Bachelor Thesis in Disaster Risk Management

Remote perspective over the ecosystems of Pirin and Rila mountains

Analysis on past, present and future ecosystem condition through the application of satellite remote sensing and risk assessment techniques

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ABSTRACT

The study addresses the need for better understanding of how mountain ecosystems in Bulgaria are affected by anthropogenic impact by introducing quantification methods of environmental variables. The research methods used, demonstrate the applicability of satellite remote sensing and modern geospatial approaches to fill data gaps and address the lack of large scale assessments on the condition of ecosystems. Two case studies are used as examples of unregulated anthropogenic activities in protected natural areas, the expansion of Bansko Ski Resort and the intensified hiking tourism in the area of the Seven Rila Lakes. The research has comparative nature as the two case studies have similarities and differences. The main differences are the episodic disturbance on ecosystems by ski resorts in comparison to continuous and cumulative effects on catchment areas and lake ecosystems from unregulated tourism. On the other hand, similarities of the two examples can be found in governance practices of protected areas, specifically the difficulties for harmonization and implementation of European environmental directives such as NATURA 2000. Additionally, both natural parks suffer substantial delays for the approval of new management plans caused by gaps in the policy making process. Main point of concern is the lack of quantifiable data on anthropogenic impact and ecosystem condition which prevents the development and implementation of relevant and strategic environmental policies.

The study presents alternative methods for the quantification of environmental variables. The methods are based on the spatial capacity of ecosystem to generate regulation services. The analyzed ecosystem services are erosion regulation and water purification of grasslands, climate regulation and flood protection of forests as well as cultural ecosystem services like natural and national heritage of national parks. The performed geospatial assessments are done in conjunction with social and environmental analyses describing governance practices and management of protected areas. The combination of various disciplines is able to identify current and future risks. The research findings show inability for optimal recovery of grasslands on the territory of the ski routes in Bansko as nearly half of the grassland territory has suboptimal vegetation density and is prone to erosion. The ability for flood protection has been decreased insignificantly to present date, however the new zoning regulations pose a treath for deforestation in nearly half of the forested catchment area above the town of Bansko. In the area of the Seven Rila Lakes, footpaths have six times larger spatial extent in comparison to footpaths elsewhere in the national park. The effects of intensively used footpaths have been investigated showing increased pressure on lake ecology through sedimentation and flow of pollutants. Results show applicability for the integration of geospatial methods and the concept of ecosystem services in ecological assessments, specifically related to the environmental impacts from investment projects in protected areas. The presented alternative approaches can complement the currently used monitoring practices on national level that lack the capacity for cost effective and continuous environmental data availability.

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ABBREVIATIONS

EIA - Environmental Impact Assessment
EA – Ecological Assessment
EPA – Environmental Protection Act
BDA – Biological Diversity Act
PAA- Protected Areas Act
SPA- Spatial Planning Act
EC – European Commission
MOEW – Ministry of Environment and Waters
SAC- Supreme Administrative Court
EFA- Executive Forest Agency
BNAO - Bulgarian National Auditors Office
NGO- Non Government Organisation
FAO – Food and Agriculture Organisation of United Nations
TAP – Territorial Arrangement Plan
NP – National Park
GIS – Geographical Information Systems
RS – Remote Sensing
DEM- Digital Elevation Model
PIHE – Pinus Heldreichii
PIPE – Pinus Peuce
NDVI- Normalized Difference Vegetation Index
NDRE- Normalized Difference Red Edge Index
ESDAC – European Soil Data Center
WWF – World Wildlife Fund

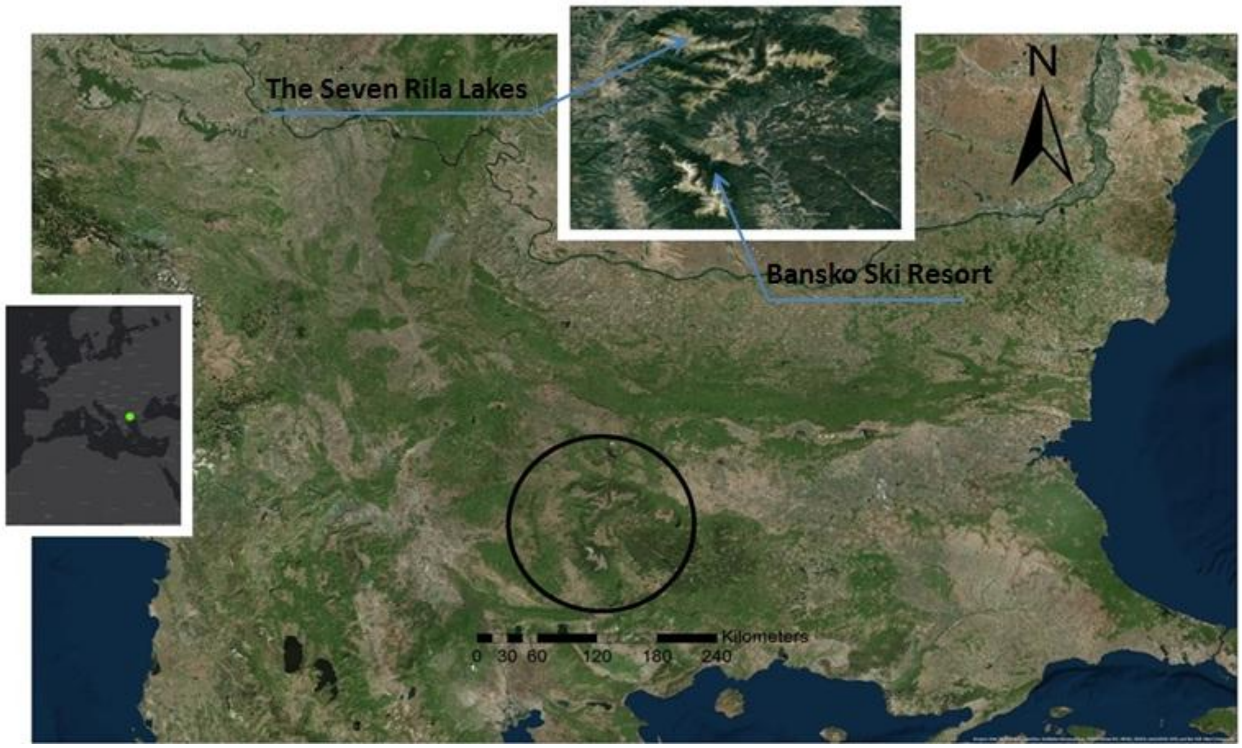
CHAPTER 1: BACKGROUND INFORMATION

Rila and Pirin mountains are one of the cornerstones of environmental diversity in the Balkan Peninsula. National parks in Bulgaria are protected areas governed by management plans. The proposed projects for new management plans induced heated debates between stakeholders on national and international level regarding the legality of future and previous investment proposals for infrastructural expansion on the territory of the protected areas. Two notable cases for intensified use of ecosystem services are the development of Bansko Ski Resort in Pirin and the constructed tourist chairlift near the Seven Rila Lakes. These projects can result in significant erosion processes, land degradation and flash floods, which occurred in the past and are expected to intensify in the future due to climate change effects and continuous anthropogenic pressure. The main motives against infrastructural development are the induced negative effects on ecosystems with high ecological value. The chosen ecosystems for the assessment include two endemic coniferous forests of Pinus Heldreichii and Pinus Peuce, five habitats of alpine and sub alpine grasslands and heaths and seven oligotrophic to mesotrophic lakes. Two additional assessments investigate the spatial extent of footpath erosion in relation to eutrophication and pollution in the Seven Rila Lakes area and the effects of graded ski route construction in Bansko Ski Resort on surrounding forests through the implementation of vegetation time series from spaceborne data.

The biodiversity and environmental status of Rila and Pirin are not local but national and international priorities. Considerable part of the territory of both mountains is protected national parks with several natural reserves. The whole territory of the national parks falls within NATURA 2000 framework. Pirin National Park was declared a UNESCO World Heritage Site in 1983 while the natural reserves in Rila National Park are included in World Network of Biosphere Reserves. According to Protected Areas Act (PAA) all national parks and protected areas in Bulgaria are governed through management plans being revised on 10 year basis. The document consists of policies on territorial coverage, types of territories, administrative and governance structures, project implementation, biotic and abiotic characteristics along with socio-economic, cultural and development analysis. A new management plan is being formulated for several years through research, assessments, public discussions and debates. The stakeholders in this process are the regional and central government bodies, local municipalities, the Bulgarian tourist union, local tourist unions, mountain emergency service, ecologists and experts related to ecotourism, ski sports, construction companies and others. Furthermore, the process requires public participation in accordance to the Aarhus convention. Preliminary research findings, reports, drafts of the new policies are public information. The approval and implementation of a new management plan will outline the environmental policies and regulations for the next period and are not subject to changes, meaning that once decisions are official, there is little room to maneuver in the next decade.

FIGURE 1: LOCATION OF RILA AND PIRIN MOUNTAINS

RILA AND PIRIN ARE NEIGBHBOURING MOUNTAIN RANGES LOCATED IN THE BALKAN PENINSULA IN SOUTHEAST EUROPE. RILA IS SITUATED NORTH/NORTH-EAST FROM PIRIN. FROM GEOLOGICAL PERSPECTIVE BOTH MOUNTAINS ARE HORST FORMATIONS, RILA HAS CRESCENT SHAPE WITH CONCENTRIC AND RADIAL FAULT SYSTEMS WHILE PIRIN FORMS AN ANTICLINE FOLD BETWEEN THE VALLEYS OF STRUMA AND MESTA RIVERS.



Source: ArcGIS/Landsat/Copernicus

The rich variety and abunance of plant species are making Rila and Pirin one of the Bulgaria main biodiversity treasure chests (WWF 2017). Rila and Pirin mountains are part of the the Rilo-Rhodope massif, located in the southwest part of Bulgaria. Rila (2629 square km) and Pirin (1210 square km) are two of the highest mountains in the Balkan Peninsula with their highest peaks Musala (2925) and Vihren (2914). Due to the considerable height and central location, the massif is considered to be main orographic factor controlling the climate in the region. The average altitude in Rila is 1487 m and in Pirin is 1033m. During the Pleistocene glaciation, snow has been present as from 2100 m elevation and the glaciers above reshaped the higher slopes with an alpine character. The old relief has been replaced by glacial forms such as circuses, moraine hills and deep trough valleys. Glacial lakes were situated at the bottom of the circuses and their rivers indented the slopes below creating terraces at different height, age and shape. (Slaveykov, Zlatunova 2009)

The great difference in altitude and expositions of the hills leads to transformation of air masses and elevation zoning of the climate. Mountain climate is present from 1000 m elevation on the northern slopes and at 1500 m on the southern slopes. With an increasing altitude all climate variables are changing. From the foot of the mountain towards the summit, the amount of rainfall increases and temperature decreases. Snow cover is present from 4 to 8 months. (Slaveykov, Zlatunova, 2009).

Flora is highly susceptible to change in altitude and elevation zones are easily distinguished. Lower areas are covered by deciduous forests represented by oak, hornbeam, ash and above them beech forests. The coniferous forests are situated at the next elevation zone represented by spruce, fir and pine trees. Their positions varies with slope orientation, pine trees favor southern slopes, while spruce favor northern orientation. Due to intensive deforestation and reforestation, the species composition is changing rapidly. Homogenous and heterogeneous forests are present and they form the upper lair of forest cover. These forests reach altitude at around 2000-2100 meters. The next elevation zone is a home to a large population of pinus mugo, which is often referred to as creeping and dwarf mountain pine. Reaching the highest areas in the mountain, alpine grasslands are presented around the rock formations. (Slaveykov, Zlatunova, 2009)

CHAPTER 2: PROBLEM DEFINITION

The interest of different stakeholders in Rila and Pirin National Parks is solely based on their different ecosystem services. Ecosystem services are “the benefits that people derive from ecosystems”. Ecosystems can provide supporting services like nutrient cycling and primary production. Provisioning services are the consumables obtained from ecosystems like food, fresh water or timber. Regulating services relate to regulation of the environmental components like climate, water and landscape. Cultural services describe the use of ecosystems for recreation and leisure but also for spiritual, cultural and aesthetic values of the environment. These services are closely related to the biological diversity of ecosystems. A loss of biodiversity may have significant results on the condition of an ecosystem (MEA, 2005). One of the main factors for the ecosystem condition in Rila and Pirin mountains is the anthropogenic impact. While the main problems in the past few decades were illegal logging and poaching, a more complicated topic arises from the demand for ski resorts and recreational activities. Two cases for intensified use of these cultural ecosystem services are the development of Bansko Ski resort in Pirin and the constructed tourist chairlift near the Seven Rila Lakes. Both of the cases relate to infrastructural expansion in the territory of the national parks. These activities can result or have resulted in significant erosion processes, land degradation and flash floods, which occurred in the past and are expected to intensify in the future due to climate change effects and continuous anthropogenic pressure.

The effects from Bansko ski resort expansion and the anthropogenic pressure in the area of the Seven Rila Lakes are one of the most discussed topics in the new governance plans. WWF (2018) reports that Pirin ecosystems are threatened by lack of strategic infrastructural planning of Bansko Ski Resort and expansion of infrastructure was solely focused on short term economic benefits. Additionally, the implemented approach to continuously expand the lift and slope capacity has been seen as a wrong strategic step which could further deepen the problem with the cultural identity of the region as it is is not suitable for mass tourism (Shabanski, 2013). In the area of the Seven Rila Lakes, the construction and continuous use of the newly constructed chairlift in 2007 has led to tenfold increase in visitors during the summer months. The ecological condition of the lake waters has gradually worsen, while there has been absence of measures from park authorities to cope with the negative impacts on the environment (Petkanchin, 2016). The European commission has been unable to intervene as the formal start of the construction precedes the inclusion of Bulgaria in the European Union. The issue with water quality of the lakes is worsening by the induced global climate change from anthropogenic activities (Nojarov, 2017). Changes in environmental conditions, specifically rainfall and temperature are leading to increased rate of rock weathering, atmospheric deposition of pollutants, longer active vegetation period and more frequent droughts.

The development of new environmental policies is an opportunity for mitigation and effective governance of the anthropogenic impact. In the same way, new policies can serve to provide a niche for further expansion of infrastructural development within the territory of the national park, in case there is an interest motivated by economic and social values of ecosystem services. Research comprising past, present and future analysis on environmental impact of infrastructural projects can regulate and define the extent of the impact on ecosystems. However, the national monitoring system is still solely based on data sampling through classical field studies conducted by highly trained experts. This approach has very high resource cost in terms of time, personnel and finances on the background of mainly project based funding. The assessment and monitoring of ecosystem condition in Rila and Pirin mountains are bound to budget costs and limited by data sampling techniques. Reliable results to detect changes are achieved through multiple assessments on early basis. The limitations of these current methods lead to data gaps and lack of information for large scale assessments on the state of ecosystems. Respectively, the lack of reliable scientific information affects the decision making for investment projects, since their influence on ecosystems is not well understood. Therefore, it is not clear how further expansions will affect the state ecosystems and whether that will increase the risk for land degradation, loss of biodiversity and flash floods.

CHAPTER 3: RESEARCH OBJECTIVE AND RESEARCH QUESTIONS

Research Objective

The objective of the research is to present findings which will demonstrate to policy and decision makers that remote sensing tools (in this case the application of satellite remote sensing and risk assessment techniques) are useful to fill in data gaps and lack of information for large scale assessments on the state of ecosystems, therewith enabling them to get insights in how further expansions will affect the ecosystems and whether that will increase the risk for land degradation, loss of biodiversity and flash floods.

The objectives are achieved through assessment on the past and current governance and policy making practices compared to the past and current condition of impacted ecosystems in Rila and Pirin National Parks and develop a number of future scenarios based on ecosystem analysis and anthropogenic influences.

