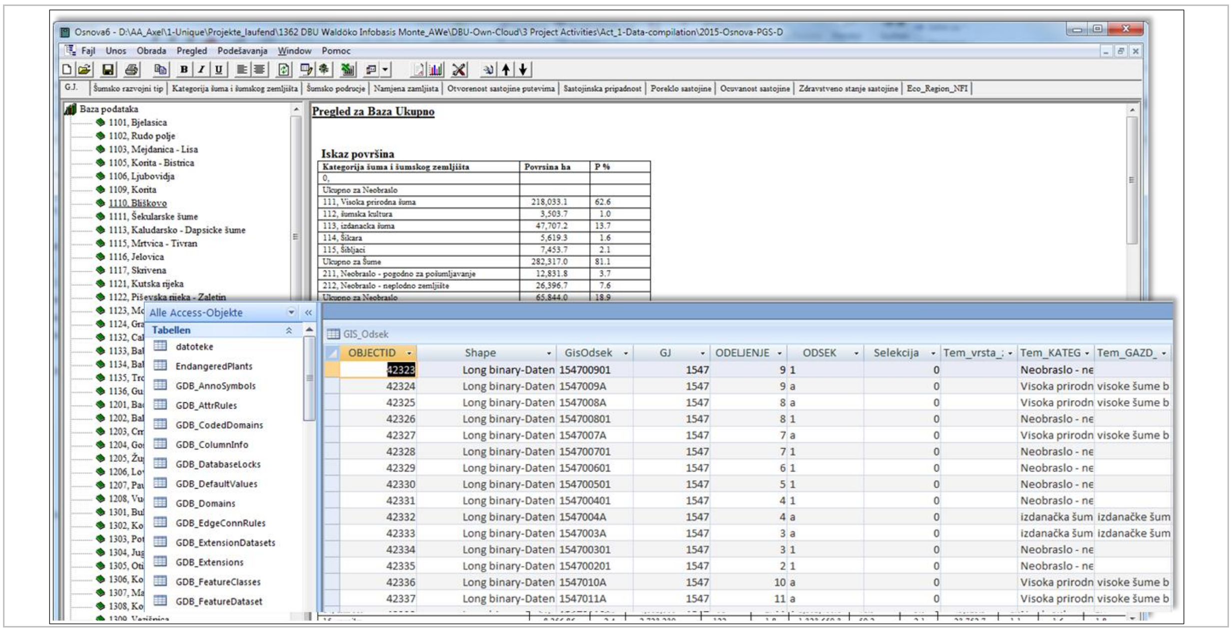


Figure 51. OSNOVA can be developed as central and spatial forest database

4.9.5.3 Step 3: Add new software components

Important software components for forest operations are missing but are available and can be added and linked.

We recommend to purchase software for operational and annual planning as well as the software for activity recording. The existing components from GREENFOR should be evaluated and considered. Both systems are coming with an interface to OSNOVA.

4.9.5.4 Step 4: Develop a dynamic forest monitoring

The continuous monitoring of changes in the forest structure is a prerequisite for a sustainable forest management based on sound decisions. It is also essential for the environmental monitoring and reporting. The following software development activities could essentially improve the described basic FIS:

- The OSNOVA software and the activity recording “EVID” need to be linked (technically existing).
- Ask for development of a new function in OSNOVA allowing to update the forest geodatabase based on activities (i.e. amount of harvested timber is subtracted from the wood volume of the respective tree species in a stand).
- Ask for improvement of the OSNOVA function for the annual update of forest stand data via simulation of annual growth. This function exists in general but is not used as standard process.

In result the forest data regarding area, species composition, structure is always very close to reality. A continuous monitoring is possible and other monitoring sources like fire damages detected from satellite images can be intersected with the forest database. A mapping activity for endangered flora or fauna can use the detailed forest description for stratification or search for habitat requisites.

4.9.5.5 Step 5: Improve the Forestry web-GIS-portal

The small FIS can be fully developed if as a last step the geodatabases of the central forest database (OSNOVA) and the activity recording (EVID) are integrated as GIS-layer and if the user interfaces can be accessed via the Forestry web-GIS-portal.

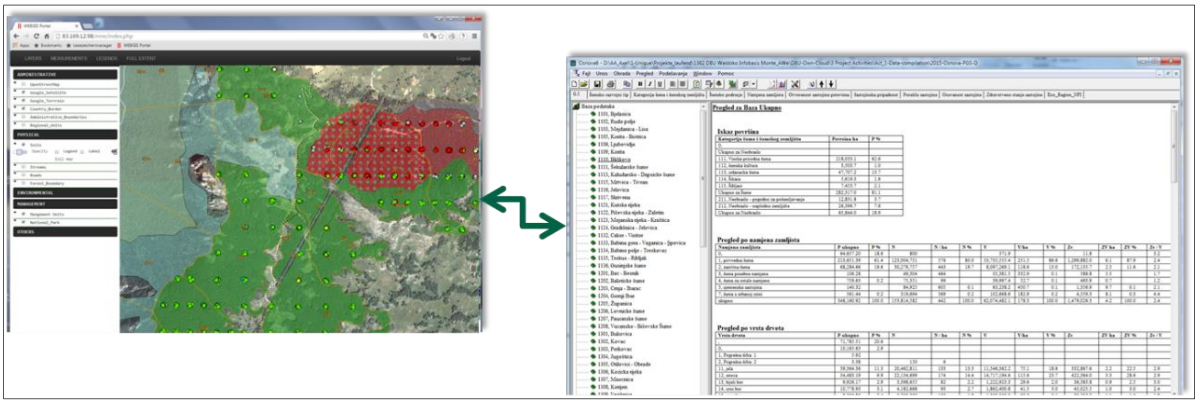


Figure 52. Integration of the spatial format of forest database (OSNOVA) and activity recording (EVID) in the web-GIS-portal

4.10 Work package 4: Implementation of the new environmental information in Forest Management Planning

4.10.1 Background and tasks

The following task have been foreseen to implement and make use of the new ecological information base in the practice of the Forest Management Planning process.

Task 1: Project supports the Forest Administration in adapting the documents relevant for Forest Management Planning – describing where and how to use the new ecological information:

- Update of the "Manual for Forest Management Planning" under incorporation of the necessary process description in the use of forest ecological base features.
- Propose changes in the bylaw for Forest Management Planning

The results are described in chapter 4.10.3.

Task 2: Implementation in the two pilot Forest Management Plans

It was planned, that the new results are used directly in the selected pilot Forest Management Units as example to create Forestry Management Plans based on or with support of the new ecological information. Both of the MU had been selected exactly for this reason, as the revision of the forest management planning was planned for 2015.

Unfortunately in both cases it was due to un-known reasons and after several interventions from the DBU-project team not possible to get the forest management planning started in 2015 as it was planned in agreement with the MARD at the project kick-off. Both FMP projects were shifted to 2016, too late for a joint implementation using the new information of the FEGDB.

As a concrete step to guide the FMP teams using site and vegetation maps for their decision making in the planning process was finally not possible, it was agreed to add two theoretical studies giving recommendations for a future utilization of the new ecological information (chapter4.10.2) and on a the development of technical solutions to support the decision making based on the new ecological information from the FEGDB (chapter 4.10.4).

4.10.2 Potentials for utilization of the new information base for decision support in forest management

4.10.2.1 Reminder to project rationales

In order to better deal with climate change, preservation of biodiversity and to meet the requirements of the EU Natura 2000 framework, Montenegro's forestry sector took the chance of this project to work on closing the data gap on basic ecological information relevant for a sound decision making.

The rationales to close the gap is illustrated in the following graph. The identified information gaps – identical with the work packages of this project - are marked in red color.

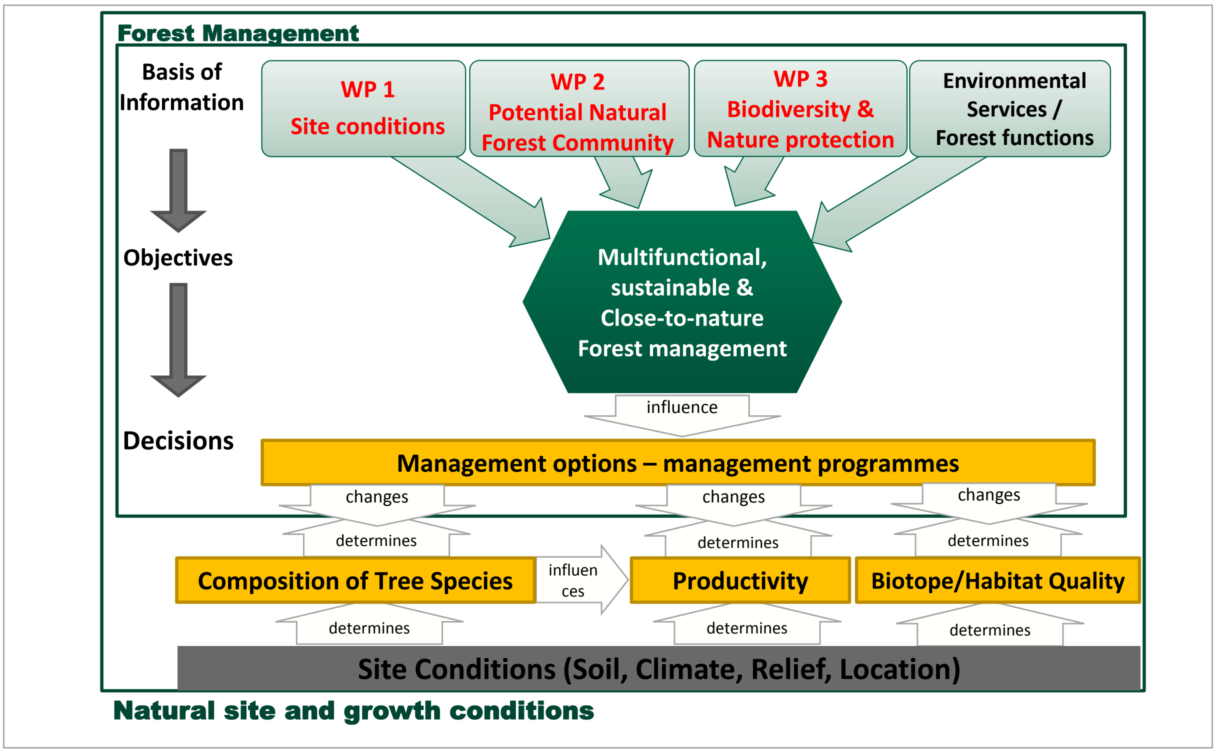


Figure 53. Close-to-nature forest management – Information base for management decisions

The Montenegrin partners have clearly stated that the project is an important milestone to achieve the objectives and principles of multifunctional, sustainable and close-to-nature forest management stated in the New Forest Policy[7].

[7] Ministry of Agriculture, Forestry and Water Management (2008): National forest policy of Montenegro. (URl: http://www.minpolj.gov.me/)

4.10.2.2 Evaluation of tree species suitability

In the course of forest site mapping, a tree species to site matching as evaluation of species suitability and adaptation to site is an integral and final step. Several successful concepts for determining site suitability of tree species are being successfully implemented in Germany and the goal of one of the dissertations from this project [8] is to propose a similar concept for determining site suitability of tree species for Montenegro. At the end of this chapter examples of concepts for the assessment of site suitability from Germany originating from the states Baden-Württemberg, North-Rhein Westfalia and Bavaria are presented.

In forest management practice the knowledge of site conditions and natural trees species mixture can provide support in answering the following questions relevant for planning measures during forest management planning:

- How well is a species adapted to the site?
- Is it part of the optimal adapted natural vegetation?
- How is it suitability - and productivity?
- What tree species are suitable and can be mixed on a site?
- What species in the stand shall be promoted or reduced?
- What is the management strategy in the stand regarding tree species composition and structure?