Main Research Question

How are ecosystems in Rila and Pirin National Parks influenced by anthropogenic activities and infrastructural expansion?

Sub Research Questions

SRQ 1a: Are there similarities or differences in anthropogenic impact and infrastructural development between the two national parks?

SRQ 1b: What are the reasons for these similarities or differences?

SRQ2: What are the effects from the change of policies in the management plans?

SRQ3: What recognizable trends from past to current ecosystem conditions can be found, based on the empirical analysis, which can serve as foundation for possible future scenarios?

SRQ 4: What are the future risks from the effects of policies, anthropogenic activities and infrastructural expansion?

CHAPTER 4: LITERATURE REVIEW

4.1 Research Methods Literature

Satellite-Based Vegetation Indices

Satellite-based vegetation indices were developed in the 70s for landscape monitoring and have become indispensable tool for a wide range of applications such as natural resource monitoring, agriculture, biodiversity, condition of ecosystems, carbon and water management and others. The development of variety of vegetation indices started with the NDVI (normalized difference vegetation index). The earliest reported use of NDVI is in the "Great Plains" study in 1973 by Rouse et al. Soon after the first application of NDVI, Compton Tucker of NASA's Goddard Space Flight Center produced series of scientific journals describing the uses of the NDVI. During 1979, Tucker also wrote about the possibilities for linear combinations, which opened the door for significant number of new indices in the next few decades. Each index has specific application and it has its advantages and disadvantages, which requires careful consideration and assessment of its suitability. In recent decades several studies found out that the Normalized Difference Red –Edge Index (NDRE) proposed by Barnes (2000) is the most robust method for detection of chlorophyll concentration in plants and early stress detection using data from the RapidEye satellite constellation. (Eitel et al. 2011, Massetti et al. 2016). While NDVI uses the ratio between the infrared spectrum and the optical spectrum, NDRE uses the red-edge region which is characterized by the area with steep increase from absorption of radiation to its reflection which is strongly correlated with chlorophyll content (Dawson, Curran 1998). This method can prove useful to detect ecosystem stress based on photosynthetic activity during the peak of the active vegetation period in the mountains in July. However, the method measures reflected radiation which is influenced by a number of different biophysical properties of plants, thus requires additional validation campaigns and in-situ data.

Ecosystem Analysis

In the late 1960s the increasing concerns about environmental degradation and recognition of the societal (economic) benefits provided by the natural environment led to definition of ecosystem services and ecosystem functions as two key concepts. There are several classification for ecosystem components, the Uk National Ecosystem Assessment, The Economics of Ecosystems and Biodiversity Project(TEEB) and the most well recognized one is the Millennium Ecosystem Assessment(MA). The MA was carried out between 2001 and 2005 with the aim to assess ecosystem change and relate it to human well-being. The outcome of this project was to establish scientific basis for actions needed to enhance conservation and sustainable use of ecosystems. The MA report presents a guideline for environmental assessment, which is suitable for various applications since the report is following the connection between ecosystem related variables and human well-being, which involves political, economic, social and cultural aspects.

A study by Burkard et al. (2009) presents an approach to quantify ecosystem services through landscape capacity approach. The approach considers various landscapes to differ in their capacity to generate ecosystem services based on changes in land use caused by human activities or natural processes. The generation capacity is structured in 6 classes ranging from 0 to 5, with 0 accounting for no relevant capacity and 1 to 5 accounting for low to very high relevant capacity. The study presents research findings that can serve as default values for landscape capacities of mountain ecosystems.

Risk and Stakeholder Assessments

Conducting risk assessments is a key objective, part of disaster resilience measures in the Hyogo Framework for Actions (2005), with aim for greater knowledge for disaster prevention and possibilities for enhanced resilience to hazards. The Resilience project (2009) is a three year study focus on developing risk reduction strategies through a combination with climate change adaption and poverty reduction strategies. An outcome of this study is the Reaching Resilience Handbook (Heijmans 2017), which provides a guideline for risk assessment techniques with focus on people's capacities and vulnerabilities. The handbook provides step by step actions for detailed assessment on disaster risk management through assessing peoples risk landscape, governance context, power relations and institutions. The framework can be adapted to address risks derived from governance practices of environmental resources through analysis on involved parties in the environmental policy making process. The framework accounts for formal and informal institutions, hence the linkage between environmental policies and regulations and social norms and traditions of the Bulgarian population with respect to mountain resources. Additionally, the framework accounts for the identification of disconnects between risks and policies which can arise from the lack of quantifiable scientific data on anthropogenic impact and environmental components.

4.2 Scientific research in the area of the Seven Rila Lakes

The morphological, chemical and biological characteristics of the lake ecosystems in Rila have been studied throughout the last century. The impacts from tourism on lake and grassland ecosystems in the area of the Seven Rila Lakes have been recorded during the past 30 years. The first extensive quantitative research on lake ecology in the area has been carried out between 1993 and 1995 (Stoyanova et al., Boteva et al. 1996). The ecological state of the Rila Lakes has been recorded through several studies in the past decades focusing on seasonal changes of biochemistry of lakes and biochemical properties of phytoplankton, zooplankton and bacterioplankton communities in relation to environmental changes and anthropogenic impact (Nikolova et al. 2012, Ognjanova-Rumenova et al. 2019, Ilieva et al. 2015, Ognjanova-Rumenova etl. al. 2009, Kalchev et al. 2004). Based on previous conclusions, a tendency for increasing air temperatures result in degenerative processes like eutrophication and increased sedimentation in the catchment area, which is further stimulated by intensive anthropogenic impact. The first evidence for assessment of ecosystem reveals changes in land use between 1988 and 2010 (Nedkov, Nikolova, Gachev 2014). The study uses assessment matrix to classify and rank land cover classes and their services by Burkhard et al. (2009). The results reveal that mountain ecosystems in Rila provide predominately regulating and cultural services and less provisioning services due to protected areas regulations. The study uses spatial approach to quantify and compare change of the capacity of the land use classes to generate ecosystem services. In 2015, the pilot monitoring assessing the tourist flow in the area has been implemented and reported by Sustainable Mountains. The initiative assessed the number of tourist using the chairlift and the amount of tourist every hour on key locations around the lakes.

4.3 Previous scientific research in the area of Bansko Ski Resort

Bansko ski resort is located in predominantly forest ecosystems. Forests in Pirin have been studied as of the end of 19th century and a pioneer researcher is Kostantin Baikushev (1895), constructed the first forest map in the country. His works still serve as identification and construction of historical events and the impacts of disturbance factors such as logging and natural hazards like forest fires, avalanches and winthrows. The old-growth coniferous forests of Pinus Heldreichii (PIHE) and Pinus Peuce (PIPE) species have been a major subject of interest in recent decades for dendrochronological studies due to their ecological value, significant age and importance as endemic species to evaluate and construct their growth response to change in climate and extreme environmental conditions (Panayotov 2006, Rangelova, Panayotov, Yurukov 2007, Panayotov et al. 2008, Panayotov 2013, Panayotov et al. 2016).

The effects of the ski resort on the surrounding environment have been poorly documented and their long term effects are not well understood. The main source of data for recent ecosystem condition has been part of the new project proposal for the management plan (2013-2023) that has been heavily criticized by non-governmental organizations (NGOs) for lack of Ecological Assessment (EA) of the new regulations. There is lack of evidence for scientific research and quantitative data on anthropogenic impact on forest ecosystems and their services.

The area of Bansko Ski resort has attracted various studies investigating the legality of the infrastructural expansion and its impact on economic and social spheres. In early nineties the main conflict for tourism development arises from ideological commitment for development of international tourism base. During these years the effects from the centralized system are still present, posing a limitation and constrains for the development of tourism operations (Pearlman 1990). This research indicates the lack of experience of the country to manage international interest in tourism which increased in recent decades. In a published article from the Bulgarian Forest Institue, Alexandrov (2005) describes the cumulative effects on forests from clear cut logging and erosion on the graded ski routes, making the bordering forest line sensitive to natural hazards like windthrows and intensive snow fall. The article mentions the risk for floods posing dangers for infrastructural damage and human life downstream. The approach for the construction and development of the resort both characterized by ski and accommodation infrastructure in the town of Bansko has been criticized for its poorly developed and executed strategy to protect natural resources and gain economic benefits for the region (Grunewald, Scheithauer 2008, Shabanski 2013). Both protection of natural resources and economic benefits are unsustainable long term. The region is not suitable for large scale ski resort, while the concessionaire and the local municipality developed the region for mass tourism practices based on affordable prizes for accommodation and ski services. A WWF report (2018) focuses on the the risks from the new regulations in the management plans. The proposed changes pose a further increase of territorial coverage which has been seen as unnecessary strategy to develop the resort and is seen as illegal with respect to the provisions of national and European environmental legislation.

CHAPTER 5: METHODOLOGY

5.1 Desk Study

The desk study comprised a review of practices and methods in each of the used disciplines in the study on national and global scale. A review of modern remote sensing and GIS techniques and approaches was done to evaluate the applicability and robustness of space-borne data for the investigation of ecosystem condition and quantification of spatial extent of anthropogenic impact. The study on ecosystem analysis focused on review of methods for quantification of ecosystem services and their applicability and integration with empirical geospatial approaches. The stakeholder assessment required a review on official correspondences between NGOs and governmental bodies, statements and reports for the policy making process, court decision statements and reports.

5.2 DPSIR, Stakeholder Analysis and Ecosystem analysis

The methods to assess and quantify anthropogenic impact comprise a multi-disciplinary approach to characterize the linkages between the political, social and environmental spheres.
The DPSIR (Drivers, Pressures, State, Impact, Response) framework has been developed by the European Environment Agency (EEA) as a strategy for environmental assessments, identification of indicators for change and effects of policies. The chosen framework is the first step to describe how the anthropogenic impact activities (drivers) lead to pressures on ecosystems, affecting the state of their ecological components, the impact from pressures and respectively the change in the state of the ecological components and the responses by policy makers to manage these drivers, pressures, state and impact.

The second step is the stakeholder analysis, which comprises the drivers, pressures and response components of the DPSIR framework. Involved parties in relation to the development of the chairlift near the Seven Rila Lakes and Bansko ski resort are identified through historical review of the events before and after their establishment. The review focuses on mandatory procedures for Environmental Impact Assessment (EIA) and approval of investment projects on the territory of national parks. The review tracks historical development of the projects and involvement of stakeholders during the environmental policy making process of the new management plans. Based on the historical review, formal (environmental policies) and informal institutions (public participation) and their role in strategies for the management of environmental resources is identified. Based on these findings, disconnects between risks and policies can be identified, with focus on old and new management plans of the national parks as well as other relevant national and international policy changes during the assessment period. The last component of the stakeholder analysis is to identify obstacles and opportunities for effective governance of natural park resources.

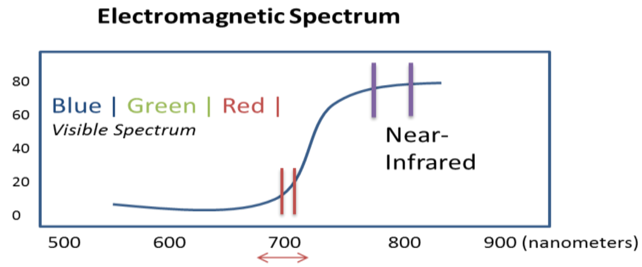
The third step is ecosystem analysis. The chosen methodology is based on the Millenial Ecosystem Assessment (MEA 2005). This step focuses on the environmental aspects, thus describing the effects from drivers and pressures on the state of the environment and the resulting impacts on ecosystem condition. Additionally, environmental pressures and natural hazards are identified and analyzed in order to disseminate and understand the impacts from both anthropogenic and environmentally induced pressures. In order to address the problem with the absence of numerical data, a spatial approach is used through the application of satellite remote sensing data in conjunction with GIS methods. A spatial boundary for both cases is determined by the catchment area within the borders of the national parks and the extent of the affected area. Within the spatial boundary, ecosystems are identified with ecological characteristics and response to environmental factors like climate and natural hazards. The spatial extent of the ecosystems is obtained with data from the national park agencies. Regulation and cultural ecosystem services are identified as significantly influenced by anthropogenic impact. This study uses the assessment matrix proposed by Burkhard et al. (2009) in order to group and estimate the capacity of the generated ecosystem services. A combination of default values and values from other studies are used to assign values for ecosystem service capacity. The capacity of the regulating services is then calculated through estimation of the spatial extent of affected territories.

5.4 Remote sensing time series data collection and processing

Data Collection

To assess temporal and spatial differences of forest ecosystem condition of PIHE and PIPE, a satellite remote sensing approach is used. The Normalized Difference Red Edge Index (Barnes 2000) is calculated from spaceborne sensor data. The index represents the ratio between the infrared and red-edge region of the electromagnetic spectrum (Figure 2). Plants have specific response in the utilization of solar radiation, characterized by high absorption in the visible part of the spectrum and high reflection in the near-infrared region illustrated with a blue line in the figure. A high difference between absorption and reflection will describe higher photosyntethic activity and chlorophyll content. The two satellites with applicable spatial, spectral and temporal resolution are Rapid Eye and Sentinel 2.

FIGURE 2 NORMALIZED RED EDGE INDEX



$$\text{NDRE}=\frac{NIR-RED\ EDGE}{NIR+RED\ EDGE}$$

Source: Author

TABLE 1 SPACEBORNE DATA

Sensor	**Spatial Resolution** (meters)	**Spectral Resolution** (nanometers)	**Temporal Resolution** (operational period and revisit time)
RapidEye	5 meters	Red Edge Band: 690 -730 nm Infrared Band: 760-850 nm	Operational between February 2009 and April 2020 with 5.5 days revisit time
Sentinel 2	10 and 20 meters	Red Edge Band: 698 – 713 nm Infrared Band: 785-899	Operational since June 2015 Revisit time 2-3 days

Based on data availability, a 5 year assessment period has been chosen between 2015 and 2019. The time series consist of 1 annual acquisition(Table 2). The month of July has been chosen for annual assessment based on several factors. The period marks the peak of the vegetation cycle with highest forest canopy density, reducing reflected radiation from forest understory. The chosen period preceedes the dryer conditions during August and their effects on tree physiological processes. The period is more suitable for precise remote sensing observation based on its topography and sun angle effects, hence sun elevation has a greater angle over the earth surface.

TABLE 2 ACQUISITION DATES

Sensor	Acquisition date
Rapid Eye	2015 07 16
Sentinel 2	2016 07 13
Sentinel 2, RapidEye	2017 07 13
Rapid Eye	2018 07 01
Sentinel 2	2019 07 18

Data Processing

The obtained images have been corrected for atmospheric and topographic effects, reducing the effects of atmospheric scattering of solar radiation and limiting the impact of terrain features on NDRE index saturation and sensitivity. Areas with clouds have been excluded from assessment. After initial preprocessing, the images have been geographically corrected to minimize spatial deviations to less than 1 pixel between each acquisition. The two images on July 13 2017 have been composited to obtain the maximum value and are further used by sensor comparison. The histograms of the selected satellite bands have been matched to provide results on a comparable scale followed by a calculation of the NDRE index. The calculations have been performed in Erdas Imagine, SNAP, QGIS and ArcGIS software.

The analysis of the time series is separated in two steps. The first step involves the use of ground reference points for tree age, which is needed to quantify the differences between forest canopy density of young and old forests. The sample sites size is between 0.1 ha and 0.5 ha depending on terrain features. Based on the reference points and the results from the first assessment, a second set of sample sites is determined, consisting of young forests only. The selected sample sites are separated in two classes. The selected PIHE sites are assessed for the effects near road infrastructure. The PIPE sites are assessed for the effects of ski routes and infrastructure. The second class for each of these tree species involves sample sites which are not affected by anthropogenic activites. The size of the samples vary between 0.4 ha and 0.8 ha depending on terrain features and proximity to infrastructure or other habitats.

The data from the sample site polygons represent numerical values of each pixel for every annual assessment, thus one pixel represents 5 different values for the given time series. The pixel values are exported in SPSS software. Every annual assessment for the sample sites has been assessed and extreme or errouneous results have been excluded in order to use normally distributed data. The method proposed by Eitel (2011) is used to indicate ecosystem stress using the 25 and 75 percentile of the annual statistical population of sampled data. The data is graphically represented by boxplots in order to visualize and compare the 25 and 75 percentiles of sample sites.

5.5 Fieldwork

The fieldwork consisted of 3 day visits for both the area of the Seven Rila Lakes and Bansko Ski Resort. The campaign investigated landscape and habitat features that are important for the analysis of previous studies and the investigation of current findings. On-site observations of habitats were performed and important locations for the analysis were recorded by control points with Garmin GPS device. In Pirin, the fieldwork comprised visits of the natural reserves Bayuvi Dupki-Dzhindzhiritsa, Yulen natural reserve and the ski routes between 1600 and 2400 meters altitude (Annex 1). The key locations relate to forest and ski route condition on the ski tracks in Bansko ski resort with damaged bordering trees due to loss of soil cover and ongoing erosion processes. The recultivation of grasslands on the ski routes was observed and assessed. The field study in the area of the Seven Rila Lakes comprised an assessment on erosion processes, their location and severity. The extent of footpaths was measured characterized by footpath width of extensively used main and alternative tourist routes as well as footpaths outside the area which are not intensively used by tourists (Annex 2).

The fieldwork involved participation during protests against the new regulations in the management plan of Pirin national park in the beginning of 2018. The participation was meant to investigate the position and views of the general public on the new regulations and the extent of the protests as media reports often differ in their portrayal of the protest activities.

5.6 Scenario Analysis

A concluding step in the analysis is the development of scenarios for the future state of the ecosystems and the development of governance practices.The scenario analysis will build on information provided in other studies and results from the stakeholder and ecosystem analysis. The constructed scenarios will have temporal extent of 10 years with 2020 as base year. Major time steps for the given period will be related to the policy and decision making. The type of scenario will be qualitative form presented as a narrative. The scenarios will aim to test both environmental changes without focusing on policies (baseline type) as well as describing the effects of certain policies and their effect on ecosystem condition (policy scenario).

TABLE 3 SCENARIOS

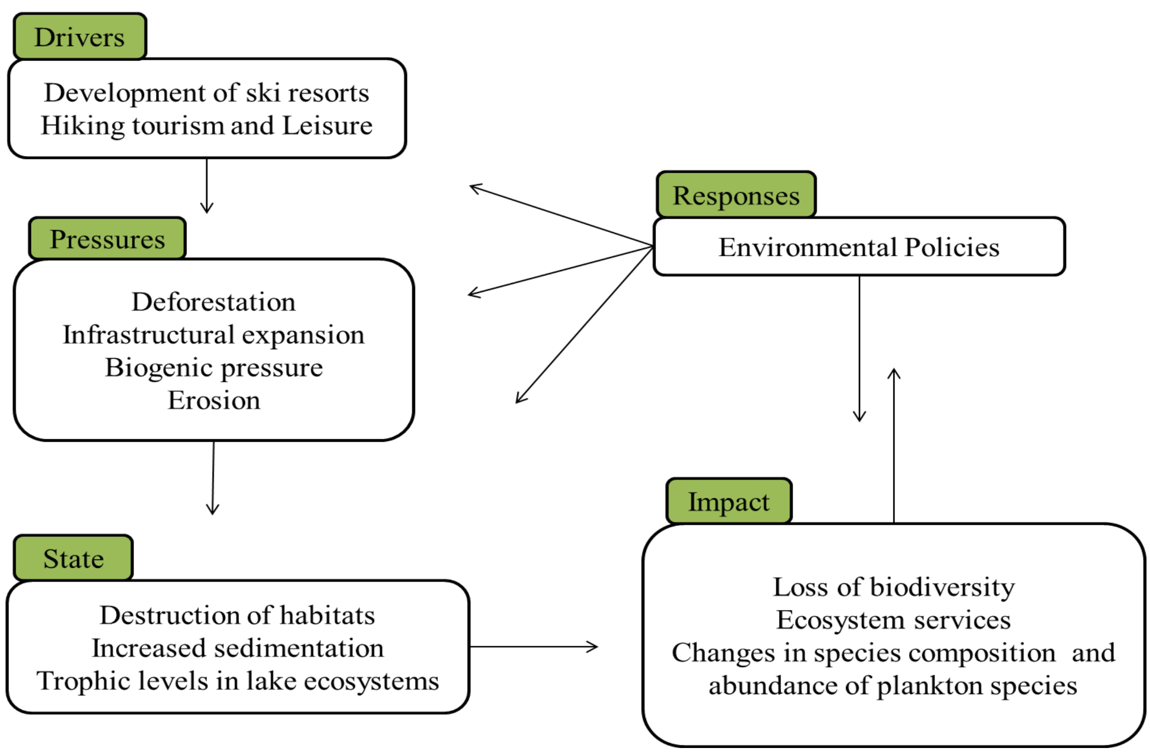
Type of Scenarios (quantitative / qualitative)	Type of Scenarios(exploratory / anticipatory)	Type of Scenario(baseline / policy)	Number of Scenarios
Qualitative form	Exploratory Exploring trends in	Combination of baseline and policy scenarios	1 baseline and 1 policy scenario

	the future by describing the past from the base year on		

CHAPTER 6: DPSIR FRAMEWORK

The initial component of the DPSIR framework are the drivers of environmental change, in this case are the anthropogenic activities. The drivers create anthropogenic pressure on the environment and can result in episodic disturbance like deforestation and infrastructural expansion or in periodic and continuous disturbance like biogenic pressure and erosion. The pressures affect the state of the ecosystems. Deforestation and infrastructural expansion result in destruction of habitats and in combination with erosion, it affects the ability of plants to purify water and stabilize the slopes. In Pirin the deforestation led to loss of endemic species of Pinus Peuce and other coniferous trees, the continuous erosion caused by the graded ski route construction resulted in loss of biodiversity on the territory of the resort due to unsuccessful recultivation efforts. As a result ecosystem services like climate regulation, erosion regulation, flood protection and water purification were significantly reduced. In Rila, the increased sedimentation from tourist footpath erosion affects the trophic levels of lake ecosystems, disrupting their species composition and abundance. The increased production in lake ecosystems can result decrease of lake water quality and quantity due to turbidity and input of pollutants like nitrogen and phosphorus.

FIGURE 3 DPSIR



The response component of DSPIR framework is the linkage between the condition of ecosystems and their governance. The controlling factor for the governance of ecosystems in Rila and Pirin are the national environmental policies, namely the Protected Areas Act (PAA), the Environmental Protection Act (EPA) and the Biological Diversity Act (BDA).
The DPSIR framework is a useful tool to identify linkages between the components and determine qualitative or quantitative indicators for change. These indicators can serve as measurements of the effectiveness of environmental policies or serve as estimations of ex-post anthropogenic impact from investment projects like the chairlift or the ski resort. The selection of indicators is analyzed and quantified if applicable in the stakeholder, ecosystem and scenario analyses.

TABLE 4 DPSIR INDICATORS

DPSIR Components	**The Seven Rila Lakes Indicators**	**Bansko Ski Resort Indicators**
Response, Drivers and Pressures	1. Spatial extent of affected areas 2. Number of daily tourists 3. Changes of management plans regulations for investment projects	1. Spatial extent of affected areas 2. Changes in management plans regulations for investment projection
State and Impact	1. Levels of pollutants in lake waters 2. Species composition and species abundance 3. Ability of ecosystems to generate erosion regulation and water purification	1. Ability of ecosystems to generate flood regulation, climate regulation, erosion regulation and water purification

The Seven Rila Lakes Indicators

Spatial extent of affected areas by erosion is an indicator that can easily be quantified with remote sensing and GIS data, in contrast field approaches require financial resources to conduct continuous assessments for monitoring. The number of daily visitors is an important indicator which is currently accounted for by the national park agency. The number of daily visitors is an important indicator for the level of anthropogenic impact and is being discussed by stakeholders as a possible limitation measure. Changes in regulations of the national parks can be both qualitative and quantitative and they can indicate the extent and possibilities for anthropogenic impact in the future as well as to indicate the effectiveness of previously implemented measures.
Trophic levels of lake waters are an important indicator for both lake and grassland ecosystems in the catchment area. Trophic levels have been recorded sporadically by both state authorities and environmental organisations through project based field campaigns. The effects from change

in the trophic levels can lead to changes in abundance and composition of species in the lakes, which can describe the effects of anthropogenic impact on aquatic biodiversity. Lastly, the condition of grasslands can be measured through remote sensing data, thus providing the ability to measure the capacity to generate ecosystem services that directly influence lake trophic levels and erosion processes in the catchment area.

Bansko Ski Resort Indicators

Spatial extent of the territory of the ski resort and the spatial extent of erosion on ski routes can reveal the effects of the anthropogenic activity in the catchment area. Similarly to the case with the Seven Rila Lakes qualitative and quantitative regulations in the management plan can indicate the extent of possible future changes on the territory of the resort, which can be spatially quantified and related to the total territory of the catchment area. The spatial extent of the affected territories by deforestation can be related to the capacity of ecosystems to generate their services as percentage of the total ecosystem territory in the catchment area.

CHAPTER 7: STAKEHOLDER ANALYSIS

7.1 Historical Review

7.1.1 Bansko Ski Resort

The initial infrastructural development of Bansko ski resort dates back to the mid-80s. The first construction of ski lifts and ski routes was meant to accommodate national ski competitions and sport events due to the emerging interest in alpine sports. The infrastructural expansion remained as it is until 2001 when the privatization of exclusive state property was already a common process under the new democratic model. In the year 2000, a public discussion was held on the Environmental Impact Assessment (EIA) report regarding proposed expansion of ski infrastructure above the town of Bansko. The project was initiated by Bansko municipality and funded by “Yulen” Ltd. The construction involved a new gondola lift to allow quicker access between the town and the area of “Bunderishka Polyana”, respectively from 991m to 1590m altitude, stretching across 6331 meters and covering 5.61 ha in total with 9m width of the lift corridor . According to the report, the new gondola lift is seen as key link for the development of the resort, which previously depended on poorly maintained road to connect the residential areas with the ski resort. The main argument despite quicker access was that the road poses a great pressure on the environment through air and sound pollution caused by the vehicles. In the EIA report the impacts on ecosystem condition from the project are separated in two graphs, during the construction and long term usage. Regarding the condition of land cover and soil, short term effects during construction are seen to have significant territorial coverage with high degree of impact, short duration and ability for recovery of natural habitats. The effects during the use of the infrastructure are seen to have limited territorial coverage with low degree of impact and duration with ability to recover natural habitats. The impacts on vegetation are described as local, significant with episodic duration during construction without cumulative impact and ability to recover natural vegetation. During the use of the infrastructure, territorial coverage is seen as local with minimal impact, long term duration and constant impact, cumulative or a combination of impacts are not considered possible and the ability to recover natural habitats is present.

During the public discussion two representatives of national environmental NGOs submit an appeal to the Ministry of Environment and Water (MOEW) to not consider the proposed Territorial Arrangement Plan (TAP), which involves the construction of the new gondola lift as proposed by Bansko municipality and "Yulen" Ltd. The motives stem from several laws and regulations, specifically the Protected Areas Act (PAA), that prohibits clearcut logging and specify the necessity to link urban development and management of national parks in spatial planning, which is not accounted for in the EIA report. Furthermore, the management plan of Pirin national park does not account for infrastructural expansion. The proposed expansion will lead to destruction of protected flora and fauna or their habitats which are within the Environmental Protection Act (EPA) and the Bern convention. Moreover, the project will interfere with the status of Pirin National Park as world cultural and environmental heritage recognized by the UNESCO convention.

On 31 July, 2000, Evdokiya Maneva - the minister of environment and water approves the territorial development plan despite the submitted appeals against it. Within the approval document the minister advises Bansko municipality to carefully balance the tourist accommodation capacity with the capacity of the ski resort in order to avoid conflicting situations regarding overuse. The use of chemicals and large scale modifications of the ski runs are not allowed according to the statement. According to the decision, several ski lifts and ski runs are considered to be excluded from the plan. In October 2000, six NGOs submit a complaint to the Supreme Administrative Court (SAC) against the approval of the EIA report and the TAP of the ski resort. The SAC rejects the appeal and considers it invalid.
In November 2001, with a decision made by the Council of Ministers, "Yulen" Ltd is announced as concessionaire of the territory of Bansko ski resort accounting for 99,55 ha within the territory of the national park. The concessionaire is given responsibility over exclusive national property in return for income percentage given to the government.

On December 21, 2001 the minister of environment and waters - Dolores Arsenova signs a concession contract with "Yulen" Ltd. Several months later, on April 2, 2002 the Ministry of Environment and Water (MOEW) allows the construction of the ski runs and lifts which were prohibited by the decision made by the previous minister – Evdokiya Maneva and were not included in the concession contract. There were 52 complaint submitted against the additional expansions which were allowed on the territory of the resort. The complaints were later on declined by SAC, followed by the construction described in the concession contract.

With a decision made on 6 August, 2004 the Council of Ministers approves the management of Pirin National Park (2004 - 2013) stating that the ski resort should not expand further than the territory described in the concession contract.

On 8 September, 2005 the regional department of MOEW presents modification of Bansko resort TAP, which accounts for new additional expansion not mentioned either in the management plan of the national park or the concession contract from 2001.

During 2007, the construction described in the concession contract and the additional expansions allowed by the regional department of MOEW were completed. NGOs report that some of the completed infrastructure is yet to receive approval from the governmental authorities.
In July 2008, the national park agency published 4 year report on the implementation of the management plan. The performance report has a section dedicated to Bansko Ski Resort. The report states that the management plan is designed in accordance with the resort TAP, however this is related to the previous version of the TAP, not the modified version in 2005.
The report accounts for various problems which emerged during the infrastructural expansion:

- Absence of strategic planning and clear perspective for future development.

- Clear inability of local authorities to cope with urban development and expansion of tourist infrastructure within the town of Bansko. The accommodation capacity has seen a major increase, exceeding the capacity of the ski resort for daily visitors.

- The report accounts for lack of cooperation between municipal administration of Bansko and the national park directorate regarding the urban expansion in Bansko, which led to increased anthropogenic impact on the territory of the resort. The report advices for further development of ski infrastructure which will be able to accommodate the tourist flow.

In June 2010, a further modernization of the ski lifts was allowed and unauthorized and illegal widening and additional clearcut logging for lift corridors has been reported by environmental NGOs. In August 2010, the national park authority issues a fine on “Yulen” Ltd regarding the additional clearcut logging. At the same time, UNESCO issues an alarming report which urges the state party to ensure that the new management plan starting from 2013 will not permit further ski development or construction of additional facilities within the resort or extension of the tourist zone into the property. UNESCO recognizes that the territory of the ski resort has been repeatedly and significantly impacted by anthropogenic activities and sees any further infrastructural development as a reason to include the territory in the “List of World Heritage in Danger”.

In 2011, a geodesic research is initiated by “For The Nature” coalition and implemented by MOEW on the territory of the ski resort in order to map ski facilities and their extent with respect to the TAP. The research results are as follows:

- 65 hectares of clearcut logging within the territory of the national park Pirin, outside the agreed 99,55 ha in the concession contract leading to 164,74 ha of used land by the concessionaire “Yulen” Ltd.