Several definitions exist for site-adapted or site-suitable tree species (among others: Aldinger & Michiels 1997, HMULF 2002, Bartsch & Röhrig 2015, StMELF 2016). A common understanding is: Tree species that are optimally adapted to defined site conditions, regardless to their naturalness or origin (e.g. oak, pines, spruce, Douglas fir or larch). Tree species of the natural forest community are mostly opti-mal adapted are competitive and bear low risks in management.

Even though sophisticated site classification methods have been developed in the past decades, site suitability of tree species is not always identified based on pre-defined sets of rules and criteria, which may bring various risks for the forest management. For instance, the incorrect assessment of site suitability might lead to incorrect choice of tree species, which may further result in poor performance of trees, including reduced growth, low vitality or timber quality, and stressed trees more susceptible to pests and diseases. Nevertheless, one of the most important goal of site classification and mapping is the assessment of tree species for their suitability to a particular site, which derives recommendation for selection of site suitable tree species. But, the selection of tree species to the site and the goals of forest owners are usually influenced by economic and juristic conditions and must consider various forest functions protection and recreational forest functions, or nature and landscape conservation. This might lead to selecting the tree species less suited to the particular site. Therefore, the challenges for forest management is to select those tree species that match the site as much as possible; to identify the optimal criteria for tree species selection applicable for current site conditions and to select tree species today that will grow well under future uncertain climate conditions, at the same time fulfilling the forest functions (Aldinger and Michiels 1997, Röhrig et al. 2006, Ray et al. 2008).

[8] The assessment of site productivity and site suitability is carried out within the dissertation of the doctoral candidate Sofche Spasikova within which a scientific basis for determining the site suitability of tree species and the recommendation for tree species selection suitable to the site for Montenegro is one of the final outputs.

For the evaluation of tree species suitability multiple criteria are used, which are correlated:

- Naturalness – natural occurrence without human influence
- Productivity - height and volume production
- Risks - Competitiveness, stability, resilience facing abiotic and biotic disturbances

Naturalness

The map of potential natural forest vegetation provides the initial information on the suitable sites for an individual tree species. This map depicts the natural distribution of tree species (Kölling et al. 2007) under the assumption that species naturally occur on sites with most favorable biotic and abiotic conditions. Furthermore, this map can be used in models (such as the "bioclimatic envelope" models) for the projection of the future suitable sites for tree species under climate change (Kölling et al. 2007).

4.10.2.2.1 Productivity

The evaluation is using a combination of the

- Forest Site Map
- Map of Potential Natural Forest Vegetation
- Tree data from sampling inventories and aggregated species data on stand level from Forest Management Plans

The correct assessment of site productivity is important in forest management. Productivity remains a fundamental concern in forest management as it is a major driver of forest resource availability. An operational prediction of species productivity is needed for the purposes of tree species selection, design of management guidelines and forecasts of timber yields in forest management planning. Climate change and the impact on forest growth calls for more attention to predict site productivity and its site dependence.

Productivity is influenced by site factors in various ways:

- it decreases when the potential evapotranspiration increases, which today is in the focus of many studies of the xeric limits of tree species (Albert and Schmidt 2010; Stojanović et al. 2013)
- nutrient conditions influence site productivity in a way that better nutrient availability increases the site index as a measure for site productivity (Albert and Schmidt 2010).

For a productivity analysis in Montenegro the data of the first National inventory (NFI) as well as thousends of inventory sample plots from forest management planning inventories are made available. The size of this database is better as in many other regions as the density of the sample plots is high (1 - 0.25 per ha) and the locations are recorded. It allows to correlate tree productivity indicators with site conditions described in the site map. The limiting and problematic factor is that the best indicator for tree productivity and growth – the site index as relation of tree height of age – is not available for most of the forest stands and also not an information available from the NFI inventory. The search, test and selection of other suitable indicators or combination of indicators as maximum tree height, increment, maximum basal area is still in progress.

4.10.2.2.2 Risk evaluation

Decisions can be derived based on a combination of

- Forest Site Map

- Map of Potential Natural Forest Vegetation

Aspect – biotic and abiotic damages:

Resistance or resilience against biotic and abiotic damages like storm, fungi and insects (bark beetle), ice break, fire risk or drought can be evaluated if adaptation and suitability of a species to a certain site is known. Risks can be better evaluated for the natural species and risk are mostly lower for them.

Statistics for forest damages and losses can be intersected with both maps to analyze risks and improve expert's evaluation.

Aspect - climate change:

As the site map is developed using climate data and soil data, prognosis of future climate can be used to evaluate impacts on site conditions (climate but also soil, water household and risks). The future site condition can be described and the suitability of species can be adapted.

Recent studies and related methodological approaches in Montenegro (Keča 2013, Matović 2013) evaluating risks and areal shift in climate change could be improved, if regionalized climate data and scenarios as well as the influence of the terrain to climate, soil and water household from the site map could have been used.

4.10.2.2.3 Derivation of species suitability recommendations

Decisions for site-suitable tree species selection can be derived based on a combination of

- Forest Site Map
- Map of Potential Natural Forest Vegetation
- Results of the risk- and productivity analysis

Herafter examples of concepts for recommendation of site suitability originating from the states Baden-Württemberg, North-Rhein Westfalia and Bavaria are presented.

- Baden-Württemberg concept for assessment of tree species suitability

In this concept, two categories of criteria are used: site adapted species and growth potential. The first category also encompasses sub criteria, such as competitiveness (the ability of a species to grow to a certain age despite its competitors), resistance to damage (the species is able to withstand risk) and soil conservation (the species does not have any negative influence on the soil). The criterion "performance" indicates that the species is suitable if it can result in certain expected yield. These criteria are summarized in a site-suitability table and available to further use by foresters as an overview of the growth properties of a certain species, denominated as "suitable", "possibly suitable", "little possible", "not suitable" and "species recommended due to biological properties" (Michiels 2015).

Table 17. Example of a site class and its properties and recommended suitable tree species (Baden-Württemberg – nach Dolderer 2016)

Beech-Sycamore maple-forest on moderately fresh silty loam

Climate and landscape: Eco-Region 1/03a – Terraces and riverine forests between city of Rastatt and city of Kehl

Occurrence: Moderately fresh to ground-water influenced fresh lowlands

Ground vegetation: Lamium galeobdolon-, Ajuga reptans-, Rubus-, Urtica dioica-, (Milium effusum-, Stachys sylvatica-, Carex brizoides-) group

Humus: Mull to Mullmoder, locally to Moder

Soil: Profound, more than 60 cm thick, decalcified, light brown to ocher yellow silty loam topsoil to clay deposited and strongly colored undersoil. Good water capacity due to high volume of pores, still only moderate nutrient supply, when the underground at root-level does not contain lime; locally free lime starting from 50 cm depth.

Soil type: podsolic brown soil and podsolic stripes of parabrown soil

Water- and Temperature availability: Moderately fresh to fundamentally fresh

Root ability, physical stability: Partly root able soil, unstable with tendency for sealed storage, sensitive; for longer periods of rain, unstable through building of loamy pulp.

Pot. nat. forest vegetation:	Sweet woodruff - beech forest (Galio-Fagetum)
Natural forest type:	Beech-Sycamore maple-forest
Main tree species:	Beech, Sycamore maple
Additional suitable species:	Sessile oak, hornbeam, wild cherry, maple, small-leaved lime, elm, (red oak)
Pioneer tree species:	English oak, silver birch, rowan, willow, Scotch pine

Silvicultural opportunities and threats:

The site responds above average to anthropogenic disturbances such as transport, pure cultures of softwood, litter and forest-pasture. Use of motor vehicles leads to the formation of "dwarf Pseudogley" in the topsoil with platy structure. Damage in the long term because the silty loams (fine loams) show poor regeneration capability.

Suitable tree species:

Beech and **sycamore** are very competitive and are able to produce strong timber. **Beech** is the strongest competitor of all tree species.

Also, when well nurtured, **sessile oak** can be expected to deliver good quality. However, it is under competitive pressure from beech and sycamore.

Black cherry is possible as well in a mixture of tree species and can be expected in very good quality. Similar mixed tree species are ash, hornbeam, small-leaved lime and Norway maple.

Douglas fir can show very good growth performance, the quality will however drop due to wide growth rings. Pruning is essential. There is no evidence on its competitiveness, in particular the one of the natural regeneration.

Scotch Pine is also suitable for this site; it roots the ground deeply and shows good to excellent growth performance. The wood quality is, however, impaired by too rapid growth.

A strong savagery occurs with opening of canopy gaps and weeds take over (gorse, blackberry).

- Concept and recommendations for tree species suitability form Nord-Rhein Westfalen

Site classification assesses the factors of a site, and when the site factors water availability, nutrient availability and elevation (length of the vegetation period) are summarized, they describe a three-dimensional realm for growth of a certain tree species. This concept describes the site suitability of tree species in a site-suitability table built on these three site parameters. Figure 54 shows a theoretical example of such a suitability table. If the water availability level is in the brown zone, the tree species is suitable for that site; if it is in the lilac zone, the species is less suitable, and in the white zone, the tree species is not suitable for the site. The nutrient availability is described by different trophy levels, whereas the length of the vegetation period is provided in number of days. The information from this table can be further used to construct site suitability maps as support tools for tree species selection. These maps are constructed for one species per map and different sites are colored differently based on their projected suitability: if the sites are colored brown, the tree species is completely suitable, lilac color of the sites means that the species is only conditionally suitable, whereas green color means that the species is completely unsuitable to that site (Asche 2001, Asche und Schulz 2010).

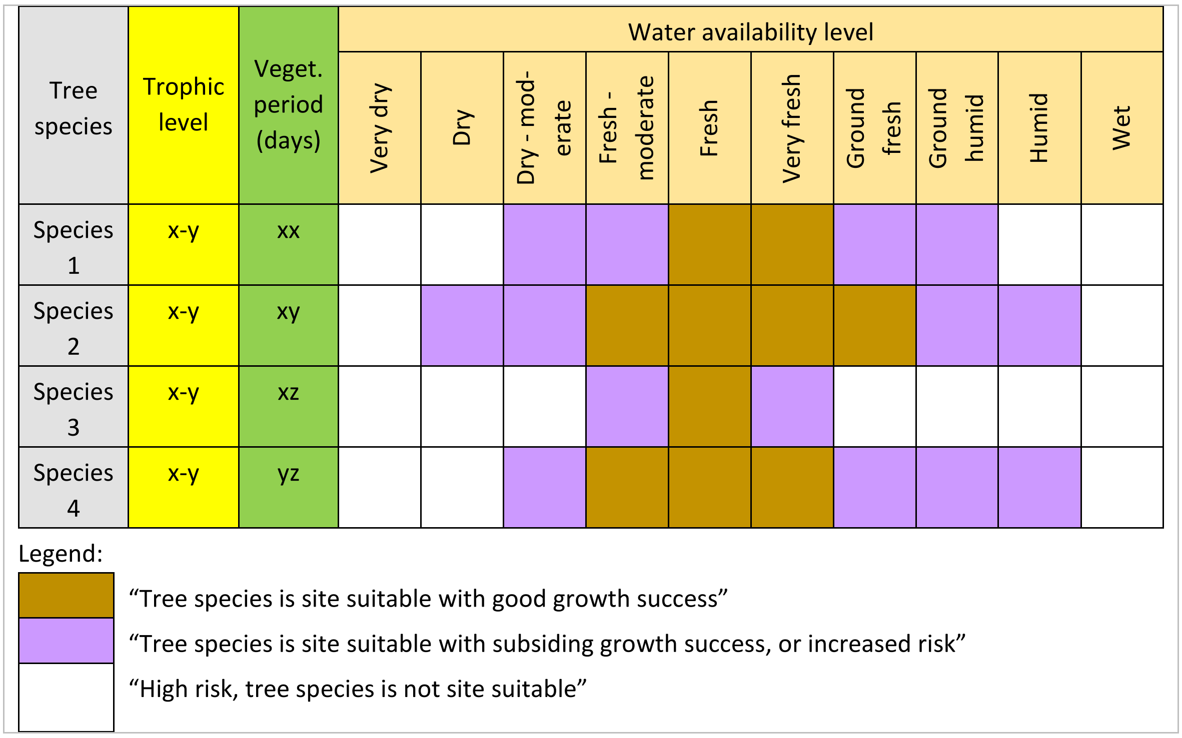


Figure 54. Tree species – site matching: suitability matrix according to water and nutrient levels as typical support tool for management decisions – a theoretical example established following Asche (2001)

- The „site information system – BaSIS" in Bavaria

This system represents a module of the Bavarian Forest Information System, which uses the current state of knowledge to provide decision support for tree species selection. As a basis, it uses current and future maps with information on cultivation risk for 21 tree species in Bavaria. The system provides decision-support information in form of recommendation for mixture of tree species adapted to the site, which also has a risk-profile (described by levels: "very small", "small", "increased", "high" and "very high" cultivation risk) and information on yield expectancy. This information is then considered by the forest owner who makes a decision on the most suitable composition of tree species, adapted to the particular situation and owner's interest, also for future conditions under climate change. The information used for estimating the cultivation risk is geology, relief, soil type, nutrient availability, water availability, aeration, and various climatic data (Taeger and Kölling 2016).

A typical output is a table with evaluation criteria and a note or a level describing the suitability for each tree species (described in the previous sub-chapters). Another typical output would be a site-suitability map, which depicts the suitability of a tree species on a certain area or region. These maps can have a direct application in the field, as they can be used in the field on mobile computers, where foresters can directly discuss with forest owners the wishes and possible site-suitable tree species for their forests. These maps can be used especially for the estimation of cultivation risk for certain tree species under future climate change conditions (Taeger and Kölling 2016).

4.10.2.3 Identification of habitats for nature conservation and occurrence of rare and endangered species

The identification process and new information created is based on a combination of

- Forest Site Map
- Map of Potential Natural Forest Vegetation
- Descriptions of "profiles" of N2000 habitats or „rare and endangered" habitats and requisites
- Central forest geodatabase with stand information (results of Forest management plans)

With the above described combination of data a given profile of typical habitats and habitat requisites for vegetation communities, for single rare and endangered species (like climate range, soil and terrain structure, forest vegetation communities, gaps in forest stands, dependency on age and dimension of trees or certain key tree species) can be used to pre-stratify forests for the identification and mapping of habitats for nature conservation purposes. Very concrete this analysis could be used in the context of the Natura 2000 implementation starting[9] 2016 in Montenegro.

4.10.2.4 Evaluation of water runoff, erosion and landslides – forest function mapping

For the evaluation a combination of the following data sets can be applied:

- Forest Site Map including data on terrain, soil, water household
- Map of Potential Natural Forest Vegetation
- Central Forest geodatabase with stand information (results of Forest management plans)

In a mountainous country like Montenegro the prevention of damages by water runoff and water erosion, landslides or avalanches and rock-fall are important. As most of the steeper terrain is covered by forest the "protection function" of forests to minimize these risk is important and base for a sound decision on optimized management practices on these sites.

Most of the data used for the site mapping can be directly used in the mapping of water erosion and landslide risks. Slope, aspect, geology, soil substrate and terrain form are essential. The information of natural forest community is support to select well adapted species and typical mixtures and structures. It finally helps managers to identify measures for soil protection and risk mitigation.

[9] The EU finaced IPA project "Establishment of Natura 2000 network" has started with implementation on 26 April 2016 and will last for 3 years (http://natura2000mne.eu/#news (retrieved 10.07.2016))

Moreover, based on the same dataset the mapping of the related forest function zones (e.g. Mountain protection forest) can be performed.

4.10.2.5 Evaluation of forest accessibility and forest road planning

For the evaluation of forest accessibility and forest road planning decisions and new information created can be derived from

- Forest Site Map
- with a special focus on its terrain information

For the evaluation how vulnerable a soils is to driving on it with heavy machinery (tractor, forwarder) during harvesting operations the data included in the site map are comprehensive. Is it too steep for skidding tail, is it too wet for harvesting operations can be answered with information on the soil type, terrain form and slope.

The terrain information of the site map, geology, soil type, depth and rockiness are basic information which can be used to optimize road networks, positioning of road lines and the cost efficient planning of forest road with 3D-GIS based software solutions.

4.10.3 Update of Planning Instructions

The Forest Administration was supported in adapting the regulations and guidelines relevant for Forest Management Planning – describing where and how to use the new ecological information.

4.10.3.1 Bylaw on Forest Management Planning

Adaptations in the bylaw for Forest Management Planning (Bylaw on detailed content and methods of Developing a Forest Management Program (Number 322-47/13-5)) have been proposed with the aim to establish the utilization of all three main elements of the FEGDB:

- Forest Site geodatabase
- Geodatabase on Potential Natural Forest Vegetation
- Information relevant for nature protection, wildlife management and biodiversity

902.

Number: 322-47/13-5

Podgorica, 26th of July, 2013.

Na osnovu člana 24 Zakona o šumama („Službeni list CG“, broj 74/10), Ministarstvo Poljoprivrede i ruralnog razvoja, donijelo je

Pursuant to Article 24 of the Law on Forests ("Official Gazette of Montenegro", No. 74/10), the Ministry of Agriculture and Rural Development, adopted

PRAVILNIK

O BLIŽEM SADRŽAJU I NAČINU IZRADE PROGRAMA GAZDOVANJA ŠUMAMA

BYLAW

ON DETAILED CONTENT AND METHOD OF DEVELOPING A FOREST MANAGEMENT PROGRAM

Član 1

Program gazdovanja šumama (u daljem tekstu: Program) sadrži podatke i izrađuje se na način utvrđen ovim pravilnikom.

Article 1

Forest management program (hereinafter: the Program) contains data and is made according to this Rulebook.

Figure 55. The Bylaw on forest management planning (version 2013) revised

The revised document is attached to this report as Appendix 5 in chapter 12.

4.10.3.2 Manual for Forest Management Planning

The Manual for Forest Management Planning is a technical document describing the business process of the planning ordered by work steps. In the latest version made available by the CMU in 2015 (Version 11.0, 22.12.2012) we proposed changes in the definition of work process, so that the new information derived from the FEGDB is systematically made available for the decision making of the planner.

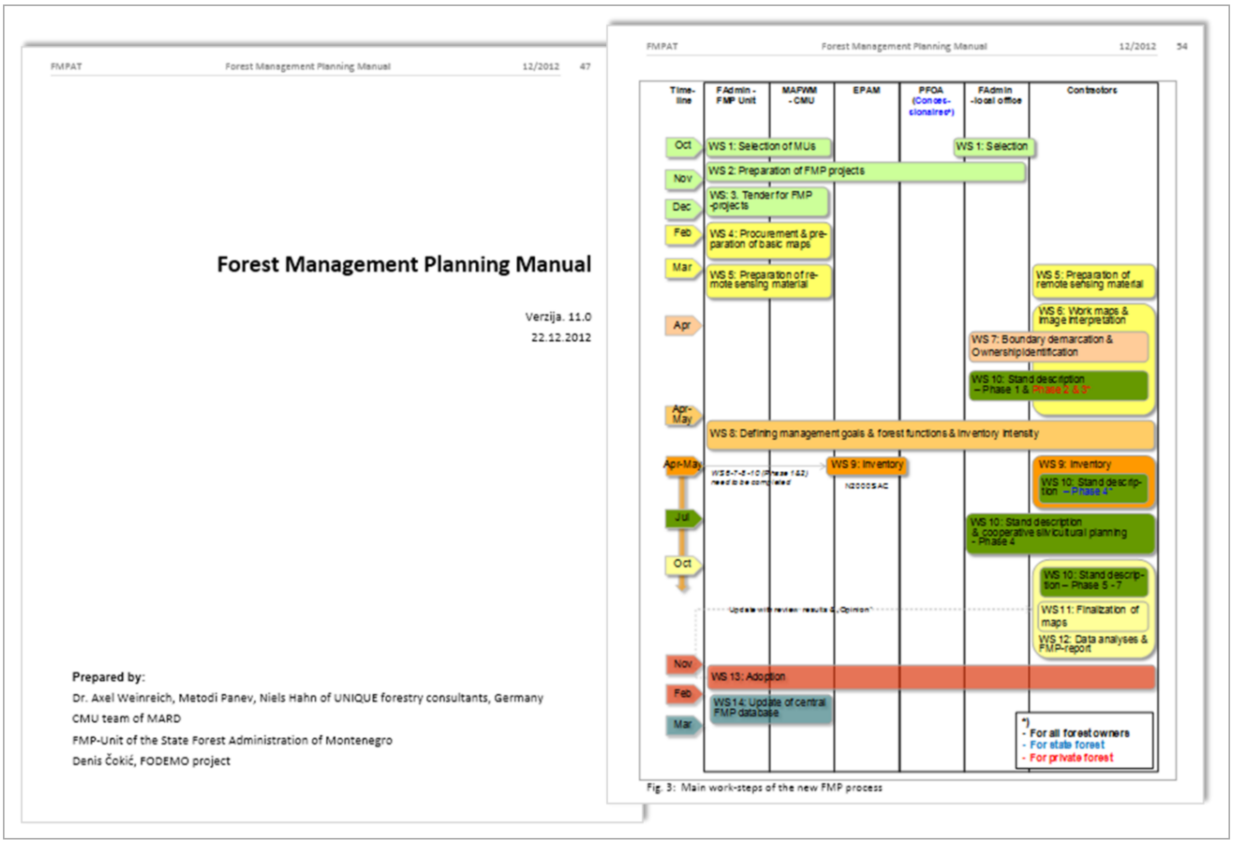


Figure 56. Forest planning manual – describing the process of the forest management planning

The proposed changes are marked in the document. The revised document is attached as Appendix 6 in chapter 13.

4.10.4 Technical Solutions for a Decision Support during the Planning Process

The easy accessibility and smart overview to all information layers relevant for the management decision in forest management is a key challenge for software systems supporting the planning process. As most of the information is location based and spatial explicit they can be retrieved using a GIS. This is especially valid for the new ecological information compiled in the FEGDB.

Optimally the planner needs - mobile - access to all the following new geo-data layers, which he combine in a comfortable and fast way:

- Forest Site Map
- Tree species suitability and productivity maps
- Map of Potential Natural Forest Vegetation
- Several layers related to nature conservation
- Erosion or landslide risk maps
- Accessibility map

The list does not include the other formerly available information layer like

- Forest stand map
- Forest operation map (results of harvest and other silvicultural activities)
- Forest function map
- Forest road and skidding trails / skidding road networks

- Topographic features like waters, buildings, and other land use classes etc.

The planner has to read from and interpret several information layer at the same time and for a certain location in space, mostly the forest stand.

In the past, for the task to describe a forest stand and the following derivation of optimal measures it was necessary to open several analogue maps, open printed tables and documents one after another. Every time the location “stand” has to be searched for. The number of documents, yield tables, maps, guidelines often led to the situation that some of these information was not at hand in the forest. Decision making was moved from the best moment – on the site and in the forest stand – to the desk (weeks later).

In contrast a GIS based user interface allows to keep the location of the stand fixed and open the related information layer very fast. However, the data extraction and input in a stand description form or selection of management activities in the planning process a manual data input is needed. Both is time consuming and error prone.

4.10.4.1 Improvements for the work step “Stand Description”

The approach to use GIS-based user interfaces and geodatabases opens the option to develop semi- or automatic data extraction from the different GIS layer. Intersection algorithms eventually combined with interpretation rules can be defined to automatically “fill” stand description data. All site attributes of a stand, the productivity of species, forest functions zones, habitats of rare and endangered species are examples to speed up data collection processes during forest management planning.

4.10.4.2 Improvements for the work step “Cooperative Silvicultural Planning”

Once a stand is described precisely the range of options for an optimal management are stepwise reduced.