In 2011, UNESCO issues a report, in which it excludes the area of Bansko ski resort of its world cultural and natural heritage and the territory received a buffer status. UNESCO recognizes the friction between the management plan, the TAP and the additional expansion in the ski zone as several decisions have been subject to legal proceedings in the country.
In its reports UNESCO admits that the World Heritage Center (WHC) has been involved in the “step-wise” process and has been reaching agreement through debating with MOEW, acknowledging that several ski routes have been built without accordance to the original TAP or have been constructed without the permission of MOEW. This has been confirmed on 18 August 2011, through a request for public information, where the MOEW – Nona Karadzhova confirms that development of ski run “Plato-1” is constructed without permission from MOEW and was not envisaged in TAP or the concession contract.

On 14 January, 2013, the mayor of Bansko municipality - Georgi Ikonomov submits a project proposal to MOEW for changes of the management plan of national park Pirin. He considers that the management plan is outdated and preventing the infrastructural development. Some of his motives are based on UNESCO decision to exclude the ski resort area from its world heritage, thus buffer zone is seen as validation and recognition of the importance of the ski resort for the local economy. The mayor proposes several changes to the environmental regulations:

- changes to the zoning of the park, which will allow reconstruction and renovation activities to be held in zone 2a and 2b, zone 3 and zone 4.
- Construction of ski runs, ski facilities according to the TAP in zone 3 and zone 4.

Environmental NGOs see this request as an effort to legalize previously made changes that are not in accordance to the management plan regulations since the management plan of the national park does not allow such modifications to take place, yet numerous expansions did happen in the previous years.

With decision made on 19 February 2013, MOEW approves the request made by Ikonomov and legalize the additional infrastructural development made between 2001 and 2011, leaving the door open for further infrastructural expansion.

On 18 March, 2013 the Bulgarian National Auditors Office (BNAO) undergoes an audit on the concession contract with “Yulen” Ltd. On 17 April, 2013 BNAO publishes the report and the results regarding the concession contract with the following results:

- For the period between 2001 and 2010, the state authorities did not implemented efficient control in ski zone Bansko.
- Absence of concession control system in MOEW, which is able to communicate the implementation of the contract.
- The control on the contract is not structured in accordance with the regulations in the national law of concessions and there are no entrusted individuals to monitor for this in the governmental body or in the municipality of Bansko.
- In 2009 and 2010 there is absence of field monitoring schedules. There has been no issued on-site monitoring by the directorate of MOEW for that period.
- Along with the ski runs, roads and facilities described in TAP 2001, there are additional spatial alterations outside the concession zone.

On November, 2014 “Proles Engineering” LTD has been assigned to develop the new management plan (2014-2023). The new regulation caused negative response by environmental organizations, recognizing the fact that the new policy making process can be an opportunity to create room for future expansions outside the concession zone.
Several national and international campaigns have been launched by “WWF Bulgaria”, “For The Nature” and “Green Balkans” to attract public attention on the issue and the importance of clarification of laws and regulations within the management plan and ensuring their appropriate implementation. One of the main issues in the development of the new management plan was the necessity for the document to undergo EIA.

On 1 March, 2017, the minister of MOEW – Irina Kostova, issued a statement to approve the new management plan without EIA. According to the EPA and the Biological Diversity Act (BDA), a new management plan should be assessed for the environmental impact of its laws and regulations. The decision was opposed by environmental organizations and a court process was initiated, which resulted in dismissal by SAC on the decision by MOEW to not undergo EIA.

Along with the necessity for the new management plan to undergo EIA, at the end of 2017, the Council of Ministers approved another reform, which modifies the currently used management plan (2004-2013). The decision was taken to court and after several procedures, the decision was refused by SAC in January 2019. After several trial procedures on April 19, 2020 SAC made a final statement that the new management plan should undergo EIA according to the BDA, PAA and EPA.

7.1.2 The Seven Rila Lakes

on 24 of January 1995, MOEW approves the EIA of the chairlift project proposed by the municipality of Sapareva Banya. One of the main motives for the decision is the lesser impact on environment in comparison with the construction of road infrastructure. The decision becomes effective on 14.10.1997 and has validity for 1 year. On 27.10.1998, two weeks after the expiration date of the approved EIA, the chief architect of the local municipality issues an approval of the project. Following the approval of the project the local municipality implements initial plans and procedures for the construction of the lift: building area and maps, materials, machines and fundaments and logistics.

The construction stops in 2001 due to insufficient funds, followed by the establishment of “”Atomic Invest LLC” comprised by the local municipality and several regional companies. BNAO performs an assessment on the company and criticizes the partnership contract, which cannot guarantee that the given rights for construction of the chairlift cannot be transferred. Despite this critique, the off-shore company “Rila Sport” JSC becomes involved in the partnership alongside the local municipality, which is followed by an assessment on the current construction progress. In the year of 2005, “Rila Sport” JSC, presented a modified version of the project, which represents changes in all types of major infrastructure, including demolishment of previously built constructions. According to national environmental NGOs, “Rila Sport” JSC deemed the requirements of EPA rather strict on new project proposals. The modifications on the previously approved project from 1998 were assessed by regional authorities and were seen as significant to the provisions of the Spatial Planning Act (SPA).

On 11.06.2007, MOEW issues an official statement granting the new modified investment project for the upper station of the chairlift only. According to a citizen alert on 28.08.2007, construction precedes approval from the municipal chief architect issued on 04.09.2007. There are also official ministry protocols for ongoing construction from 22.08 and 10.10 not related to the approved upper station area. On 15.10 the investor files a new request for approval of the project using the expired EIA from 1995. The request has been approved by MOEW on the basis that it comprises the same area and the scope of the project does not exceed the previously approved plan.

The modified investment project and its approval process has been heavily criticized by national environmental NGOs and seen as illegal. In 2008, an informal citizen organization “”Grazhdani za Rila”(Citizens for Rila) submits a letter to SAC motivated by the growing public displeasure regarding the negative impact on nature in the area of the Seven Rila Lakes caused by the newly constructed chairlift. Numerous points of concern address the legality of both the original and modified projects. A key issue shared between citizens and environmental organizations is the fact that the original project has been granted construction approval without active EIA. Moreover, the original project was initiated before the establishment of the national park management plan in 2001. Therefore, the project territorial coverage falls within the national park borders. The new project in 2007 is not coordinated with the management plan and its regulations which prohibit infrastructural development such as chairlifts. Moreover, the lack of active EIA results in inability to assess the effects of high anthropogenic impact caused by the chairlift on territories within the national park, specifically the zone for limited anthropogenic impact. Further administrative remarks note the fact that the ministry did not provide information in the public database with decision if a new EIA is necessary or not, according to art. 93 of EPA, such official statement is required. The approval of the new investment plan with the expired EIA is seen as contradictory to the provisions of EPA and PAA. The destruction of protected areas is also a violation of the Bulgarian criminal code as stated by NGOs.

The ministry of environment recognizes that the EIA has indeed expired, however the approval for construction by the chief architect in 1998 has been issued, which was not declined through administrative or court procedures, therefore it has been implemented. The ministry recognizes that the investment project has changed in terms of infrastructure but does not see this to affect the area differently than originally planned. Despite the fact that the project was initiated without active EIA, there is lack of legal basis to undergo a new EIA since that procedure is implemented for new project, while the modified project investment is not seen as a new project but as reconstruction. According to the minister, the municipality of Sapareva Banya has been sanctioned as responsible for implementing the reconstruction without assessment on the necessity of EIA.

Following the construction of the lift, the territory of the national park has seen a considerable rise in visitors. According to the national park agency the number of tourists in the area has risen from 14 908 in 2004 up to 41037 in 2009. Until that moment there is no assessment on the advisable number of tourists in the area, activities by the agency comprise monitoring practices only. In 2010 the chairlift transport capacity increased up to 700 people per hour.

The rise in tourist interest led to the organization of two stakeholder meetings on 11.11.2011 and 28.05.2012. The involved parties attending the meetings were ministry representatives, parliament members, representatives of regional governmental bodies including the national park agency, the Bulgarian Academy of Science (BAS), the Executive Forest Agency (EFA), environmental NGOs, regional police department, Rila sport, invited local citizens and the mayor of Sapareva Banya. During the meetings, the different parties laid their views and concerns regarding the management and development of the area. Variety of pressing matters were addressed concerning reduction of environmental law violations by tourists and local population, through coordination between governmental and regional authorities, which shared the lack of personnel and resources to perform monitoring in the area. Regarding anthropogenic impact on the lake ecosystems, several strategies were discussed. Environmental NGOs stress the need for upper limit of daily visitors in the area along with national park visitor tax which will aid the strained resources by the national park directorate. The proposed ideas were welcomed by the minister of MOEW, while they caused displeasure by the local business and municipal representatives having the argument that it would be unfair only one municipality to have such regulations in the national park and it would negatively influence the economy in the area.

Another point of concern regarding the ecosystem is their past and current state, which was discussed by the national park representatives who handle the monitoring of lake and grass habitats. According to their research initiatives, no negative impact has been seen on lake ecosystems until that point in time, while the main point of concern is the footpath erosion. A large project initiative has been initiated by the national park agency to cultivate and preserve species affected by tourist path erosion. The conclusion of the second meeting regarding ecosystem management was focused on the new management plan of the national park, which followed in the coming years.

7.2 The role of formal and informal institutions in the national parks governance procedures

7.2.1 Formal Institutions

Protected Areas Act (PAA)

The Bulgarian PAA is a crucial formal institution for mountain ecosystems that defines categories, functions, regimes and governance of protected areas. There are six categories included in the act:

- natural and managed reserves, national parks, natural landmarks, natural parks and protected sites.

According to PAA the purpose of national parks such as Rila and Pirin is maintenance of diversity of the ecosystems and protection of wildlife, conservation and maintenance of biological diversity within the ecosystems (Article 18, paragraph, 2 items 1-3). These objectives are of crucial importance as set by lawmakers. Other objectives that adhere to those are scientific research, education, recreation, development of tourism and environmentally sound livelihood for local communities. (Arcticle 18, paragraph 2, items 4-6).

With respect to infrastructural development the PAA has a strict regulation defined in Art.21, which prohibits:

- Any construction, with the exception of hiking shelters and chalets, water catchments for drinking purposes, treatment facilities, park management and visitor service buildings and facilities, underground communications, repair of existing buildings and roads, and sports and other facilities.

The PAA is undoubtedly interlinked with the policy making process of management plans of the national parks. Based on Art.56-66 of the PAA, management plans of national parks conform to the categorical requirements and regimes of protected areas as well as to the requirements of international treaties. Each management plan contains specific objectives for the protected areas description, condition of ecosystems, standards and recommendations for activities in the natural environment, short-term and long-term action programs associated with scientific research on condition of ecosystems. The management plans are commissioned by MOEW. The elaboration of management plans requires organization of public discussions and participation by representatives of central and local government authorities, research, academic and NGO associates before the approval by the Council of Ministers.

Environmental Protection Act (EPA)

The EPA is concerned with environmental protection, preservation of biological diversity and environmental components, the control and management of factors damaging the environment, implementation of control and restriction of pollution sources. EPA is responsible for the functioning of the national system for environmental monitoring, responsible for environmental strategies, programmes and plans, environmental information access, economic organization of environmental protection activities as well as the obligations of the state, municipalities, the corporate bodies and individuals with respect to environmental protection. The objectives of the act are to regulate the regimes for preservation and use of environmental components, establish admissible standards for the quality of the environment, implementation of EIA and Ecological Assessment(EA), management of territories with special regime of protection like Pirin and Rila national parks and economic regulation and financial management of environmental resources.

With respect to plans and programmes in Rila and Pirin national parks key articles in EPA are art.81 art. 85 which state that both EIA and EA shall be implemented for plans, programmes and investment proposals for construction, activities and technologies or their changes or extentions, upon which implementation are possible significant impacts over the environment. Specifically, EA is mandatory for plans and programmes in the field of tourism, spatial planning and land use.

EA has the following criteria:

Determine the characteristics of plans and programmes, their significance for the integration of ecological consideration and promotion of sustainable development, related environmental problems, implementation of community environmental laws as well as characteristics and the consequences in the territory which might be affected and the ecological consequences for the terrotry which might be affected with regard to feasibility duration, frequency, reversibility, cumulative effects of expected impacts, potential cross-border impact, potential effect and risk for human health and environment, accidents, spatial scope of consequences, vulnerability of the affected territory and impact on regions or landsacapes of recognized national, communal or international status and protection

An EIA report has a broader scope of criteria covering socio-economic and environmental aspects. With respect to influence of effects of investment proposals on ecosystems, EIA has the following requirements:

- A description of the relevant aspects of the current state of the environment (baseline scenario) and a summary of their likely evolution, if the investment proposal is not implemented, as far as natural changes from the baseline scenario may be estimated based on the availability of environmental information and scientific knowledge
- Description of the likely significant effects of the impacts of the investment proposal on the environment resulting from the construction and operation of the investment proposal, the use of natural resources in the affected area
- The emissions of pollutants, noise, vibration, radiation and non-ionizing radiation; the occurrence of adverse effects and the disposal of and recovery of waste
- The results on the environment as a result of hazards and catastrophes
- Vulnerability of the investment proposal to the risk of major accidents and/or disasters that are relevant to it; relevant information must be obtained through risk assessment.

Biological Diversity Act (BDA)

The BDA regulates the relations among the state, the municipalities and the juristic and natural persons in respect of the conservation and sustainable use of biological diversity in Bulgaria. As stated in Art.1, biodiversity conservation is an integral part of national wealth and priority and responsibility of the state and regional government and the citizens. The act has the purpose to conserve all natural habitat types important both for Bulgaria and the European continent specifically endangered, rare, endemic plant, animal and fungal species within the National Ecological Network. The BDA has an important purpose to integrate and harmonize the Eropean Ecological Network NATURA 2000 in its regulatory provisions. Both Rila and Pirin National Parks are considered important protected areas according to the European directive with identification codes BG0000495 and BG0000209 respectively.

Section 5 of the BDA determines the regulations with respect to management plans, spatial-development plans and projects. The measures for management plans of national parks shall include:
- prohibition or restriction of activities contrary to the requirements for conservation of specific sites subject to protection
- preventive action to avoid unforeseeable adverse events
- supporting, steering and regulating activities
- restoration of natural habitats and habitats of species or of populations of plant and animal species

- conduct scientific research, education and monitoring.

Concerning spatial-development plans, building-development proposals that are not essential for the management of the national parks, either individually or in conjunction with other plans and programmes, which are deemed to have significant negative impact on ecosystems shall be assessed as to the compatibility with protection regulations of the conservation area (Art. 31, par. 1). The article 31, refers to the execution of EA and EIA as described in EPA regulations.

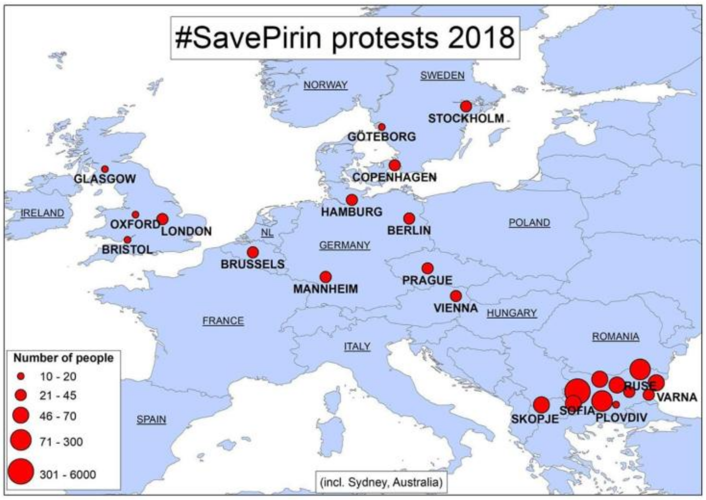
7.2.2 Informal Institutions – The role of the public in the application of environmental regulations

Through the historical review of this chapter, it has been clear that the role of the general public in Bulgaria has an important role in shaping the regulations of the management plans of the national parks, which is one of the requirements set by environmental laws previously discussed. However, the public involvement has been more pronounced during policy making procedures where public participation is not defined as required by law. The response has been triggered through the observed negative effects from currently running investment projects and lack of appropriate measures by state authorities to limit environmental impact. Public reaction is further stimulated if additional changes and modifications of either environmental regulations or investment plans have negative impact on protected areas in the future. The role of the public has been modulated by environmental organizations which are the first to alarm for negative environmental outcomes and often lead protest and awareness campaigns. The impact of the public involvement has been implemented through requests for public information, filed complaints, public statements, protests, campaigns, scientific research and journalism.