The new software approach allows to filter management options in a decision tree based on the stand description data automatically. Prerequisite is that a clear set of management strategies and a set of measures exist in the forest enterprise. In result the planner receives a pre-selection of management recommendations and concrete measures automatically. This decision support function improves the consistency, plausibility of plans and makes them transparent for the whole organization. Moreover it saves time in the planning process.

4.10.4.3 Improvements for the work step “Reporting”

A time consuming task in forest management planning is the production of final reports containing textual and tabular information and include – typically separately – printed maps.

Considering the described approach of the web-GIS-portal and the spatial integration of the Forest database (OSNOVA), a flexible set of standard reports and digital maps can be prepared documenting the result of the forest management planning process.

In many cases a combination of map layers contains more information than any textual description (for example: Description of location of a MU or a stand, distribution of site classes or terrain conditions). Now, the planner can easily combine map layers and produce any thematic map of importance for him.

The software approach avoids writing exhausting Forest Management Planning documents. The textual part mainly to evaluate forest condition and to explain planning decision can be reduced to a minimum.

As the new approach to implement a small FIS contains a dynamic forest management database system, the planner but also any other user can produce reports describing the actual state of the forest at any moment in time. The printed planning documents – outdated after several years of management - are not the primary source of information anymore.

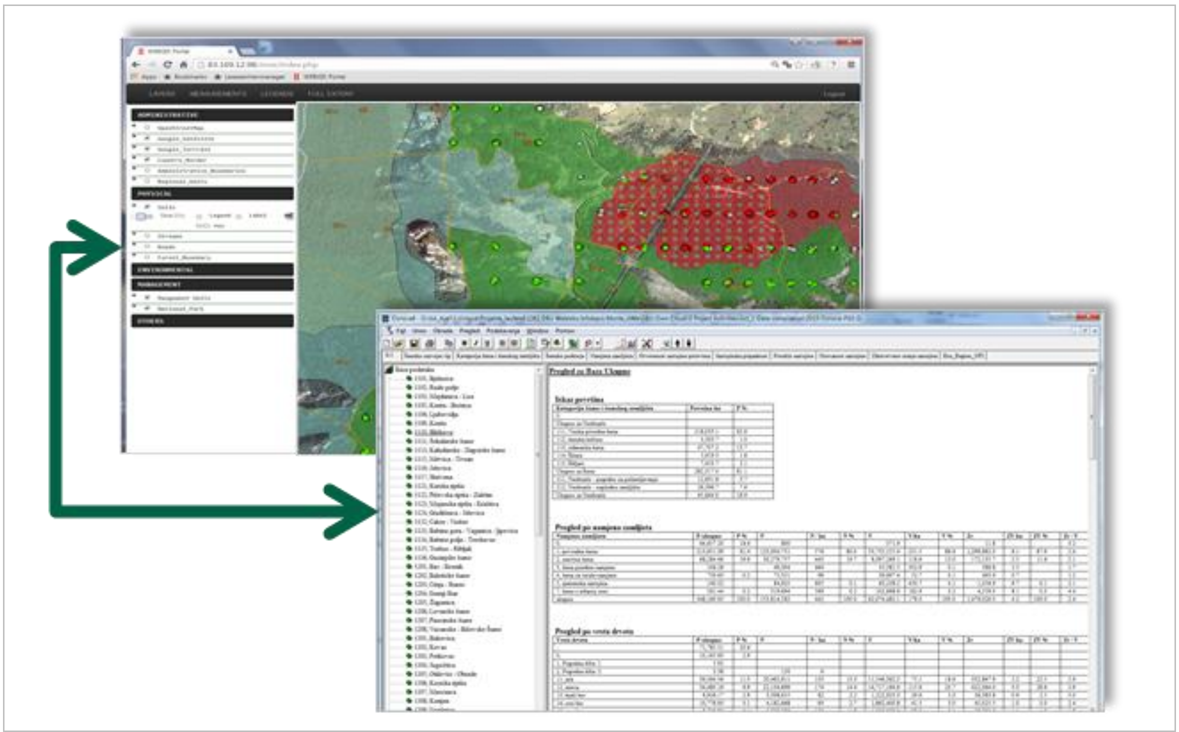


Figure 57. Illustration of a technical solution support decision making in forest planning

5 DISCUSSION

5.1 Overall project layout and expected results

Main objective of the project was to develop an innovative concept to improve the ecological data base for sustainable forest management and forest nature conservation. The approach should be tested in selected case studies. This is linked with these specific aims:

- Improvement of the knowledge of forest site classification;
- Improvement of the knowledge of the potential natural forest vegetation;
- Compilation of all available information for forest conservation, and integration of all available ecological basic information into a public „forest ecological data base“;
- Case study for the transfer of the new ecological information in „Sustainable Forest Management Plans“, including the definition of forest development types and vegetation types;
- Integration of all available data banks into the new „Forest Information System“ (FIS);
- Transfer of knowledge through qualification of Montenegrin forestry personnel;

- Development of a forest management plan for a selected forest enterprise (case study).

The following chapter reflects the plans and achievements regarding

- Project layout
- Project organization and cooperation
- Evaluation of the cooperation between the partners
- Work progress and deviation from the planned work and results

5.1.1 Project layout

The project included a large from 3 countries (see list in the introductory part). It included two Ministries in Montenegro, which means also the main institutions responsible in managing the forest ecosystem for forestry and nature conservation. Practice partners from Forest Administration (Fadmin) as well as EPAM have played a decisive role in the project layout. Most of the in-kind contribution was on the shoulder of the Fadmin, especially with respect to the data collection and field campaigns (staff, transport etc.)

An important factor in the layout was the attempt to allow qualified training of 2 Montenegrin doctoral Students with support from the Serbian faculty for Forestry and the German partners. It was planned to concentrate most of the scientific work in method development via the doctoral projects, dealing with the concept development, data recording and analysis in two management units.

Parallel to these activities, the web-based forest ecological geodatabase (FEGDB) should be developed, and integrated as a module into the Forest Information System (FIS) (see 4.9). This new environmental information should become implemented in Forest Management Planning, including improved decision support (see 4.10).

The duration of the project was planned for three years, i.e., including 2 seasons of field work. In the first vegetation period, a pretest was planned. The developed methodology was to be applied in the second vegetation period, when in two forest management units should be inventoried, parallel to a forest inventory, and resulting in an integrated Forest Management planning by using the data for the decision making. In the following winter season, the data analysis was planned.

5.1.2 Project organization and cooperation

The initial planning of the cooperation with the project partners is described in Figure 1. The tasks were distributed between the partners, and specified with respect to the specific approaches and expected results.

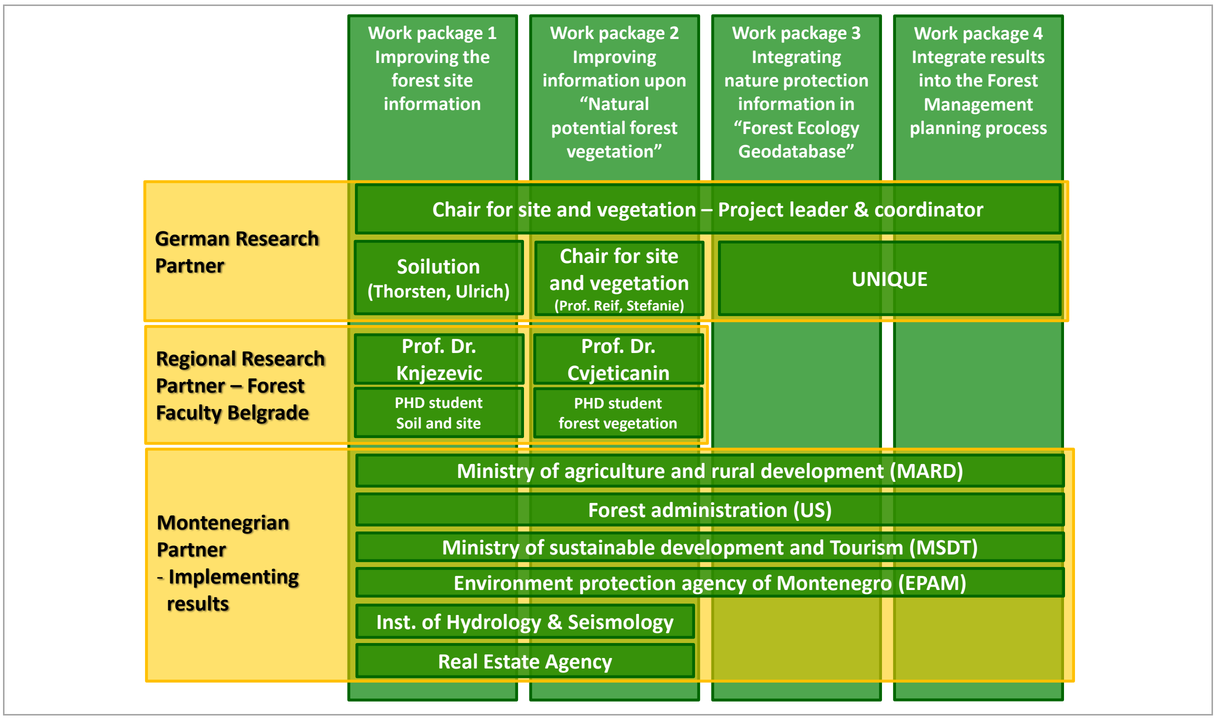


Figure 58. Organization of cooperation with the project partners

The project was coordinated at the Chair of Vegetation Science and Site Classification, Faculty of Environment and Natural Resources (UNR), University of Freiburg. This included the organization and contracting

- with the project partners from the two German companies UNIQUE (Dr. Axel Weinreich, Metodi Panev) and SOILUTION (Dr. Ulrich Steinrücken, Dr. Thorsten Behrens);

with the Montenegrin Ministries and their institutions, namely

- MARD including Forest administration: Financial and personal input (Minister Prof. Dr. Petar Ivanović, Deputy Minister Adem Fetić, Blazo Jokanović, Vito Tepavčević)
- EPAM: Environmental data and advise (Dr. Dragan Roganović, Ervin Spahić)
- Hydro-Meteorological Institute: Meteorological data, advise (Luka Mitrović, Mirjana Ivanov)

The Real Estate Agency of Montenegro: DEM-, Lidar-data (Dragan Kovačević, Snjezana Šoskić)

with the Serbian University of Belgrade and separately with the two supervising Serbian professors from pedology and vegetation science. This included Prof. Dr. Milan Knezević, Dr. Marko Perović, Prof. Dr. Rade Cvetičanin, and the two doctoral candidates Milan Gazdić, Srdjan Pejović who also included by specified contracts.

An additional cooperation was established with the University of Montenegro: Prof. Dr. Danka Petrović supervised the plant identification.

The coordination was implemented through internal meetings and workshops. The most important ones are listed in Appendix 3 in chapter 14. Additionally the two doctoral candidates could be financed by external resources for a stay at the University Freiburg (January and March 2015 and 2016). Aim of these stays was the co-supervision of specifying the doctoral concepts, the data input, analysis, and method development.

5.1.3 Description and evaluation of the cooperation with the project partners

The **cooperation with the University of Belgrade**, Faculty of Forestry, was initiated from the beginning of the project. The cooperation aimed for a common supervision of two doctoral candidates who had to be selected together and in common agreement with the Ministry of Agriculture and Rural Development of Montenegro (MARD). Finally, two candidates from Montenegro were selected, both previous forestry students (Srdjan Pejović, Milan Gazdić). One of them was working and will continue to work at MARD, the other student was looking for a job. The supervision should contribute to develop the concept of site classification and the spatial statistical analyses.

In the beginning it was planned and agreed, that the contribution of the University of Belgrade to the project will be the employment the two doctoral candidates. A new bylaw from December 2013 hindered this solution, which also meant that the doctoral candidates would have to pay ca. 14.000 € of study fees (for 3 years per doctoral candidate) (see below). Finally after long negotiations it was agreed that the University of Belgrade contributes in form of a study fee reduction of 17.900 €, which means that every doctoral candidate still has to pay ca. 5.000 € of study fees (in 3 years). Therefore the project had to finance this unexpected financial burden for the two candidates without having a specific budget for that.

Negotiations with the MARD provided one part of the solution: The doctoral candidate was granted to leave for the dissertation, with continued payment of his salary from MARD. The DBU-project agreed to finance the costs for his field work, and the remaining study fee load (9.646 €). The other doctoral candidate (M. Gazdić) was financed by a project-internal DBU-granted scholarship (in total 16.206 €).

The two supervising professors from Belgrade (Prof. Dr. Rade Cvjetičanin, vegetation; Prof. Dr. Milan Knježević, pedology) recieved contracts to reimburse them for their contribution including all expenses (3.400 € each). Before we installed an official cooperation contract between the two universities was a time-consuming process; thereafter individual contracts with each of these professors could be established.

Complicated was the cooperation with the Forest Administration of Montenegro, which was an independent institution at the beginning of the project, but became integrated into MARD beginning of 2014. This affected the cooperation between these institutions. The main difficulties were caused by restrictive budget rules allowing no flexibility which is needed in a cooperation project. Other problems rose because there were too less cars in the Fadmin, and too less available staff capacity for such a project. It needed the support directly from the Ministry in April 2015 to improve the infrastructure provided from MARD for the second season (2015) of field work. Despite of that the focal points of the project could be kept over 2 years, but the supporting field teams (from Fadmin) changed over time.

The **cooperation between the partners from Germany** (University of Freiburg; UNIQUE forestry and land use and Soilution) was without problems.

5.1.4 Work progress and deviation from the planned work and results

The work process and deviations from planned work and results will be discussed in detail in the following chapter discussing the results of the different work packages. Moreover a tabular list of the project activities are presented in chapter 14, Appendix 7. Summarizing the following tasks were performed:

- Two test areas have been successfully selected, the sampling design FoSiM and the methodologies for collecting soil and vegetation data in the field were developed.
- The two Montenegrin doctoral candidates were trained in the field and tested the methodologies in the field in 2014 and 2015. Based on their preliminary results (analyses during winter 2014/2015), the sampling design was revised and updated for the second vegetation season, where it was successfully implemented.
- The ecological limitation of the main tree species were successfully identified, however, due to missing growth data, the performance of the tree species (e.g., increment growth) in relation to the site factors could not be shown within this work.

Specific problems caused deviations from the planned work and project implementation:

- The two selected test areas should have originally been chosen statistically as areas independent from the forest management classification, but due to practical reasons, they were chosen as management units. Nevertheless, the two chosen management units are representative by geology, vegetation diversity and topography.
- The choice of management units was very much dependent on the fact that not every management unit is managed every year, therefore it was imperative that the two selected management units should be planned for managing in 2015. This was in order to have the possibility to implement the new ecological information new management plans.
- Some challenges were faced due to lack of climatic data, which have been collected in Montenegro over the years quite inconsistently.
- Due to restructuring of the public sectors in Montenegro in 2012, and change of legislative in Serbia, some problems occurred, which caused deviation of the planned work for the project:
  - Due to budget reduction of MARD and the forestry administration, there was also a problem with the transport vehicles needed for the project. The number of available 4-wheel cars was reduced to a minimum and MARD could not spare cars for the project anymore. After many rounds of meetings, also directly with the minister, the field work started end of July, 2014, three months later than originally planned.
  - There was an agreement with MARD that if we deliver the precise budget for the vegetation season 2015 before the budget for MARD was settled in December 2014, there should not be a problem to provide the cars, staff and gasoline in 2015. But nevertheless, similar challenges were faced as in the previous year, which resulted with a delay of the beginning of field work in the second vegetation season.
- Additionally, other changes were made:
  - Two new partners were included: the Real Estate Agency, which delivered the LIDAR and DEM data, and Prof. Dr. Danka Petrovic, a vegetation expert who facilitated the plant identification in the field and the laboratory in 2014.
  - An additional doctoral candidate (Sofche Spasikova) was included in the project.
  - The equipment for field work was not possible to be bought in Montenegro. For this reason, the project leadership took over the task of buying the equipment and transporting it to Montenegro.

5.2 Work package 1: Method development in two test areas

5.2.1 Pre-Study

Forest site mapping is a highly specific and data demanding process. It comprises the interaction of roots with parent material, relief and soil genesis as well as the interaction of the entire plant with local and regional climate conditions throughout the year. This makes site mapping a complex task since all these factors have to be accounted for. Terrain changes over some meters as parent material and soil genesis does. Even more complex terrain interacts with climate and both with parent material – all driving the suitability for plant growth. In this context we were aiming at the best available dataset possible for forest site mapping.

In situations where high resolution spatial information on soils is largely missing new spatial modelling approaches are required to efficiently derive the required site data. In this context spatial mapping and modelling relies on available environmental covariates which are relevant for deriving statistical models and thus the spatial distribution of the specific soil or site property to model. Hence, a good data basis is crucial. This comprises spatial resolution as well as information content. A high resolution with strong errors is problematic as is coarse scale data with a good description on information content.

Based on the available data this project mainly relies on the climate data at a resolution of 100 m, the DEM with a resolution of 2m and a soil map at a scale of 1:50,000 (cf. chapter 4.1.2). Normally this range of resolution and scale is not appropriate for setting up a model. Additionally, the information content is questionable to some degree. The climate data relies on only a very few climate stations not distributed evenly across topography. The DEM at 2m showed shows artifacts resulting from the LIDAR/TIN based generation. Hence it was resampled to 10 m. This is also a more reasonable resolution to match the other covariate data. The soil map has a very restricted information content with respect to forest site mapping.

Concluding is can be stated that the data basis for environmental covariates was not optimal. However, it was used for model building.

5.2.2 Identification of test areas

The two selected test areas should have originally been chosen statistically as areas independent from the forest management classification, but due to practical reasons, they were chosen as management units, and based on the pre-study. Some challenges were faced due to lack of climatic data, which have been collected in Montenegro over the years quite inconsistently.

The choice of management units was also very much dependent on the fact that not every management unit is managed every year, therefore it was imperative that the two selected management units should be planned for managing in 2015. This was in order to have the possibility to implement the new ecological information new management plans.

As a result of the pre-study two out of the 135 Montenegrin "Forest Management Units" were selected as areas to test the developed methodology of site and vegetation survey, analysis and mapping. Only two management units were in the pipeline to be inventoried in 2015 and were meeting most of the criteria for the selection of the pilot areas. They both are quite homogenous regarding the soil conditions, but with a high diversity in the vegetation. The management units (MU) selected as test areas were Štitovo (1541) and Bjelasica (1101).

5.2.3 Method development I: General concept, data Preparation, sampling Design

The general concept was to adapt and apply existing methods to identify the relevant parameters for site classification (temperature, nutrients, water), and to relate them to the species composition, stand structure and growth performance (e.g., increment growth for trees) of the vegetation.

Data preparation was mainly focusing on generating a concept map which can be used as a basis for sampling design and mapping should comprise all relevant data to provide a system of landscape units which should be as homogeneous as possible regarding their site characteristics. This goal was archived and all subsequent steps were based on this map.

Sampling design was adjusted during the second year at provide a design which reduces travel time in the field. This is a non-optimal design do to possible spatial auto-correlation effects. However, it was required to be able to obtain enough samples.

Problems were created by the inaccessibility of some areas within the selected Management Units. Certain extra- and azonal forest types apparently were not represented within the preselected plot positions. Therefore in MU Bjelasica, the plots with dominating *Ostrya carpinifolia* were additionally included.

5.2.3.1 Soil sampling

Regarding this project where the FoSiM method was developed and applied for the first time, the field survey effort was underestimated. For a refinement and application of the method as well as tests of the transferability, more samples should be taken to estimate the variances. This was planned but was not achieved. This was mainly caused by external factors as well as the limited field experience during the beginning of the project.

A central problem is the measurement of the pH value. Each profile should be more than 60cm in depth to estimate the nutrient regime correctly and the procedure to measure the pH value must be conducted very carefully. Repeated measurement for each horizon seem necessary.

Courses in field survey and pH measuring are crucial for deriving reliable data and to enable the surveyors to apply the method. This requires much more effort than generally possible in such projects.

5.2.3.2 Vegetation sampling

In general the number of plots was not enough to include all forest types. Work and resource capacity problems of Fadmin hindered to follow the planned layout to full extent.

- Due to budget reduction of MARD and the forestry administration, there was also a problem with the transport vehicles needed for the project. The number of available 4-wheel cars was reduced to a minimum and MARD could not spare cars for the project anymore. After many rounds of meetings, also directly with the minister, the field work started end of July, 2014, three months later than originally planned.
- There was an agreement with MARD that if we deliver the precise budget for the vegetation season 2015 before the budget for MARD was settled in December 2014, there should not be a problem to provide the cars, staff and gasoline in 2015. But nevertheless, similar challenges were faced as in the previous year, which resulted with a delay of the beginning of field work in the second vegetation season.

Certain extra- and azonal forest types apparently were not represented within the preselected plot positions. Therefore in MU Bjelasica, plots with dominating Ostrya carpinifolia were additionally included. Another problem was detected for the Stitovo inventory by the insufficient floristic and site factor differences between the plots of plot groups, which caused floristic autocorrelation instead of coverage of local site variability.

Severe constraints provided the identification of the plant species on the sample plots. Most individuals have to be identified in a sterile condition. The lack of a Montenegrin flora book, and deficits in experts experience caused incomplete species lists on certain sample plots. This affects the validity of each classification which will be based on these plant lists. This was one reason to concentrate the analysis on the distribution limits of the selected tree species.

5.2.4 Metod development II: Classification

5.2.4.1 Classification of sites

A site classification model was developed in this study by SOILUTION based on the general approach as applied in Germany. This method, as described in chapter 4.3 and comprises the water regime, the temperature regime as well as the nutrient regime. It is a complex approach relying on the quality of the available covariate data as well as the quality of the field mapping results.

For the general application and depending on the available budget the soil chemical and partly the soil physical properties should be measured using vis-NIR infrared spectroscopy. This would allow for a much more precise classification of the sites as well as reduced soil genetic knowledge of the field survey staff. Also the climatic parameters and the climatic indices should be modelled with better precision. The ecologically relevant time periods (e.,g., monthly versus seasonal versus annual period) to analyze distribution limits (of tree species and forest types) must be considered in a more profound way. Also the relation between climatic and soil data could be improved, applying the water balance model (Allen et al. 1998).

5.2.4.2 Classification of vegetation

From Serbia there exists a forest classification which uses the dominating tree species and additionally the ground flora for a broad, general classification (Tomić, 2004). Appling this “top-down” approach, the plots could be attributed to existing forest types. For local and regional analyses, a numerical classification of the recorded species composition of the 271 sample plots would be desirable. Because of partly incomplete floristic data, and lack of time for numerical classifications, this step was started, but remained unsatisfactory.

5.2.5 Site productivity and species suitability assessment

The site productivity analysis was planned in relation to existing data from Forest Management plan related inventory data (sampling plots) and sampling plots of the National Forest Inventory of Montenegro (NFI, 2013). The theoretical conceptual based for such a site productivity and species suitability assessment was developed (see above).

Because of missing growth data from the available forestry datasets for this project, an analysis of the performance of the tree species in relation to the site factors could not be shown. However, one of the objectives (S. Spasikova) of the newly started, doctoral dissertation within this DBU Project is to develop an innovative method for analysis of the relation between site and growth data. With the help of this methodology and the estimated site productivity of the forest sites, the further step would be the implementation of this knowledge and the development of support-tools for recommendations for tree species selection suitable to the site in Montenegro.

5.2.6 Case studies: Regionalization of site characteristics

Using the FoSiM approach there is an important gain in information regarding forest site management compared to the existing soil map (1:50,000). The scale of the FoSiM map is in the range of 1:10,000 to 1:20,000. It comprises information on water balance level and nutrient regime which is one the one hand based on available environmental covariate information as well as new field measurements and surveys.