Protests against the infrastructural expansion in Pirin national park. Sofia, Bulgaria 04.01.2018

Source: Author

FIGURE 4: SAVE PIRIN PROTESTS



Source: For the Nature, 2018

The result from the effort made by the general public has been recognized most prominently in the decision of SAC on 16.01.2019 regarding the new management plan of Pirin NP. Within the decision, SAC mentions the importance of the careful analysis on international regulations based on the high public interest. Furthermore, the report by the administrative court states that NGOs and the general public are able to better read and comprehend environmental laws than the ministry of environment appealing against the need for EA and EIA of the new management plan of the national park. Another important recognition of the public involvement is the initiated criminal procedure against Bulgaria made by the European Commision (EC) regarding the implementation of NATURA 2000. According to the EC, the reasons for the initiation of the procedure are the multiple complaints for violations of European directives for protected areas, specifically plans and projects granted permission without sufficient environmental and ecological assessments.

Since the general public can be seen as a user of ecosystems and their services, people can observe at first hand the condition of ecosystems and their change through time. In case of failing governmental structures and procedures, the results can be seen clearly through the consequences from unmanaged natural hazard and risks, illegal logging and loss of biodiversity. These observations often trigger responses by the general public and due to the prolonged lack of appropriate management and governance procedures, public responses become more organized and coordinated to make them more effective. Responses against infrastructural expansion in the Bulgarian mountains date back to their initialization, yet public response becomes substantial years later when the results from poor management and governance become more apparent. Based on the discussed evidence of formal and informal institutions it can be concluded that they have complementary nature in recent years. Given the discussed facts, the role of the general public in environmental laws and regulations have become an important aspect of environmental policy making and implementation in Bulgaria and as it seems it will certainly be needed in the future.

7.3 Identifying disconnects between risks and policies

7.3.1 The proposed management plans and the policy making process

In its definition the management plans of the national parks gives general characteristics of the protected area and its components, objectives for governance, norms, regimes, requirements and recommendations for activities related to forestry, land use, water management, development of infrastructure, and governance procedures. The management plans can include short term and long term action programmes connected with scientific research and monitoring of ecosystems and other environmental components, protection of endangered species, habitats and ecological education.

The management plans of the national parks are renewed on 10 year basis, meaning that new environmental legislation, changes in biotic and abiotic factors in the ecosystems and even changes in political, social and economic environments can orchestrate respectively changes in the management plans in the national parks. The changes of the zoning regulations are the reason for the noumerous court trials regarding necessity of EIA on the new management plan between 2017 and 2020.

Observed changes in the regulations of the proposed management plan of Pirin NP

TABLE 5 CHANGE OF ZONING REGULATIONS IN THE NATIONAL PARK PIRIN

A COMPARISON BETWEEN OLD AND PROPOSED ZONING REGULATIONS IN THE MANAGEMENT PLANS

Currently Active Management Plan	**Proposed Management Plan**
"The following restrictions apply on the whole territory of the park: Constructions of new and expansion of existing ski infrastructure. Artificial light on territories outside the defined zone for infrastructure"	"The following restrictions apply on the whole territory of the park: Constructions of new and expansion of existing ski infrastructure, except permissible constructions in the respective zones. Artificial light on territories outside tourist and infrastructure zones.
"All human activities are prohibited In zone 2a – zone for protection of forest ecosystems and leisure with the following exceptions"	"All human activities are prohibited In zone 2a – zone for protection of forest ecosystems and leisure with the following exceptions" Item added: 10. Water Catchment
"All human activities are prohibited in zone 4 – zone for infrastructure, with the following exceptions..."	"Any human activities are prohibited in zone 4 – zone for infrastructure, with the following exceptions..." Item added:

	"11. Activities related to expansion of ski runs, construction of ski lifts within zone 3 – zone for tourism, according to approved governance plans or alteration of existing governance plan or investment project/proposals with approved EA and EIA..."
"Construction, reconstruction or repair on the territory of the park can be performed in zone 4 – Zone for infrastructure only"	"Construction, reconstruction or repair on the territory of the park can be performed in zone 4 – Zone for infrastructure only, and zone 3 – zone for tourism"
Prohibited are any constructions on the territory of the national park except: 13. Additional construction of approved ski routes and constructions and sites according to the approved and active governance plan of "Ski zone Bansko" and the respective EIA from year 2000."	"Prohibited are any constructions on the territory of the national park except: 13. Activities for additional construction, expansion of ski routes, ski lifts construction in zone 3 – zone for tourism, and in zone 4- zone for infrastructure according to approved governance plan or alterations of existing plan, investment project/proposal with approved EA and EIA…"
"All human activities are prohibited in zone 3 – zone for tourism with the following exceptions…"	"All human activities are prohibited in zone 3 – zone for tourism with the following exceptions…" Added item: 11. Activities for additional construction, expansion of ski routes, ski lifts construction in zone 3 – zone for tourism, and in zone 4- zone for infrastructure according to approved governance plan or alterations of existing plan, investment project/proposal with approved EA and EIA…"

Based on the comparison between the management plan and the proposed version of Pirin NP, infrastructural development is allowed in zone 2a (45,2%) for construction of water catchments, in zone 3 (2.2%) and zone 4(0,6%) for the construction of ski infrastructure, which makes 48% in total of the territory of the park. The new changes in the zoning regulations will ease the requirements for new investment proposals for reconstruction and expansion of ski infrastructure not only on the territory of the buffer zone of the ski resort but on nearly half of the territory of the park can allow for logging practices. The capacity for water catchment will increase greatly, which could pose a stress on water resources and aquatic species downstream.

Observed changes in the management plan of Rila NP

There aren't significant changes between the management plan currently running and the proposed version in terms of anthropogenic impact regulations and this has been a subject to a debate during public discussions. The most notable change in the zoning of the park related to the increase of the limited anthropogenic impact zone with 4000 ha. Based on public discussions, the opinion of environmental NGOs is that the proposed increase of the zone territory, which also serves as buffer zone between natural reserves and outside territories is not sufficient to guarantee protection of the ecosystems. The issues around the new management plan are related to its completeness, applicability and effectiveness.

Based on the ecological assessment major threat to lake ecosystems is the persisting process of lake sedimentation and eutrophication resulting in increased population of specific species of algae. A recommended solution is to decrease anthropogenic impact near the lake ecosystems. The flora in Rila NP has been classified with moderate susceptibility, flora in remote and hardly reachable terrains is in stable condition, while flora near locations with intensive tourism is highly vulnerable. Intensive and unregulated tourism in the area of the Seven Rila Lakes has caused footpath trampling negatively impacting invertebrate species and triggering erosion processes causing loss of grass communities and soil substrate. The problem with footpath trampling and erosion continue to intensify each summer season. The unregulated amount of daily visitors causes intensive use of official tourist paths often resulting in widening of the hiking paths area, appearance of new and alternative routes, which are not regulated, marked or monitored by the national park authorities.

The main friction between the anthropogenic impact and the regulations set in the proposed management plan is the lack of quantifiable data on the effects from unregulated tourism in the area of the Seven Rila Lakes. There is lack of understanding on the scale and magnitude of anthropogenic impact that ecosystems can endure without surpassing certain estimated threshold of biogenic pressure. Without such quantifiable data, environmental regulations related to anthropogenic impact cannot be applied or designed to manage the consequences on ecosystem condition.

7.3.2 Past impacts from policies and regulations

Several factors created varying environmental regulatory structures in Bulgaria during the last two decades. The country adopted the Aarhus convention in 2004 which requires the involvement of the general public and NGOs in the policy making of the natural environment. The country was appointed as a member state of the European Union in 2007. The inclusion in the European Union led to the harmonization with European environmental conservation and protection practices and thus prioritization them as leading environmental policy in the country. Both management plans of Rila and Pirin National Parks were developed before these changes, which defines the difference in their policy making process in comparison to the currently proposed new management plans. As described in the first chapter of the stakeholder analysis, authorities declined numerous requests and complaints by environmental NGOs during the procedure of approval of both project proposals for Bansko and Seven Rila Lakes in their initial stage 20 years ago. In contrast, both the general public and environmental NGOs had a much stronger role in recent years after the adoption of international policies. Despite the increased involvement of non-governmental bodies in national environmental protection procedures , MOEW has been heavily criticized by the European commission for failing to implement the ecological framework NATURA 2000. BNAO performed an assessment regarding the performance towards the harmonization and adoption of European legislation in the past 13 years.

According to the audit report (BNAO 2019), there are mistakes made by MOEW leading to considerable delay regarding the harmonization of national legislation and partial inclusion of NATURA 2000 requirements. There is lack of strategic framework for long term planning with national goals for protection and sustainable development of biodiversity. The organization and governance of the ecological framework is not effective due to unclear responsibilities across the structures of MOEW, lack of working mechanism for effective communication and coordination between involved parties on national, regional and local level and private sector and lack of transparent accountability of public expenditure and achieved results. The created systems for monitoring, control and reporting of the condition of the ecological framework aren't effective due to gaps in monitoring practices, annual reporting of biodiversity status and protected areas and absence of collection and organization practices of initial and aggregated data on set of indicators for evaluation of biodiversity. Lastly, there is inability to record progress on achieved results for the realization of the integration of the ecological framework due to lack of monitoring systems, control which hampers the collection of detailed and updated field information. There is lack of periodic reporting structures and absence of data on species and habitats and their ecological status. There is lack of accountability of the condition of ecosystems and species in Bulgaria, which could show the level of protection and improvement of ecological status.

7.4 Obstacles and opportunities for the environmental governance

Until May 2020, both proposed management plans of Rila and Pirin NPs are not yet approved or implemented. The final court decision on April 19, 2020 regarding the need for EA and EIA of the new management plan of Pirin NP stated that these assessments are mandatory for the management plan and declined the appeal of MOEW which previously made a decision on 01.03.2017 to not perform these assessments. The management plan of Rila National Park has been reworked as of 2016 since the proposed version has been heavily criticized for failing to meet contract clauses for its development. The opinion of environmental organizations on the substantial delays is that the management plan has been put on hold until the current situation of the management plan of Pirin National Park is resolved. Therefore predictions lead towards lack of progress on the new management plans in the coming years.

The general public has been actively involved in the policy making process of the new management plans both with respect to the Aarhus convention and as a complementary informal institution. The involvement in the policy making process of environmental organizations and the public resulted in the dismissal of the new regulations of the management plans leading to the establishment of mandatory procedures and assessment previously lacking. The policy making processes however showed inability of state authorities to integrate and value expert opinions from the private sector in the new proposed regulations, which is causing substantial delays in the formulation of the new management plans.

The main motive for the important role of the public is the value of nature mostly for its cultural ecosystem services. The most common agreement shared between participants during protests, debates, and information workshops was the prevention of further expansion of infrastructure in the national parks and the environmentally sound performance of currently running investment projects. To this point, the joint effort of environmental NGOs and the general public has been able to put infrastructural expansions on hold through several court decisions.

However, the environmental impact from established anthropogenic activities both in Rila and Pirin NPs remains unclear and unquantifiable to present date. This influences assessment of past impacts, current status and future scenarios for ecosystem condition. An important remark has been made by MOEW in response to official request for information in 2010 for the capacity of the chair lift near the Seven Rila Lakes. In its response, MOEW points towards Art. 79, par. 2, item 2 from PAA, which states that the minister of MOEW can cease activities or sites, which pollute or damage the natural environment in protected areas above the advisable norms. However, as previously discussed, such norms for negative impact thresholds are not established or researched, therefore there cannot be a legal basis to perform such decision. The proposed management plans can establish such practices for determination of quantifiable thresholds and indicators of anthropogenic impact by investment projects currently operating.

CHAPTER 8: ECOSYSTEM ANALYSIS

8.1 Environmental Factors

Rila and Pirin Mountains are an important orographic factor in the Balkan Peninsula due to their height and the relatively southern location in the area, forming an important link between Mediterranean and continental climates. The high mountain regions are characterized by permanently cold temperatures in winter and high precipitation during summer. These climatic conditions influence snow cover, water quantity, annual vegetation processes, characterized by the start of the vegetation period, the duration and end of the active cycles. The environmental conditions are best described as dynamic throughout the year. These conditions vary across the mountains, best characterized by the comparison between southern and northern regions in Pirin. Northern parts in Pirin receive ample precipitation during summer months, whereas southern regions are warmer and dryer. In Rila, the contrast is less recognizable but temperature and sun exposure are in contrast between slopes with northern and southern exposition which shapes species composition and ecosystem characteristics.

Studies on weather parameters from previous decades reveal trends for warming of air average temperatures since the late 70s with 0.4 degrees Celsius per decade (Grunewald et al. 2016). The most recognizable trends are during the months of June, July and August. According to Lelieveld et al. (2012), the air temperature is expected to rise between 3.5 and 7 degrees Celsius on the territory of the country by 2099. Reliable estimation of changes in precipitation is difficult to be achieved due to spatial variability and alternating dry and humid years (Najarov, 2012).

Climate change may have significant effect on weather patterns that occur on annual basis. Global warming can cause shift in the duration and intensity of rainfall, snowfall as well as to introduce unusual temperature fluctuations and trends. A shift towards warming temperatures and dryer conditions will result in frequent heat stress, drought, floods and forest fires (Grunewald, 2013). Due to this setting for the mountain ecosystems, small changes may have significant effects on ecosystem condition to provide functions and services. Due to the rich variability in climate conditions caused the topographic features across the two mountain ranges and scarcity of weather stations, future predictions for climate trends are yielding mixed and unreliable results on local level. Ecosystems develop mechanisms to cope with the various weather conditions throughout the year and align their processes to optimize growth. A more robust species with respect to favoring conditions dominate in their habitats.

Environmental Effects on endemic coniferous tree species in Pirin

Due to their significant age, old-growth forests of Pinus Heldreichii and Pinus Peuce offer the opportunity to analyze the effects on tree growth and development from environmental factors through dendrochronological studies. The results of these relationships reveal that although both species occupy similar territories, the valley of Bunderishka river in particular, they can have both similar and different reactions to environmental factors such as precipitation and temperature throughout the year. Pinus Peuce is less susceptible to high temperatures and low precipitation during summer months in comparison to Pinus Heldreichii. This can be explained by the exposition and the soil type of Pinus Heldreichii habitats, which are characterized by higher sun exposure and shallow soil lair on steep and rocky terrain which has less capacity to retain soil moisture. In years with high temperatures and normal precipitation during the summer months both species have similar growth response. Both species have decreased growth development in years characterized with very low precipitation during summer months. On the contrary Pinus Heldreichii is able to grow relatively well during colder vegetation periods with ample precipitation. Despite that both species are affected by higher temperatures and lack of precipitation, this similar trend is only recognizable in drought periods July and especially August when soil moisture reserves are depleted for habitats of Pinus Peuce. In case of years with low precipitation in June, Pinus Heldreichii has lower growth due to the less soil moisture capacity. (Panayotov et al. 2008)

Environmental effects on the ecosystems in the area of the Seven Rila Lakes

The alpine and subalpine heath and grassland communities are exposed to extreme weather conditions which are typical for the mountain landscape, specifically very low temperatures, winds and winter storms. The ecological factors change rapidly throughout the year. During winter, storms can cause removal of snow layer, exposing vegetation to cold temperatures varying between -20 C to -40 C. In summer the weather conditions accommodate active vegetation period characterized by intensive rainfall precipitation, drought periods are not uncommon. The peak of the vegetation is in July.

Several authors suggest that prolonged climate warming can enhance richness of species in the alpine and sub alpine habitats in short term only. Alpine and subalpine biodiversity is expected to decrease over long term as cold-adapted species will lose their dominance over species tolerating warmer temperatures (Pauli et al. 2007). Based on the fact that ecological conditions change with increase in altitude it is expected that species of lower altitudes may migrate and reclaim higher elevation. Such trend has been observed with altitudinal increase of the tree line (Klanderud and Birks 2003). A limited factor for this process is that the grassland species in the alpine vegetation belt in Rila and in Pirin, occupy relatively low nutrient dense soils, which may lead to change in species and subtype composition rather than imminent threat of invasive species.

8.2 Natural Hazards

Natural hazards are fundamental ecological process, which is often seen as a negative factor for forest ecosystem health. However, natural disturbances and calamities contribute to forest heterogeneity, biodiversity and improving the adaptability of tree species to changing environmental conditions. The larger diversity in species composition and genetics is crucial for resilience and productivity of forests (Panayotov et al. 2016). According to the results from dendrochronological studies on Picea Abies species, trees situated in zones that are prone to extreme conditions and rapid environmental changes have higher resistance, thus need fewer resources to cope and adapt in comparison with habitats that have favorable growing conditions(Panayotov et al. 2011).

Having the above mentioned facts in mind, the anthropogenic impact can be seen as an additional disturbance factor, which can have both positive and negative contribution to ecosystem condition. Investigating the impacts from anthropogenic activity alone is insufficient to draw conclusions, having in mind that the constantly changing ecosystems are adapting to various processes at the same time. Ecosystem change should be seen as a collective result from both natural and anthropogenic effects. The important variable to recognize trends and possible causes is scale. In order to investigate the role of anthropogenic activities it is important to describe the natural hazards that are present in Rila and Pirin national parks, their scale, impact and recurrence.

8.2.1 Fires

According to the Executive Forest Agency (EFA), the majority of forest fires in the country are caused during periods of prolonged drought. In order for a fire to develop, a set of conditions is needed to be present to create the setting for large scale spread. Forest fuel relates to any plant based material that can be ignited such as branch, leaf, cone, bark, moss, ect. The chemical and physical properties are important for combustion although they do not vary greatly between species. Important aspect of forest fuel is surface area to volume ratio, which determines the heat needed to reach their ignition temperature (Panov, 2007). In terms of fuel availability forests in Rila and Pirin national parks are rather resourceful considering the limitation for forestry maintenance and the physical properties of coniferous species.

Although the availability of burning material is important for spread of the fire, present fuel moisture content relates to the potential for such event to happen. Fuel moisture content is directly related to environmental conditions such as temperature, rainfall and humidity. Prolonged drought can diminish moisture content of plant matter, which enhances combustion and fire spread. Humidity plays an important role for the fire spread. Higher percentage of moisture content in the atmosphere will significantly reduce the rate of fire through moisturizing the fuel material, hence if the fuel material has lower moisture content than the atmosphere, moisture will be transferred from the atmosphere to the forest fuel and vice versa. Relief is also an important factor in mountainous terrains. Slope is a crucial factor that affects fire spread through exposition, meaning that terrains exposed to solar radiation will be more prone to fire events. Slope steepness can predispose trees to heat up easier through heat transfer from lower to higher elevation. In narrow and rigid terrains, fire can easily spread from one slope to another through heat and spark transfer. Winds are another important environmental factor as they can provide additional oxygen, increase intensity of burning material, transfer sparks and small burning particles as well as moisture from the burning material to the atmosphere.

The presented general description of fire hazards above is important as each of these factors can be related to Rila and Pirin forests. Despite availability of fuel material, relief is highly rigid, characterized by drastic change of slope exposition and elevation. In terms of environmental conditions southern slopes of both mountains and at lower altitudes can be considered to have higher risk for fire hazards due to drought and sun exposure. In the past and in present time, the risk for the development of large scale fires is rather low considering that the mountains experience snow cover from October to Jun, accompanied by high humid content in the atmosphere, frequent rainfall and low average temperatures. In general, both Rila and Pirin are considered to be water rich mountains due to the availability of water resources. However, due to climate change these conditions may change and affect partially the national parks by increasing the risk of fire events.

According to the data provided by the national park directorate in Pirin, during the period between 2004 and 2013 there are 17 fire hazards that happened, only two developed to a larger scale event. Total coverage of all fires was 17,4 hecaters out of which 15,6 are grassland and 0,75 is coniferous trees. According to the data provided by the national park directorate in Rila between 2004 and 2013, on the territory of the national park there were 19 fire hazards that occurred, only two developed into a large scale event. Total coverage of the fire events accounts for 330,6 hectares out of which 17,7 hectares affected coniferous forests. The largest fire that occurred covered 250 hectares of grasslands and shrub habitats located in south-western part of the mountain.

8.2.2 Windthrows

Due to their height and structure conifers are susceptible to windthrow, which is characterized by uprooting trees and leveling them to the ground, caused by intense and consistent bursts of wind. This is an event that can occur throughout the year and can have effect on single or multiple trees, in extreme cases on large portions of forest cover. Windthrow is most prominent in altitude between 1600 and 1900m elevation. The most affected tree species are spruce (51%) due to their shallow root system. Homogenous forests are more susceptible to large scale windthrows while young and diverse forests are more resistance, while forests consistent of older trees experience fall of single trees in most cases (Panayotov, 2016).

Trees have some existing defense mechanism along with the development of stronger and deeper root system. Trees with larger and developed crown experience higher friction with the wind, which causes small to medium branches to break and fall down. This process reduces the friction between the wind and the tree crown and lowers the chance for serious damage. However, trees that have been damaged loose some valuable resources which are important part during the vegetation season. Recurring events on annual basis can create persistent ecosystem stress and cause dying of weakened and damaged trees by not only destroying their branch system, small and weaker roots may break apart, cutting out some valuable mineral and water resources. The consistency and density of forest cover has an effect on wind speed and intensity. After reaching dense forest, the wind goes above the forest canopy and accumulates further above the tree crowns. After such accumulation, the wind direction is downward to the tree roots. Scarce tree line in close proximity to dense forest or windy location, tend to experience severe wind events. (Panayotov, 2003).

8.2.3 Avalanches

Avalanches pose a great risk for forest ecosystems and in recent years their threat towards humans rose as well due to increased practice of skiing sports in avalanche prone areas. Large scale avalanches can occur on annual basis during the winter and spring seasons and the locations that they usually take place are easily recognizable. Some forests that experience higher threat of avalanches are Pinus Peuce and Pinus Heldreichii in Pirin on the slopes of Todorka and Vihren peaks in particular. Vegetation cover can have distinctive features based on avalanche recurrence. The absence of higher coniferous trees, reflects high recurrence, whereas the presence of sparse conifer trees reflects avalanche recurrence with longer proximity. The avalanches form gullies at the very top of the slopes where steepnes varies between 40 to 80 degrees and altitude is between 2200 and 2800m. Moving down the slopes the snow mass reaches altitude at around 2200 to 1600m, thus affecting the coniferous belt. Both mountains have an abundance of alpine slopes with scarce vegetation at higher altitude, which have considerable sun exposure. These are perfect conditions as a period of warm weather can form a firm layer of the snow. This event followed by a snowfall causes the two snowfall layers to have little grip between them and increase the risk for a hazardous event.

8.2.4 Floods

Within the study area flood risk is most prominent for river Glazne in the region of Bansko Ski Resort in Pirin. Glazne's catchement area spans across two valleys, which form several lake systems at their top, respectively supply two rivers, Bunderishka and Damayanitsa, which from into Glazne at lower altitude. Glazne water level is highly dependent on snowmelt and rainfall and vary on monthly basis. The river has high water levels during spring and early summer due to snow melt and the water supply is generally high throughout the year. Bansko ski resort fall within the catchement area and is in close proximity to the town of Bansko. Two flood events occurred in 2010 and 2016. Both of the events occurred during late fall/early winter, the river overflown and caused damage resulting in considerable infrastructural investment for reconstruction. The floods occurred due to intensive rainfall and considerable rise of Glazne river. Possible causes for the occurrence of high water levels are poor condition of the river bed due to lack maintenance and absence of adequate planning and implementation of infrastructural flood risk reduction measures. Morever, it has been arqued about the role of the ski routes and chairlifts and their contribution to increased run off due to decrease of forest cover in the catchment area. Although the territory of the ski routes reflects little percentage of the total catchement area, they are located in close proximity to the town of Bansko and the locations which are being flooded. Lack of vegetation causes water run off to reach rivers at much higher rate as trees hold rainfall due to their size and leaf system, use water as a source of nutrients and are able to form permeable but solid soil lair. Ski slopes with little to no vegetation, especially during the months of November and December contribute for additional intense discharge, which doesn't necessary represent dangerous volumes of water but the intensity at which it has been discharged due to topographical features and conditions specific to late fall months result in short term spike of water levels. There has been mixed recommendations on the issue. NGO's are advising for less infrastructural approaches towards management of water quantity of the river, while to local authorities have aimed to reconstruct and lift the concrete river banks at risk locations.

8.2.5 Biotic factors

During recent decades large number of coniferous forests across the globe experience increase in the population of Bark Beetles. These insects have their part in healthy ecosystems, however an increase in their population can cause them to spread and affect hundreds to thousands of hectares. The beetles usually attack weak or fallen trees as they have little to no resistance against the invaders. In order to overtake a healthy tree, there needs to be considerable rise in the population of the beetles. This usually happens due to the occurrence of a natural hazard such as windthrow or avalanche which causes the death of sufficient amount of trees, thus enough material to support the increase in population. Another condition that is important for the increase of bark beetle infestation is weather. Prolonged drought can pose stress on conifers, thus weakening their defense mechanisms during the active season for the beetles. During recent years, on the territory of Bulgaria a massive windthrow and snowfall events, especially during early 2015 led to enourmous spread of Bark Beetles on the territory of the whole country affecting several thousands of hectares. Tree age also matters as most affected trees are old Spruce. The reports from IAG show that during the months of July and August, drought periods are characterized by a considerable dye of from bark beetle infestation.

Although in Rila and Pirin, this is not a main cause for concern, it certainly shouldn't be ignored. The reason for the absence of large beetle populations is the high altitude, which is characterized by lower temperatures, longer winter and higher annual precipitation. On the other hand the occurrence of natural hazards is rather prominent and this can be accompanied by rising temperatures due to global warming. Another benefitial factor for future risks on the issue is the inability for prevention of the spread through removal of dead or affected trees due to national park regulations regarding the use of heavy machinery and any maintenance in old grown forests. Certainly the risk of bark beetles on its own is rather low, but a combination of factors, most importantly, climate variables, can contribute to increase of such biotic hazards in the coming decades.

8.3 Impact versus Likelihood Assessment

TABLE 6: IMPACT VERSUS LIKELIHOOD ASSESSMENT OF NATURAL HAZARDS IN RILA AND PIRIN MOUNTAINS

Hazard	**Impact**	**Likelihood**
Fire	Destruction of forest cover, shurbs and grasslands. Can affect group of trees to large portions of the forest ranging from a few hectares up to a few hundred	Higher likelihood on slopes with southern orientation at lower altitudes. It occurs on seasonal basis during the summer months and autumn.
Windthrow	Destruction of forest cover. Can affect single trees, group of trees or portions of the forest cover ranging up to a few tens of hectares.	Occurs mostly during winter and spring and affects weak or trees with shallow root system
Avalanche	Destruction of forest cover. Impact is intensified at avalanche prone areas. Poses a threat to human life.	Seasonal, occurs during winter and early spring depending on weather conditions
Flood	Can cause significant infrastructural damage and pose a threat to human life.	It occurs on inter-annual basis. Due to global warming and climate change, the risk is increasing particularly for the period between October and December.
Biotic threads	Can cause drying and death of single trees, group of trees or large portion of forest cover up to several hundreds of hectares.	Currently, it is only present at lower altitudes and is within natural limits.

The risk for the occurrence of the selected natural hazards in Rila and Pirin mountains is described by their impact and the likelihood for such events to happen. Out of these hazards, anthropogenic impact has a major role on floods and fires, while all of the selected hazards are affected by environmental factors and climate change in particular. According to EFA more than 90% of forest fires in Bulgaria are man-made. The likelihood for flood events is also minimal without human intervention. Global man-made climate change also has indirect impact on hazard risks by intensifying their recurrence and increasing their severity (Heyck-Williams 2019). Both mountains can suffer similar consequences, although a major difference can be the southern location of Pirin, which can contribute to higher annual average temperatures providing favorable conditions for forest fires and biotic threads like bark beetles.

8.4 Selected Habitats

8.4.1 Selected habitats of coniferous forests in Pirin

There are several types of coniferous species on the territory of Pirin national park and in the area of Bansko Ski Resort. Pinus Heldreichii (PIHE) and Pinus Peuce (PIPE) are endemic tree species with high ecological value. Both tree species lack extensive research on global scale, thus their condition is not sufficiently researched in comparison to other coniferous species, which makes them important for this research. The effects from anthropogenic impact on PIHE and PIPE are further described in chapter 10, thus this section aims to provide general characteristics of their habitats and analyze their ecosystem services.

TABLE 7 ECOSYSTEMS WHICH FALL INTO THE STUDY AREA OF BANSKO SKI RESORT

Ecosystems	**Habitat type according to EUNIS**	**Habitat type according to Natura 2000**	**Picture** *(source: fieldwork)*
FORESTS Coniferous Forests	T3-8 Mediterranean and Balkan subalpine Pin us heldreichii-peucis forest	95A0 High oro-Mediterranean pine forests	

Pinus Heldreichii

PIHE are endemic species occurring in the Balkans with small population in south Italy. PIHE forests are present in Croatia, Bosnia-Herzegovina, Montenegro, Serbia, Albania, Macedonia, Greece, Italy and Bulgaria. In Bulgaria, PIHE covers 1200 ha. Most of the old grown and naturally developed forests are located in the sub-alpine vegetation belt on the northern slopes in Pirin on marble terrain, covering altitudes up to 2200 meters. Old grown forests are characterized by species older than 400 years and some older than 700 years (Panayotov et al. 2010; Rangelova & Panayotov, 2013). The oldest tree recorded is the Baykushev Pine in Pirin, with approximate age of 1300 years. On territories less affected by human activities, PIHE share similar characteristics with Pinus Peuce, thus forest composition is mostly affected by natural hazards. PIHE can coexist with Pinus Sylvestris on slopes with eastern exposition, while on lower altitudes near Bunderishka River, the species share habitats with Picea Abies and Pinus Peuce. Homogenous forests with similar age of the trees are a result of logging practices in the beginning of XX century. Naturally developed forests of PIHE have low density, characterized by unbalanced spatial and vertical structure with tree species of various ages and diameter.