Regarding this project where this method was developed and applied for the first time, the survey effort was underestimated. For a refinement and application of the method as well as tests of the transferability, more samples should be taken to estimate the variances. A central problem is the measurement of the pH value. Each profile should be more than 60cm in depth to estimate the nutrient regime correctly and the procedure to measure the pH value must be conducted very carefully. Repeated measurement for each horizon seem necessary.

Courses in pH measuring, Excel and GIS data handling are crucial for deriving reliable data and to enable the surveyors to apply the entire method. As any field survey, FoSiM requires a certain technical effort. This comprises GPS, field car, soil augers, spades etc. However, FoSiM was developed under the aim to reduce these efforts to a minimum.

For future applications FoSiM provides a great potential to efficiently obtain new forest site data – not only for the whole of Montenegro but any other region missing information on forest site conditions.

5.3 Work package 2: From actual to potential natural forest vegetation

The knowledge of the actual vegetation of apparently less anthropogenic disturbed plots, combined with existing maps, forest history information, and expert knowledge provides the base to construct the potential natural distribution of species (e.g., tree species) and plant communities (e.g., forest types) (WP 2). The principle is to conclude from existing near-natural plots and their site-vegetation relationships to the vegetation which would occur under “natural” conditions on the other, more disturbed plots.

The method for identifying, recording or modeling of the relevant site data was successfully developed, and applied to the main tree species within the two test regions. The knowledge of the limits of their occurrence provides the base for further modelling of their distribution. This step provides the amplitude and the limit of species (and when applied also forest types), but could be performed within this project only for selected tree species in the two ecologically different regions (Stitovo, Bjelasica).

The tree species distribution as the most important component of the potential natural forest vegetation could be related to the most important site factors, and the potential distribution was constructed based on these ecological assumptions described before. The presented results show important ecological limits of tree species (and forest types). These limits could be quantified which provides the basis for mapping of the limits of tree species and related forest types.

It was shown for the MU Stitovo, that light-demanding tree species, namely pines (*Pinus heldreichii*) and other pioneers, are limited by competition of shade-creating canopy trees, and not by abiotic site factors, at least locally or in the region. On sites where beech and fir can grow, light-demanding tree species can occur as pioneers after disturbance (e.,g., fire, clearcut); in the climax forest they can be a minor species, or completely absent. The next steps, which could not be implemented in this project, would be to

- Classify the vegetation of seminatural forest sample plots
- Identify and quantify their probability of occurrence including the distribution limit of single tree species as well as forest types in relation to quantified water, temperature, and nutrient parameters.

Based on these results, derived from near-natural sample plots, the distribution of single species as well as forest types could be performed.

5.3.1 Deviations

It was planned to construct environmental envelopes for the main tree species and the classified forest types. These could have been used to create distribution maps of their potential natural distribution in relation to sites. Within this project, only the method to identify distribution limits could be achieved. More effort has to be invested in identifying the relevant site factors, and relate them in the adequate temporal resolution (time periods). In a subsequent step maps could be created.

5.4 Work package 3: Development of a Forest Ecological Geodatabase

The concept behind the development of a forest ecological geodatabase (FEGDB) is based on the idea of compiling all information that are relevant for forestry, forest ecology, biodiversity and nature protection in one system allowing an easy access and analysis for the decision making in forest management and as information for the environmental sector and environmental monitoring.

The evaluation of the current status regarding forestry and environment related (geo)-data showed that at EPAM /MSDT not many datasets could be provided in a digital format. Systematic mapping of habitats and rare and endangered species has been started recently. However boundaries of protected areas are available.

In contrast the forest sector has a huge digital dataset from the regular forest management planning process and the related inventories. As nowadays the plot position is recorded via GPS, all trees measured can be located in the landscape and correlated theoretically with their site conditions. Also rare tree species are recorded. These data are not yet used by the environmental sector, but are an important source for the currently started EU funded project to implement Natura 2000[10].

The assessment of GIS standards and web based geodatabases in the forest and environmental sector showed that information systems based on GIS techniques and spatial databases are not existing in all related institutions. Therefore, the proposed new tool, the “Forest Ecological geodatabase” and the selection of a web-GIS-portal could not be build up based on existing structures. It was developed as prototype with all relevant functions and after discussion of the basic design with the partners. Additional data set could now be integrated any time. At the end of the project the draft site maps from both of the pilot management units will be installed (see chapter 4.6).

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[10] The EU finaced IPA project “Establishment of Natura 2000 network” has started with implementation on 26 April 2016 and will last for 3 years http://natura2000mne.eu/#news (retrieved 10.07.2016)

Missing steps for a final implementation are:

- A final decision on the organizational frame to run the FEGDB between MARD and MSDT
- The definition of work processes to use the edit functions for data collection and red-lining of respective geometries (like: habitat mapping, recording of sightings)
- The administration and maintenance of the system
- Definition of additional data to be installed
- Definition of user right and public access

The Montenegrin partner are recognizing the benefit of the web GIS platform as a very easy approach for giving access to this information and for more intensive use inside their institutions (EPAM, CMU, Forest Administration), allowing to share forestry and nature protection relevant information between the Ministries and with the public.

The second approach to organize access to the information of the FEGDB was to integrate it as one module into the recently planned “Forest Information System (FIS)”. Target was that the new spatial information are fully integrated in the FIS and accessible from inside the system and not only via a separate website. Here important deviations from the planned activities were necessary as a survey (see chapter 4.9.2) showed that the planned new FIS is still only marginally implemented. In result the connection and integration into a theoretical and ideal design of the future FIS was presented (chapter 4.9.4). Based on the existing software solutions a stepwise and cost efficient approach to establish a more comprehensive and modular FIS was developed and presented (chapter 4.9.5)

5.5 Work package 4: Implementation of the new environmental information in Forest Management Planning

The work package groups activities foreseen to implement and make use of the new ecological information base in the practice of the Forest Management Planning process.

The support to the Forest Administration in adapting the two most relevant regulations for Forest Management Planning describing where and how to use the new ecological information, could be completed as planned. It is a proposal and the MARD has now – after completion of the project - to decide how the proposals will be used for an official revision of both documents:

- Manual for Forest Management Planning
- The bylaw for Forest Management Planning

The new information could not been used directly for the management planning process in the selected pilot Forest Management Units. One main reason was that it was not possible to get the forest management planning started in 2015. Both FMP projects were shifted to 2016, too late for a joint implementation using the new information of the FEGDB. Other reasons were that a map of natural potential natural forest vegetation could not be provided as project result due to the reasons explained in chapter 4.7.4 of this discussion.

Instead two theoretical studies have been produced and are presented:

- Recommendations for a future utilization of the new ecological information (chapter 4.10.2) and
- Recommendations for the development of technical solutions to support the decision making for the planning forest engineer based on the new ecological information from the FEGDB (chapter 4.10.3).

The recommendations for a future utilization of the new ecological information also address one important step, which was started, but not completed, in site and mapping of PNV, the derivation of trees species suitability, based on an evaluation of tree species distribution, correlation with site condition and vegetation analysis, evaluation of site dependent tree species productivity and risks. Here the dissertation project (see chapters 4.5) has started and will provide results in 2017 (see chapter 4.10.2.2). The database to analyze the site conditions for tree species is exceptional good in Montenegro as the tree measurements of the National forest inventory as well as inventory data from the forest management plans can be located and intersected with site parameters.

As no test implementation was achieved within the project duration, all partners concretely discussed the development of a "follow-up project", latest at the final workshop April 2016. This can be interpreted that the Montenegrin partners are interested to overcome the shortcomings of the existing project. This is also true for the Serbian partners and the Serbian forest sector, which was looking at the outcomes of the project as well.

The new ecological information is recognized as important from the side of the South-East European partners from Montenegro and Serbia. Both partners are heading to finalize and implement the new methodology in their respective countries. A follow-up project under the framework of IPA2 Cross border cooperation was discussed in May 2016 with the Ministry in Serbia, the MARD in Montenegro and the respective DBU-partners.

6 CONCLUSIONS

Conclusion I – What was accomplished?

- A method for analysis of site and vegetation patterns was developed and tested
- Method for deriving the potential natural forest vegetation on the basis of actual tree species distribution was developed
- Relevant forestry and forest-based environmental data are collected and compiled into a "forest ecological geodatabase"
- Training of young scientists and forest practitioners is ongoing
- Cooperation between institutions and countries has been installed

Conclusion II – Remaining deficits

- Training of young scientists and working teams lasted longer as expected
- Final method to derive a site and vegetation map based on the data analysis is not yet complete and requires further activities - if financially feasible
- The analysis of the relationship between site and productivity of trees could not be achieved at this point, because the agreed forestry planning inventories in the pilot areas were postponed for one year
- An additional doctoral dissertation on site suitability of trees in Montenegro (S. Spasikova) is therefore still under development and requires a continuation of the project.

Conclusion III - Perspectives and midterm impacts

- DAAD Summer schools

An exchange program between the University of Freiburg, and the Universities in Montenegro, Macedonia and Romania was established in the form of summer schools (DAAD, "Ostpartnerschaften")

- Option Cross Border IPA

In 2016, MARD in cooperation with the MSDT is planning to submit an application to the EU under the EU IPA funding in IPA Cross Border Program Montenegro - Serbia. Both countries have signaled a great interest via their ministries. This could result that starting summer 2017, both countries will the developed methods and tools within this project to be implemented in other management units and thus to considerably greater area in both countries. This is done with the aim to obtain a nationwide site database and a nationwide map of potential natural forest vegetation.

- Natura 2000

In the line of the development of Natura 2000 management plans in Montenegro, the results of the management plans will in future be available to the forestry sector via the forest ecological geodatabase.

- Inter-sectoral cooperation

The cooperative approach of this project between MARD and MSDT opened an opportunity to harmonize methods and data between the forest and environmental sector and cooperate with several other projects, which are under development in both of the Ministries.

The consequent implementation of the methods and tools developed can open synergies with current and up-coming projects:

- Implementation of Natura 2000 in Montenegro
- Establishment and development of the environmental information system
- Activities of the “Climate change focal point”.

7 PUBLIC RELATIONS

7.1 Public presentation of the project

7.1.1 Presentation of the project for the Montenegrin general public

On April 10th, 2014, a public presentation of the project took place in the Chamber of Commerce in Podgorica. This presentation had a public character and served to inform the general public of Montenegro about the objectives of the project. Participants of this event were the Ambassador of the Federal Republic of Germany, Dr. Pius Fischer, representatives of ministries and other governmental institutions of Montenegro, the German partners of the project, as well as the Montenegrin media.

7.1.2 Media attention for the project its results

The final project workshop took place on April 12th – 13th.The workshop was opened by the Minister for Agriculture and Rural Development, Prof. Dr. Petar Ivanović, who in his speech, emphasized the importance of the project for the forest sector of Montenegro. The opening of the Minister was followed by the press center of MARD, accompanied by TV journalists from Montenegro. A report, including photo and video report of the workshop is available on the website of the Ministry under: http://www.minpolj.gov.me/vijesti/159985/Odrzana-konferencija-Uspostavljanje-sumsko-ekoloskih-stanista-u-Crnoj-Gori.html

7.1.3 Presentation of the project to the German ambassador in Podgorica

The DBU team had active communication concerning the project progress and difficulties in the project implementation with the German ambassador in Podgorica, Mrs. Gudrun Steinacker, the follower of Dr. Pius Fischer. This communication was intensified during the final project workshop which took place on April 12th – 13th, 2016, resulting with a meeting of the German partners from the DBU team with Mrs. Steinacker on April, 14th, 2016. On this meeting we updated Mrs. Steinacker about the success of the final project workshop and presented her with the ideas and intentions for a follow-up project in Montenegro, potentially with a cross-border cooperation with Serbia.

7.1.4 Publishing of results and participation of different partners in the results

The results will be published in the form of DBU-final report. It is also planned the results of the project to be published in the form of scientific articles within the 3 doctoral theses carried out in the project.