Pinus Peuce

PIPE are endemic Balkan coniferous tree species occurring in Serbia, Montenegro, Albania, Macedonia, Greece and Bulgaria. Pinus Peuce forests cover small territories in Bulgaria, however they have high importance on altitude above 1900m in Rila, Pirin, Slavyanka and Central Stara Planina mountains. The forests dominated by PIPE cover nearly 19 000 ha. in Pirin. Pinus Peuce is dominant on altitudes above 1900m, while it can coexist at lower altitudes with Picea Abies, Pinus Sylvestris and rarely with Pinus Heldreichii on specific locations in Pirin. PIPE avoids limestone terrain and prefers silicate-rich rocks. The forests are characterized by their significant age, half of which are older than 120 years, with many trees being identified to be older than 400 years and some older than 600 years (Panayotov et al. 2010). PIPE forests are located on steep, hardly reachable and remote terrains which have not been extensively utilized by human activities in the past, which resulted in preservation of the natural forest development. The forests can be separated in two types – homogenous and heterogeneous. Homogenous forests have similar age due to previous natural hazards on their territory. Heterogeneous forests are characterized by species with various age, predominantly older species.

8.4.2 Selected habitats in the area of the Seven Rila Lakes

The selected habitats in Rila NP comprise a number of coexisting grassland and heath ecosystems within the valley of the Seven Rila Lakes. Namely, the habitats and their respective NATURA2000 codes are Apine and Boreal heaths (4060), Species-rich Nardus grasslands (6230), Siliceous alpine and boreal grasslands (6150) and Oro-Moesian acidophilus grasslands (62D0) and Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoeto-Nanojuncetea(3130). Other habitats on the territory include Siliceous rocky slopes with chasmophytic vegetation (8220) and Siliceous scree of the montane to snow levels (8110), which do not fall within the scope of the study.

TABLE 8 ECOSYSTEMS AND HABITATS (BIOTOPES) WHICH FALL INTO THE STUDY AREA OF SEVEN RILA LAKES VALLEY.

Ecosystems	**Habitat type according to EUNIS**	**Habitat type according to Natura 2000**	**Picture** *(source fieldwork)*
FRESHWATER ECOSYSTEMS Oligotrophic lakes	C3.4 Species-poor beds of low-growing water-fringing or amphibious vegetation	Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoeto-Nanojuncetea(3130)	

NATURAL AND SEMI-NATURAL GRASSLAND ECOSYSTEMS **Xerophytic pastures and meadows** **Acidophylous subalpine grasslands**	E4.31 Alpic Nardus stricta swards and related communities	Species-rich Nardus grasslands (6230)	
	E4.32 Oroboreal acidocline grassland	Siliceous alpine and boreal grasslands (6150)	
	E4.39 Oro-Moesian acidophilous grassland	Oro-Moesian acidophilus grasslands (62D0)	
TEMPERATE HEATH AND SCRUB **High mountain ericoid heath and scrub**	F2.25 Boreo-alpine and arctic heaths	Apine and Boreal heaths (4060)	

Oligotrophic to mesotrophic standing waters

These habitats are characterized by blue to dark blue color, high transparency of 10 to 15 meters and low temperatures during summer months 10-12 degree C, 10-14 mg/dm3 oxygen compositions and neutral Ph of 6,7 to 7,2. The lakes share the same catchment area in the valley, respectively receive water either from water bodies situated above the lake or from snow drifts during spring and summer melting. In their later stages of development, appearance of aquatic plants and sandy sedimentation on the lake bed is observed. Their low nutrient content to intermediate productivity is defined by the very specific characteristics mentioned above making them vulnerable to environmental changes and eutrophication.

Species-rich Nardus grasslands

These species include huge variety of sub-types occupying oligotrophic habitat, found on nutrient-poor soils on various types of Siliceous rocks with decreased calcium content in the upper layer of the soil due to intensive precipitation. The grasslands are considered a climax vegetation or in stable state.

Siliceous alpine and boreal grasslands

The grass communities generally occupy the alpine vegetation belt between 1900m and 2900m altitude, most prominently dominating mountain summits and higher altitudes, comprised of mainly endemic boreal and alpine species coexisting with mosses and lichens.

Oro-Moesian acidophilus grasslands

Subalpine and alpine grassland communities typical for the central Balkan Peninsula developed on Siliceous rocks and poor calcium substrate soils from 1600m to 2900m altitude. The grasslands are comprised by a number of Balkan endemic and rare species. The habitats are characterized by dense, closed and unsculptured composition.

Apine and Boreal heaths

The Alpine and Boreal heaths habitat is located above the natural tree line and below the alpine grass formations. The heaths cover terrains with shallow mineral soils, loose rock and sediments on steep slopes which are often unstable and prone to erosion. The quality of the habitats is characterized by the presence and abundance of vascular plants, mosses, lichens and alpine fungi.

8.5 Ecosystem services

The analysis on ecosystem services is based on identification of affected regulation services by anthropogenic impact. The identified services in the study area in Bansko Ski Resort are climate regulation and flood protection by forests as well as erosion regulation and water purification of cultivated ski route grasslands. In the study area of the Seven Rila Lakes the identified ecosystem services are erosion regulation and water purification of natural grasslands and heaths. The first step of the analysis identifies the capacity of ecosystems to generate services based on classification matrix method. After the classification, the capacity of ecosystems is estimated based on their spatial extent in the catchment area. Any deviation from optimal or natural condition reflects the level of the capacity outlined in assessment matrix and these changes are spatially quantified. Additionally, analysis on service capacity dynamics during the past two decades is constructed based on findings from the stakeholder analysis and quantifiable results on ecosystem service capacity, aiming to illustrate how ecosystems change and recover after anthropogenic perturbations.

8.5.1 Classification Matrix of ecosystem service capacity

In order to define and describe the services of the chosen ecosystems and related that information to anthropogenic effects, a landscape capacity approach is used as proposed by Burkhard et al. (2009). A classification matrix is used to assess the capacity of each ecosystem to provide a particular service. The classes use numerical form ranging from 0 to 5. For this study the default values estimated by the authors are used. Some of the values for the area of the Seven Rila Lakes use estimates based on the study from Nedkov et al. (2014).

TABLE 9 ECOSYSTEM CAPACITIES IN THE AREA OF BANSKO SKI RESORT

Ecosystem in the area of Bansko Ski Resort	Regulating Services	Local And Global Climate Regulation	Flood Protection	Water Purification	Erosion Regulation	Cultural Services	Recreation	Natural Heritage
Coniferous Forests	18	5	3	5	5	10	5	5
Grasslands	13	2	1	5	5	7	3	4

0 = No relevant capacity, 1 = low relevant capacity, 2 = relevant capacity, 3 = medium relevant capacity, 4 = high relevant capacity, 5 = very high relevant capacity

The values in the assessment matrix are a combination of default values provided in the study by Burkhard (2009) and Nedkov et al (2014).

TABLE 10 ECOSYSTEM CAPACITIES IN THE AREA OF THE SEVEN RILA LAKES

Ecosystem in the area of the Seven Rila Lakes	Regulating Services	Water Purificatio	Erosion Regulation	Cultural Services	Recreation	Natural Heritage
Heaths	8	4	4	7	3	4
Grasslands	10	5	5	7	3	4
Lakes	0	0	0	10	5	5

8.5.2 Ecosystem Capacity Results in the area of Bansko Ski Resort

The selected area of interest in Pirin covers territories falling into several functional zones. The zoning of the parks defines the regulations within each zone, hence the possibilities for people to obtain ecosystem services. Based on the environmental regulations and the effects from anthropogenic impact, the selected services are regulation and cultural only. Provisioning services are affected indirectly and their condition is difficult to be estimated spatially.

TABLE 11 PIRIN NATIONAL PARK RELEVANT ZONING REGULATIONS

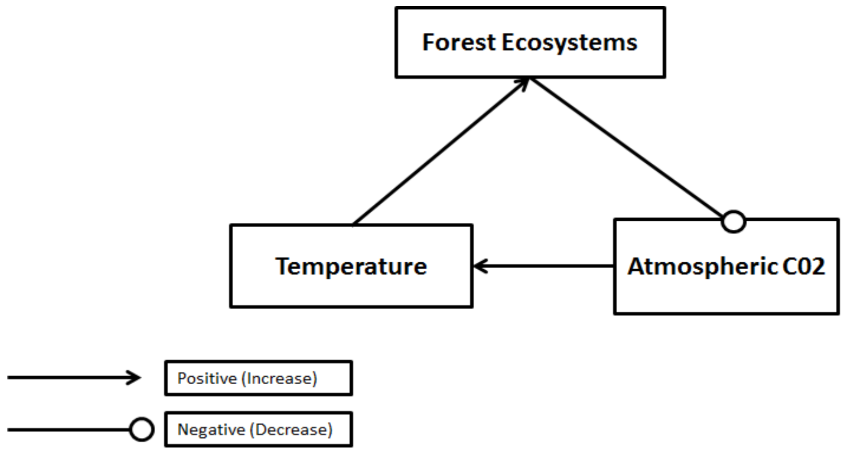
Functional Zone	Zoning Regulation
Natural Reserves	All human activities are prohibited except educational and research activities, ecosystem maintenance under the approval of the ministry of environment and water, after the approval of the Bulgarian academy of science and the Bulgarian council of biodiversity
Zone for limited anthropogenic impact	All human activities are prohibited except hiking tourism, research and educational activities
Zone for ecosystem protection and recreation	All human activities are prohibited except: Fire hazard response and prevention, tourist routes maintenance, hiking and recreation, gathering of wild foods for personal needs, regulation of animal species, pasture.
Zone for Tourism	All activities are prohibited except fire hazard response and prevention, waste management, hiking tourism, gathering of wild foods for personal needs, landscape maintenance, regulation of animal species, sport activities.

Source: Management plan of Pirin National Park (2004-2013)

Local and Global Climate Regulation

Effects of land use change on ecosystem capacity can be quantified as spatial percentage of the total forest area within a spatial boundary, in this case the catchment area. The approach can quantify not only global climate regulation but also local regulation. The local climate regulation comprises the ability of forests to regulate surface temperature and evapotranspiration. In this application the effects on these processes require much higher spatial resolution from remote sensing data, therefore they are out of the scope of the research. Coniferous forests influence the global climate by carbon storage and sequestration. With the ability to absorb atmospheric carbon (CO_2) and release oxygen, forests are considered an important component in climate regulation. To illustrate the relationship (Figure 5) between climate and forests, a system approach is used by Lee R.Kump et al. (2010).

FIGURE 5 FEEDBACK MECHANISM OF FOREST C02 SEQUESTRATION

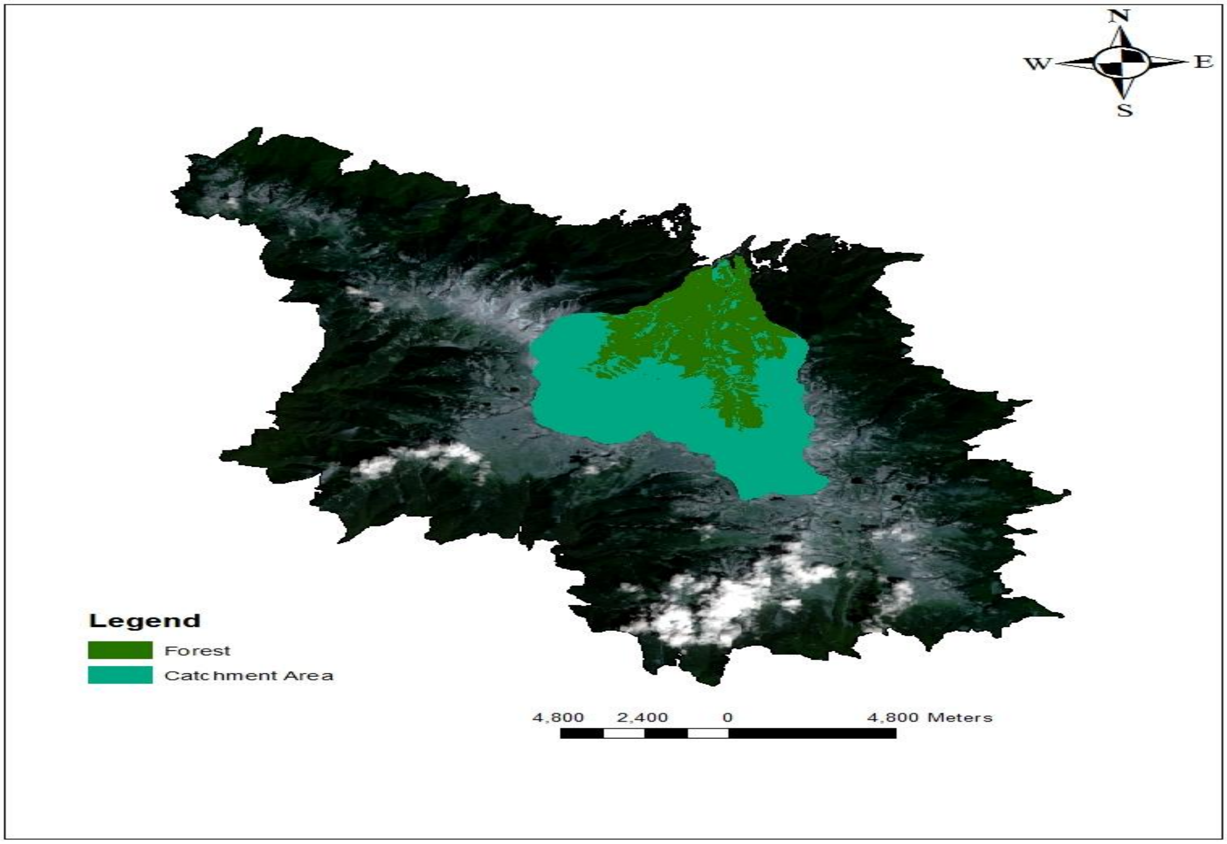


Source: Author

The approach considers the Earth to be a system composed of various feedback mechanisms between sub-systems. These feedbacks describe the relationship between components such as forests, temperature and atmospheric CO2. Relationships can be either positive or negative, respectively to increase or decrease the variables of the affected component. In the given example of feedback mechanism, forests decrease the amount of CO2 in the atmosphere. CO2 concentrations increase temperature and increasing temperature stimulates forest growth. This feedback mechanism alone is stable and components will achieve balance over time. However, due to various sources of C02, forests lack capacity to compensate, respectively rising temperatures especially in mountain ecosystems can cause growth of species with superior adaptation abilities towards dry and warm environmental conditions.

According to the estimations made by FAO (Karsenty et al. 2003) 1 hectare of forest canopy can sequestrate between 6 and 10 metric tons of CO2 per year. It has been estimated that the lost forest territory is 122.64 ha in total of ski routes a chairlifts. Respectively, this coverage equals sequestration capacity between 735.84 to 1226.4 metric tons of CO2 per year. These numbers represented the approximate ranges based on forest condition. The spatial extent of climate regulation and flood protection is equally affected.

FIGURE 6: CATCHMENT AREA IN THE STUDY AREA OF BANSKO SKI RESORT



Background image source: Copernicus Sentinel 2, 2018

To understand the effects of ski infrastructure on flood protection service of coniferous forests a spatial approach has been implemented. The catchment area has been determined based on the lowest water accumulation point in the valley within the borders of the national park. The determination of the extent of the total catchment area has been performed in ArcGIS software. The forest cover data has been provided by the national park agency which has been clipped to the extent of the catchment area in order to estimate the territory of the forests in the catchment area. The catchment area comprises the two valleys of the rivers Bunderishka and Damyanitsa, which are tributaries of Glazne river which flows through the town Bansko. The assessment revealed that on the territory of the park, the tributaries have a total catchment area of 6425 hectares. The catchment area comprises alpine, sub alpine and forest ecosystems. Coniferous forests account for 2168 ha on the catchment area.