The following partners of the project participated in the results:

- Chair of Site classification and Vegetation Science: Project leader, Prof. Dr. Albert Reif, researcher Dr. Stefanie Gärtner and project coordinator / doctoral candidate Sofche Spasikova take over the development of methods for improving information on potential natural forest vegetation and site productivity
- Forestry Faculty in Belgrade: Prof. Dr. Rade Cvjeticanin, Dr. Marko Perovic, phytocenologists take over the development of methods for improving information on potential natural forest vegetation
- Soilution Dr. Ulrich Steinrücken, Dr. Thorsten Behrens GbR: develop methods for selection of model parameters and improvement information on forest sites
- Forestry Faculty in Belgrade: Prof. Dr. Milan Knjezevic develops together with Soilution the method of work package 1: improving information on forest sites
- MARD and the Forest Administration participate in the results, by supporting the implementation of improvements in information for potential natural forest vegetation and forest sites
- The company UNIQUE forestry and land use GmbH (Dr. Axel Weinreich, Metodi Panev) develops together with the Montenegrin partners of MARD and MSDT the forest ecological geodatabase. Based on the many years of experience in the forestry planning in Montenegro, UNIQUE aids the implementation of the new forest ecological information into practical forest planning.

In this project, 3 doctoral candidates are supervised and take part in the results. Srdjan Pejović took over the site and vegetation sampling in MU Štitovo; Milan Gazdić took over the site and vegetation sampling in MU Bjelasica. In addition to implementing the developed methods in the 2 test areas, these two doctoral candidates trained the inventory teams of the Forest administration in the field. The coordinator of the project, Sofche Spasikova was included later as a doctoral candidate in the project, and works with data from the National Forest Inventory Montenegro, climate data and GIS data for her thesis. Her work is dedicated to the identification of criteria for tree species suitability and selection of tree species suitable to the site conditions, and the implementation of these criteria in Montenegro as an exemplary area.

Apart from the three doctoral dissertations which continue after the ending of the project, this project lasted three months longer than planned. Reason for the cost-neutral project extension was the need for proper timing of the final workshop, which according to the project time-frame should have taken place in February. After a series of appointment scheduling by the German, Montenegrin and Serbian partners, and after careful consideration of the program for the workshop, the project team decided to postpone the final workshop to April, 2016. This allowed the project team not only to prepare a successful workshop for the presentation of the project results with prior coordination with the partners from Montenegro, but also the springtime provided the opportunity to demonstrate the developed methodologies in the field, as well as to train additional Forest administration staff for this methodology.

Main user of the project results is the Ministry for agriculture and rural development (MARD) together with the Forestry administration of Montenegro, as these two institutions are directly responsible for development and implementation of methods for forest planning in Montenegro. Further users of the project's results are the Ministry for sustainable development and tourism (MSDT), the Environmental Protection Agency of Montenegro (EPAM), as well as the Montenegrin public and other interested governmental and non-governmental institutions in Montenegro.

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8 APPENDIX 1. LIST OF REQUIRED AND OBTAINED DATA

List of relevant (spatial)-datasets - requested and used					
Used in WP	**N°**	**Dataset**	**Description**	**Used**	**FEGDB**
1, 2 ,3	1	Digital topographic map	Digital topographic maps - In vector format (cities, roads, waters)	Yes	X
1, 2	2	Digital Elevation Model (DEM)	Based on new LiDAR data	Only in pilot MU	
			SRTM free world wide DEM	Countrywide	X
1, 2	4	Soil map of Montenegro	Digitalized soil map of Montenegro (FUSTIC): Soil types Geology Soil depth Skeleton content	Yes	X
		Book: Soils of Montenegro	Soil profile data (horizons, chemistry) and digital map of soil profile position	Yes	--
2	5	European vegetation map (excerpt Montenegro)	Vector file of the European Vegetation Map - Adjusted for Montenegro during the National Forest Inventory	Yes	X
1, 2, 3	6	Administrative data of Monte-negro	Administrative data: Country border; municipalities	Yes	X
3	7	Biodiversity and Nature pro-tection	National parks	Yes	X
			Emerald sites	Yes	X
			Environmental protection	Not available	--
			Species protection, special habitats, distribution of rare or endangered species	Not available	--
1, 2, 3	8	Forests and other forest land	Forest mask – Landsat based analysis during NFI	Yes	X
1, 2, 3	9	Forest administrative units	Forest Bio-Regions – homogenous climatic and land-scape	Yes	X
			Forest estates	Yes	X
			Forest management units	Yes	X
1, 2, 3	9	Forest Management Plans	Central Database of the Forest Management Plans	Yes	--
1, 2, 3	10	Data and maps of NFI	Geodatabase with results of the first NFI	Yes	X
1, 2	11	Climate data - requested for the period of 30 years	Compiled maps as raster files of the main climatic values for a) monthly average values and b) vegetation period. Additionally, the same values on country level and for each meteorological station:		Available data can be imple-mented
			- Precipitation	Yes	--
			- Temperature (min, max, mean)	Yes	--
			- Evapotranspiration	Not available	--
			- Radiation	Not available	--
			Maps (or Penmann-Montith calculations) of: - Cloudiness - Humidity - Wind speed	Not available	--
			Extreme periods: - Drought – summer - Frost periods - winter	Not available	--
	12	Climate change projections	Of temperature, precipitation etc.	Not used, but available	--
2	13	Distribution of tree species		Not available	--
2	14	Geo-Botanical data	Indicator species list for forest types	Not available	--

List of relevant (spatial)-datasets - requested and used					
Used in WP	**N°**	**Dataset**	**Description**	**Used**	**FEGDB**
2	15	Forest vegetation types	Including vegetation data, Brain-Blanquet-releves	Yes	--

9 APPENDIX 2. DEVELOPED SUPPORT TOOLS FOR FIELD WORK

Manual – Description of soils in the field (in Montenegrin) - available in the supporting CD material

Tally-sheet Vegetation

Vegetation Relevé – List za uzorkovanje

Data		Releve No.	
Lokacija		Ime	
Visina		Veličina parcele	
Topografija		Forma parcele	
Nagib %		Vegetaciska forma	
Aspekt			
Percent poklopca	Sloj drva		
	Sloj grmlja		
	Sloj biljaka		
	Sloj mova		
Geološki supstrat:		Tekstura zemljišta	
Tip zemljišta		Forma humusa	
Sloj drva		Sloj grmlja	
Sloj biljaka			
Sloj mova		**Skala zastupljenosti poklopca (BB)** r redak, usamljeni, s malim poklopacem rare, solitary, with small cover <1%, 1-2 individue + malo, s malim poklopcem <1%,3-10 individue 1 brojan, ali manje od 5 percent poklopca, ili mestimičan, s poklopcem do 5%, 10-50 individue 2m procent poklopca < 5%, > 50 individue 2a procent poklopca 5 - 15%, 2b procent poklopca 15 - 25%, 3 procent poklopca 25 - 50%, 4 procent poklopca 50 - 75%, 5 procent poklopca 75 - 100%, I	

Fitocenološko uzorkovanje sensu Braun-Blanquet

10 APPENDIX 3. LISTS OF FOREST PLANTS FROM BOTH MU

List of forest plants from Bijelasica (Josifović, 1977; Šilić, 1977, 1990)

Abies alba
Acer campestre
Acer platanoides
Acer pseudoplatanus
Achillea millefolium
Agrimonia eupatoria
Ajuga reptans
Allium ursinum
Alnus incana
Anemone apennina
Anemone nemorosa
Aremonia agrimonioides
Asarum europaeum
Asperula longiflora
Asperula odorata
Asperula purpurea
Asperula scutellaris
Asplenium viride
Astragalus glycyphyllos
Athyrium filix-femina
Atropa bella-donna
Avenella flexuosa
Betula pendula
Brachypodium sylvaticum
Briza minor
Bromus sp
Calamintha nepeta
Campanula bertolae
Campanula pyramidalis
Carduus sp
Carex pendula
Carex sylvatica
Ceterach officinarum
Cheiranthus cheiri
Cynodon dactylon
Circaea lutetiana
Cirsium sp
Clematis vitalba
Convallaria majalis
Corylus avellana
Coronilla coronata
Crategus laevigata
Daphne blagayana
Danaa cornubiense (= Physospermum cornubiense)
Dentaria bulbifera
Daphne mezereum
Dianthus sp.
Dryopteris filix-mas
Dryopteris dilatata
Epilobium angustifolium
Epilobium montanum
Epipactis helleborine
Euonymus latifolia
Euphorbia angulata
Euphorbia amygdaloides
Fagus sylvatica
Phylitis scolopendrium
Fragaria vesca
Fraxinus excelsior
Galium lucidum
Galium odoratum
Galium rotundifolium
Galium sylvaticum
Gentiana asclepiadea
Geranium robertianum
Geranium sylvaticum
Glechoma hirsuta
Globularia cordifolia
Hedera helix

Helianthemum alpestre
Hepatica triloba
Heracleum sphondylium
Hieracium bauhinii
Hieracium tomentosum
Homogyne alpina
Hypericum perforatum
Hypericum maculatum
Juniperus communis
Juniperus nana
Lamium galeobdon
Leontodon crispus
Lilium martagon
Linaria vulgaris
Lonicera alpigena
Lonicera nigra
Lotus corniculatus
Lunaria rediviva
Luzula forsteri
Luzula luzuloides
Luzula sylvatica
Malus sylvestris
Mercurialis perennis
Muscari racemosum
Mycelis muralis
Neottia nidus-avis
Nardus stricta
Ostrya carpinifolia
Oxalis acetosella
Paris quadrifolia
Picea abies
Pinus heldreichii
Pinus nigra
Pinus sylvestris
Plantago lanceolata
Plantago major
Tussilago farfara
Polypodium vulgare
Polystichum aculeatum
Polystichum lonchitis
Polytrichum formosum (moss)
Polygala vulgaris
Polypodium vulgare
Polystichum setiferum
Populus tremula
Potentilla alba
Potentilla erecta
Prenanthes purpurea
Prenanthes purpurea
Prunus avium
Pteridium aquilinum
Pulmonaria officinalis agg.
Pyrola secunda
Pyrus pyraster
Pyrus pyraster
Quercus cerris
Quercus petraea
Rhamnus fallax
Rosa canina
Rubus fruticosus agg.
Rubus idaeus
Ruscus hypoglossum
Salix caprea
Salvia glutinosa
Sambucus nigra
Sanicula europaea
Saxifraga crustata
Saxifraga rotundifolia
Sedum acre
Sedum ochroleucum
Senecio sp.
Sesleria autumnalis
Silene vulgaris
Sambucus nigra
Sorbus aria
Sorbus aucuparia
Sorbus austriaca
Sorbus torminalis

Stachys officinalis
Thalictrum aquilegiifolium
Thymus alpestris
Thymus serpyllum agg.
Tilia cordata
Trifolium medium
Trifolium pratense
Trifolium repens
Tussilago farfara
Ulmus glabra
Urtica dioica
Vaccinium myrtillus
Veratrum album
Verbascum divisma
Veronica officinalis
Veronica urticifolia
Viola reichenbachiana

List of forest plants from Štitovo (Josifović, 1977; Šilić, 1977, 1990)

Abies alba
Acer heldreichi
Acer platanoides
Acer pseudoplatanus
Achemilla hybrida
Achillea millefolium
Agrimonia eupatoria
Anemone baldensis
Anemone nemorosa
Anemone ranunculoides
Arctostaphylos uva-ursi
Aremonia agrimonioides
Asarum europeum
Asperula cynanchica
Asperula longiflora
Asperula purpurea
Asperula scutellaris
Asplenium fissum
Asplenium viride
Avenella flexuosa
Betula pendula
Brachypodium rupestre
Brachypodium pinnatum
Brachypodium silvaticum
Briza minima
Bromus sp
Prunella grandiflora
Calamagrostis arundinacea
Calamagrostis varia
Calamintha alpina
Calaminta nepeta
Campanula bertolae
Campanula pyramidalis
Canpanula scheuchzeri
Carduus sp
Carex humilis
Carlina acaulis
Carpinus betulus
Cerastium moesiacum
Cheiranthus cheiri
Chrysanthemum chloroticum
Cirsium eristithales
Cirsium sp
Clematis vitalba
Corylus avellana
Coronilla coronata
Cotonaster integerrima
Crepis dinarica
Danaa cornubiense (= Physospermum cornubiense)
Dentaria bulbifera
Dentaria enneaphyllos
Dianthus prenjus
Dianthus silvestris
Diantus petraeus
Diphasium alpinum
Dryopteris filix-mas
Epilobium anqustifolium
Epilobium montanum
Epipatis latifolia
Fagus silvatica
Festuca drymeia
Festuca pungens
Fragaria vesca
Fritillaria montana
Galium lucidum
Galium rotundifolium
Galium silvaticum
Galium verum
Gentiana ambliphylla

Gentiana asclepiadea
Gentiana lutea
Geranium robertianum
Globularia cordifolia
Hedera helix
Helianthemum alpestre
Helianthemum nummularium
Hepatica nobilis
Heracleum sphondylium
Hieracium alpinum
Hieracium bauhinii
Hieracium pavichii
Hieracium pilosella
Hypericum perforatum
Iberis sempervirens
Juniperus communis
Juniperus nana
Lamium galeobdon
Laserpitium marginatum
Leontodon crispus
Leontodon sp
Lilium alpestre
Linaria vulgaris
Lonicera alpigena
Lonicera formanekiana
Lonicera nigra
Lotus corniculatus
Luzula silvatica
Melica ciliata
Mercurialis perenis
Mycelis muralis
Myosotis nana
Moehringia muscosa
Monotropa hypopitys
Muscari racemosum
Nardus stricta
Orchis pallens
Oxalis acetosella
Paris quadrifolia
Pinus heldreichi
Pinus nigra
Pinus silvestris
Pyrola media
Pyrola secunda
Plantago lanceolata
Poa alpina
Poa nemoralis
Polygala vulgaris
Polystichum lonchitis
Polygala croatica
Polygonum viviparum
Polystichum setiferum
Populus tremula
Potentilla clusiana
Potentilla erecta
Potentilla opaca
Prenanthes purpurea
Primula vulgaris
Prunus spinosa
Pulsatilla alpina
Rhamnus fallax
Ranunculus montanus
Rhamnus rupestris
Rhamnus saxatilis
Rosa canina
Rosa pendulina
Rubus idaeus
Rumex scutatus
Salix caprea
Salix purpurea
Salvia glutinosa
Sambucus nigra

Sanicula europaea *Viola* *reichenbachiana*

Satureia vulgaris

Saxifraga caesia

Scabiosa portae

Sedum alpestre

Sedum ochroleucum

Senecio rupestre

Senecio visianinus

Sesleria autumnalis

Sesleria nitida

Silene acaulis

Silene viridiflora

Silene vulgaris

Solidago virgaurea

Sorbus aria

Sorbus aucuparia

Sorbus torminalis

Stachys jacquinii

Stachys officinalis

Stachys recta

Stachys alpina

Thalictrum aquilegiifolium

Thymus serpyllum agg.

Thymus balcanus

Thymus alpestris

Trifolium medium

Trifolium pratense

Tussilago farfara

Urtica dioica

Vaccinium myrtillus

Veratrum album

Verbascum divisma

Veronica officinalis

Veronica urticifolia

Viburnum maculatum

Vicia incana

11 APPENDIX 4: USER GUIDE FOR THE WEB GIS PLATFORM

- The USER GUIDE FOR THE WEB GIS PLATFORM is attached as a separate PDF document to this report, available in the supporting CD material

12 APPENDIX 5: BYLAW FOR FOREST MANAGEMENT PLANNING – REVISED

- The revised Bylaw on detailed content and methods of Developing a Forest Management Program (Number 322-47/13-5)) is attached as a separate PDF document to this report, available in the supporting CD material.
- The original MS Word document containing proposed adaptations in track-change mode is provided to the MARD and the Forest Administration.

13 APPENDIX 6: MANUAL FOR FOREST MANAGEMENT PLANNING – REVISED

- The revised manual is attached as a separate WORD document to this report, available in the supporting CD material.
- The original MS Word document containing proposed adaptations in track-change mode is provided to the MARD and the Forest Administration.

14 APPENDIX 7. OVERVIEW OF ACCOMPLISHED ACTIVITIES

	Date and place	Activity	Participants	Goal
1.	27.-28.11.2013 Podgorica	Kick-off meeting	All partners	Personal introduction, presentation of project goals, planning
2.	March – June, 2014	Data compilation, development of the methodology	All partners	Compilation of the necessary forest, climate, soil and DEM / LIDAR data
3.	10.04.2014 Podgorica Chamber of commerce	Official presentation of the project	Project partners, German ambassador in Montenegro	Public presentation of the project in front of Ministries representatives, politicians, media and the Montenegrin public
4.	28.-29.4.2014 Podgorica	Internal Workshop	German partners	Preparation of the forthcoming Methodology workshop in Montenegro
5.	11.-15.5.2014 Podgorica, Management Units	Methodenworkshop	All partners	Workshop for finalizing the methodology and training of the doctoral candidates
6.	27.-31.7.2014 Management Units	Supervision of field work	Doctoral candidates, Soil- and Vegetation experts from Germany and Montenegro	Practicing of field work, start of field work phase
7.	16. 01. – 15 03. 2015 Freiburg	Supervision, training of the doctoral candidates	Doctoral candidates, German partners	Introduction to „R“ Introduction to water supply, water balance model Development of doctoral concepts Practising English language skills
8.	23.-24.03.2015, Podgorica	Workshop	All partners	Preparation of the next field phase
9.	25.01.-25.03. 2016, Freiburg	Supervision	Doctoral candidates, German partners	Data analysis and results
10.	12.-13.04.2016, Podgorica	Final workshop	All partners	Presentation of project results and discussion of follow-up possibilities

15 APPENDIX 8. FOTO-MATERIAL FROM PROJECT ACTIVITIES

This appendix is found in the supporting CD material.

16 APPENDIX 9. PUBLIC PRESENTATION OF THE PROJECT

Press Handout for the official public presentation of the project on 10.04.2015:

Saopštenje za javnost

Prezentacija crnogorsko – srpsko – njemačkog istraživačkog projekta "Poboljšanje baze šumsko-ekoloških podataka za održivo gazdovanje šumama i zaštitu šuma u Crnoj Gori"

U četvrtak, 10. aprila 2014. godine u 17.00 u Privrednoj komori Crne Gore tim istraživača i stručnjaka iz oblasti šumarstva i ekologije iz Crne Gore, Srbije i Njemačke predstavio je nedavno započeti projekat "Poboljšanje baze šumsko-ekoloških podataka za održivo gazdovanje šumama i zaštitu šuma u Crnoj Gori", zajedno sa nadležnim ministarstvima – Ministarstvom poljoprivrede i ruralnog razvoja i Ministarstvom održivog razvoja i turizma. Nekoliko crnogorskih institucija iz sektora šumarstva i zaštite životne sredine: Uprava za šume, Agencija za zaštitu životne sredine, Zavod za hidrometeorologiju i seizmologiju i Uprava za nekretnine Crne Gore će zajedno sa istraživačkim timom raditi na projektu u narednih 2 godine.

Ideja o organizovanju ovog događaja je bila da se visokim zvaničnicima iz resornih ministarstava i javnosti predstavi koncept projekta. Pomenutoj prezetaciji prisustvovao je ambasador Savezne Republike Njemačke, Pius Fischer, pomoćnik ministra za sektor šumarstva, Adem Fetić i predstavnici projektnih partnera.

Da bi bolje odgovorili na izazove klimatskih promjena, zaštitu biodiverziteta i ispunili zahtjeve EU koje se tiču Nature 2000, crnogorski sektor šumarstva treba da obezbjedi osnovne ekološke informacije koje sada nedostaju. To je važna prekretnica za postizanje ciljeva i načela multifunkcionalnog, održivog i prirodi bliskog gazdovanja šumama koje je definisano u Nacionalnoj šumarski politici (http://www.fodemo.com/home2). Trenutno, upravljanju šumama nedostaju sljedeće informacije kao osnova za planiranje i podršku u odlučivanju: informacije o šumskim staništima, o takozvanim "potencijalnim prirodnim šumskim vegetacijama" - što podrazumijeva vegetaciju koju bi priroda formirala bez ljudskog uticaja, kao i aktuelno poznavanje rijetkih i ugroženih vrsta, biotopa i staništa koje treba uzeti u obzir pri gazdovanju šumama i sprovođenju radova u šumarstvu.

Projekat FODEMO "Razvoj šumarstva u Crnoj Gori" koji je finansirala Vlada Velikog Vojvodstva Luksemburga u periodu od 2003 -2013. godine, (www.fodemo.com) je uspostavio informacioni sistem koji opisuje strukture šumskih (gazdinskih jedinica) baziran na dobrim šumskim podacima i pripremio prilično kompletnu sliku o šumama i šumskim resursima Crne Gore kroz izradu prve Nacionalne inventure šuma. Međutim, osnovne ekološke informacije sa podacima o šumskim staništima, potencijalnim prirodnim šumskim zajednicama i aspektima zaštite prirode još uvek nedostaju.
Iz tog razloga, glavni cilj projekta je da se uvede novi, inovativni metodološki pristup za poboljšanje ekološke baze podataka za održivo gazdovanje šumama i očuvanje šuma, koji bi se testirao u nekoliko pilot područja Crne Gore. Projekat će izraditi ovaj metodološki okvir u narednih 2 godine.

Takođe, projekat će pomoći da se razviju koncepti za brzo prikupljanje i regionalizaciju ključnih osnovnih ekoloških informacija za održivo gazdovanje prirodnim šumama u Crnoj Gori, što će se postići kroz inovativne metode i IT rješenja, specijalno razvijenih da bi obezbjedili ove podatke u budućnosti.

Kao sljedeći korak, oba ministarstva će se fokusirati na implementaciju metodologije za ukupnu površinu pod šumom i šumskih zemljištem koja iznosi skoro 700.000 ha (oko 70% teritorije Crne Gore) počevši od 2015. godine – što bi eventualno moglo uraditi uz podršku EU-IPA fondova.

Doprinos ovog projekta za sektore zaštite prirode i šumarstva u Crnoj Gori biće značajan:

- Poboljšanje osnova za donošenje odluka za ciljno održivo i prirodi blisko gazdovanje šumama;
- Nova, fleksibilna metoda kartiranja šumskih staništa, prilagođena dinamičnim promjenama stanišnih faktora, sa dodatnim fokusom na potencijalne prirodne šumske zajednice će se primjeniti u praksi u sektoru šumarstva Crne Gore;

- Provjerene informacije o zaštiti prirode biće dostupne šumarskim službama i omogućiće po prvi put brz pregled nalaza i razmatranje u planiranju gazdovanja šumama. Povećaće se i svijest o pitanjima očuvanja šuma u administraciji u šumarstvu;
- Projekat će doprineti redovnu razmjenu informacija između šumarstva, zaštite prirode i sektora lovstva.

Kooperativni pristup u ovom projektu između Ministarstva poljoprivrede i ruralnog razvoja i Ministarstva održivog razvoja i turizma je izuzetna prilika da se usklade metode i podaci i sarađuje sa nekoliko drugih projekata koji su u fazi razvoja u ovim ministarstvima. Naime, postoji mnogo sinergije sa predstojećim projektima koji će se finansirati kroz EU-IPA podršku: projekat"Jačanje sistema zaštite životne sredine u Crnoj Gori" i projekat "Uspostavljanje i razvoj informacionog sistema zaštite životne sredine". Štaviše, projekat podržava i aktivnosti "Fokalne tačke za klimatske promjene".

Ovaj crnogorsko - srpsko – njemački istraživački projekat je finansiran od strane "Njemačke fondacije za zaštitu životne sredine" – DBU (http://www.dbu.de) sa 125,000 €.