The territory of Bansko ski resort and the temporal territorial changes that were previously described in chapter 7 lead to the following estimations:

TABLE 12 SPATIAL CAPACITY OF CLIMATE REGULATION AND FLOOD PROTECTION

Anthropogenic territories	**Territorial coverage** (ha)	**Forested Catchment Area** (ha)	**Loss of Annual carbon sequestration capacity** ***(metric tons/year)***	**Territorial Coverage in catchment area (%)**
Forests affected by construction of ski lifts or ski routes	122.64	2168	735.84 to 1226.4	5.65

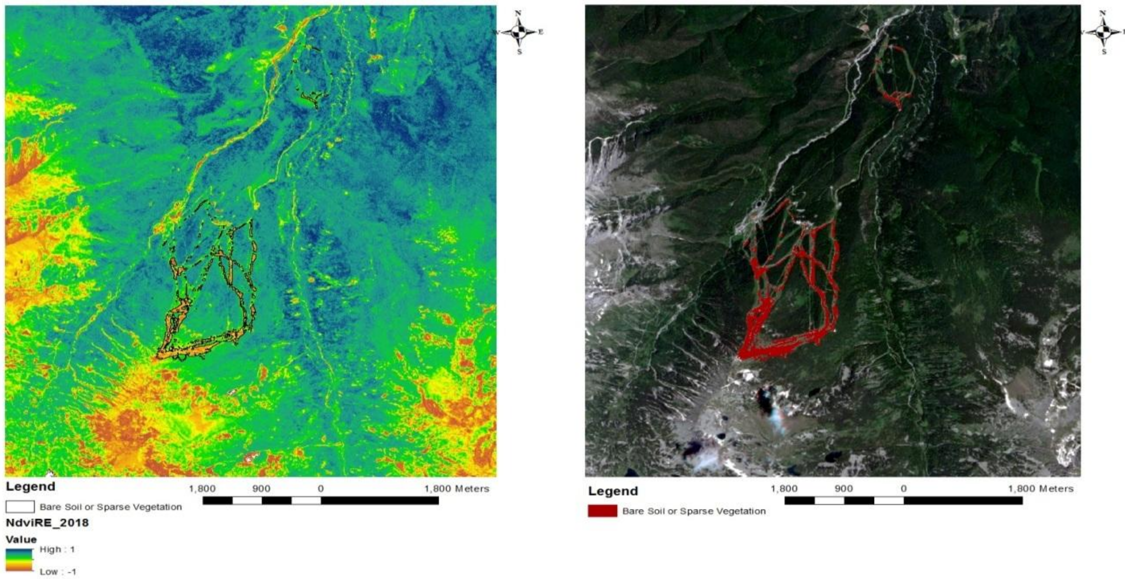
Erosion Regulation and Water Purification

According to the proposed Project management plan of Pirin national park (2014-2023), the territory of ski routes of Bansko ski resort cover 116, 1 ha. The vegetation on the ski routes is combination of naturally cultivated and artificial grasslands. Depending mainly on microclimate conditions and anthropogenic factors (trampling, use of artificial snow, water erosion, etc.) the grassland vegetation density and composition can vary. The proposed management plan suggests that 13, 9% of the ski routes with vegetation cover between 0%-30% is threatened by erosion. The measures against erosion consist of sowing, run off trenches and infrastructure for slope stability at location already exposed to intensive erosion processes. The area of the ski routes is considered prone to erosion due to mainly the anthropogenic impact of clear cutting and use of heavy machinery on the ski routes in combination with the considerable slope steepness of the area.

The capacity of grasslands to prevent erosion is estimated to be highly relevant according to the classification matrix. A spatial approach is used to determine the area of the ski routes which does not have sufficient capacity to provide erosion regulation services. For the calculation, Normalized Difference Vegetation Index (NDVI) index has been calculated with cloudless RapidEye satellite image July, 2018. The resulting NDVI image has been classified using polygon selection of sparse vegetation or bare soil samples sites, grasslands and coniferous forests with values based on the results from Q. Hassan et al. (2019). From the resulting classification image of the whole area, the total estimated territory of sparse vegetation or bare soil has been estimated to be 57, 1 ha or 49, 1% of the territory of the ski routes. Ski roads have been excluded from the calculation to avoid erroneous results.

The visual representation of the results is shown with the maps below, respectively with NDVI and RGB background:

FIGURE 7 CALCULATION OF SPATIAL EXTENT OF AREAS PRONE TO EROSION



An additional classification has been applied to separate sparse vegetation and bare soil. The estimated area of bare soil on the ski routes is 15, 93 ha, which is 13, 66% of the total ski run territory which is close with the estimate provided by the directorate of the national park. The results reveal that nearly half of the territory of the ski routes has vegetation density below the optimum values for sufficient generation of erosion regulation and water purification services.

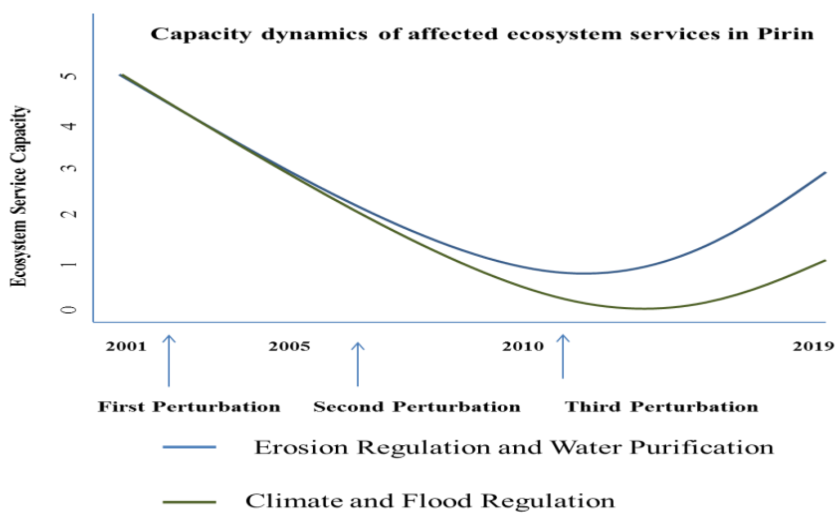
TABLE 13: EROSION AND WATER PURIFICATION CAPACITY OF SKI ROUTES

Land Use Type	Erosion Regulation Service Capacity *(values used from the assessment matrix of Burkhard et al. 2009)*	Area	Percentage of total area
Bare soil	0	15,93 ha	13,7%
Sparse Vegetation	1-4	41,17 ha	35.4%
Dense Grasslands	5	59 ha	50.9%

Capacity Dynamics of affected ecosystem services by anthropogenic impact

After the approved concession contract and modified TAP of Bansko ski resort, the initial construction of new ski infrastructure marks the first stochastic perturbation for ecosystems on the territory of the concession area. The second perturbation is linked to the expansion after the modifications made in 2005 and the third perturbation is the modernization of the infrastructure in 2010. In this example the intrinsic and extrinsic variability are not taken into account (because their variability is hard to be estimated and related to anthropogenic impact), although these do play an important role for recovery of ecosystem capacity. The removal of forest cover caused rapid decrease of the capacity to regulate all ecosystem services. The recovery rate of the affected area was based on slope reconstruction and replantation of new vegetation. The maximum capacity of erosion regulation and water purification remains highly relevant as both forests and grasslands can provide highly relevant capacity. The 3 episodic perturbations differ in severity and spatial extent. Therefore, 3 states are assumed, the initial state, the state after the last perturbation and the current state. By 2011, the ski routes have low relevance for erosion regulation and water purification. Visual interpretation of satellite images and NDVI analysis revealed the slow rate of recovery of vegetation after the first perturbations.

FIGURE 8: CAPACITY DYNAMICS OF AFFECTED ECOSYSTEM SERVICES IN PIRIN



Source: Author

As measured in 2018, the ecosystem capacity ranges between 0 and 5. Based on the given numbers for spatial extent and eroded areas, currently the ecosystem capacity of grasslands on the territory of the ski resort is estimated to have medium capacity to regulate water quality and slope stability on average. However, during the assessment period of 17 years, some areas on the ski tracks did not recover any capacity to generate regulation services. These areas are highly affected by loss of top soil lair and show inability to sustain vegetation cover, which was caused by the graded ski route practice of removal of tree trunks resulting in slope instability.

The climate and flood regulation capacities show different outcomes. Following each perturbation and the ecosystem transformation from forest to grasslands, the potential to generate highly relevant climate regulation capacity decreased to relevant capacity. The capacity to regulate floods decreased from medium to low. This explains the lower recovery and inability to restore the previous capacity of these services. It has been estimated that currently, the grassland ecosystems on the territory of the park have low relevance to generate climate regulation and flood protection services.

Based on previous results it can be concluded ecosystems in the study area of Bansko Ski Resort have different response rate for recovery of their ecosystem services. The effects from the anthropogenic impact on ecosystem service capacity of water purification and erosion regulation may be recovered long term with appropriate maintenance practices. The maintenance practices implemented in the past 17 years have failed to recover the full capacity of these ecosystem services. On the other hand, the capacities for flood protection and climate regulation cannot be restored to the previous extent and the effect is permanent due to the land cover change and the differentiating service capacities of forests and grasslands to generate those services.

8.5.3 Ecosystem service capacity in the area of the Seven Rila Lakes

Intensive use of footpaths for recreation purposes can negatively affect soil substrate's stability and composition, leading to negative impacts on erosion regulation and water purification capacity of heaths and grasslands. As previously mentioned in Chapter 7, footpath trampling and can lead to loss of vegetation cover while areas with greater slope steepness and shallow top soil layer can develop gully erosion. Furthermore, plants have the ability to uptake pollutants like phosphorus and nitrogen from the soil. Loss of vegetation cover can decrease water quality. Different forms of nitrogen (nitrate or ammonia) can cause eutrophication and acidification of water resources. Phosphorus is another pollutant responsible for eutrophication of waters and soils, often being transported with sedimentation, which is further increased by gully erosion and can cause excessive growth of algae in lake ecosystems (Stevens, 2008).

In order to quantify the effects of intensive use of hiking trails on erosion regulation and water purification, a spatial approach is used to identify the territory of the ecosystems in the catchment area of the lakes and the territory of the affected area by footpath trampling and erosion. There are two types of hiking trails in the area of the Seven Rila Lakes, primary and secondary. Their total length based on the provided GIS data by the national park agency is 5538m. Based on fieldwork assessment, several differences have been found between the data and the primarily used trails by tourists. Some of the primary trails differentiated from the most common routes tourists use and some of the secondary trails were missing. In order to address the missing data, trail vectors were corrected and missing secondary trails were included. The main difference were spotted at the area of “”Platoto” where the tourist flow is directed at shorter route, while the alternative route between the old hut and the Bubreka lake was missing from the data. The corrected data accounted for 7692 m of trails.

After fieldwork assessment (Annex 2) and further investigation through google earth imagery, it has been observed that trails vary greatly in dimensions. There aren't any standards provided in the management plan of Rila NP that state the specific width dimension of hiking trails. The dimensions of trails outside the intensive anthropogenic impact area have been assessed to build reference measurement between intensive and normal use. Their dimension varied based on topographical features that are area specific, although a maximum width of 1 m can be chosen for reference.

In order to quantify the total area of the trails, several width measurements were taken and based on the length of the trail sections buffers were computed, resulting in the following measurements:

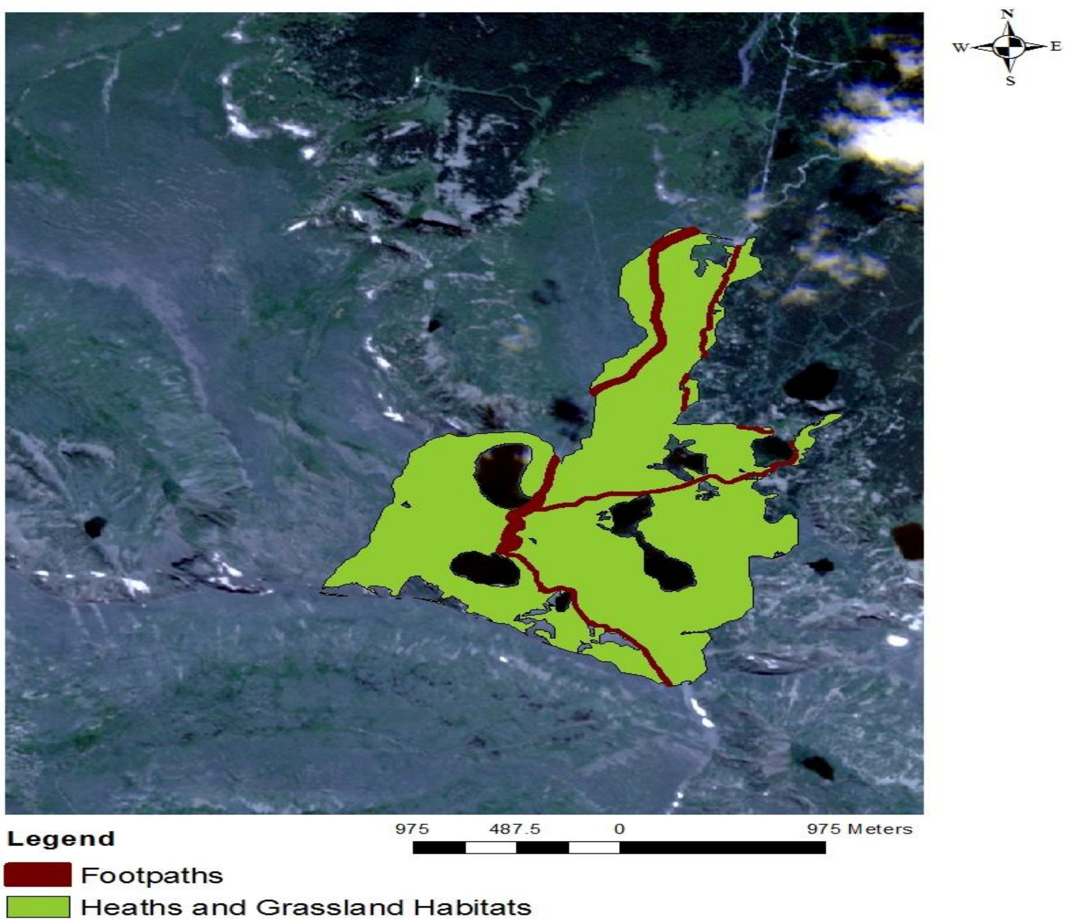
TABLE 14 FOOTPATH'S BUFFER LENGTH AND WIDTH

Buffers	**Footpath Length**
2 meters	4916 meters
10 meters	1415 meters
20 meters	816 meters
Total Length	**7692 meters**

The buffers do not represent the actual path width but the progressively degrading area by footpath trampling and/or footpath erosion, meaning that vegetation can be present within the buffer but is experiencing anthropogenic pressure due to unregulated tourist flow.

After the trail selection and buffer estimation, the catchment area of the lakes has been determined. A selection of the spatial extent of heaths and grasslands within the catchment area that accommodate the trails was identified and the parts of the trails that did not fall within the catchment area of the lakes or within the chosen habitats were excluded from the assessment.

FIGURE 9 FOOTPATH'S SPATIAL EXTENT IN THE CATCHMENT AREA OF THE SEVEN RILA LAKES



Background image source, Planet Labs RapidEye, 2015

Based on this assessment it has been calculated that heaths and grassland habitats cover an area of 287 ha (Figure 9). The total area affected by intensive footpath trampling and erosion is 7, 87 ha or 2, 74% of the total area of the ecosystems. In order to calculate the extent to which footpaths without intensive anthropogenic impact differ from footpaths with intensive use by tourism, the buffer size of each section was multiplied by its length and the sum of all section was divided by the total length of the trails. This is expressed with the following formula:

B j – Buffer size
L i – Footpath Length

B avg. – Average buffer size

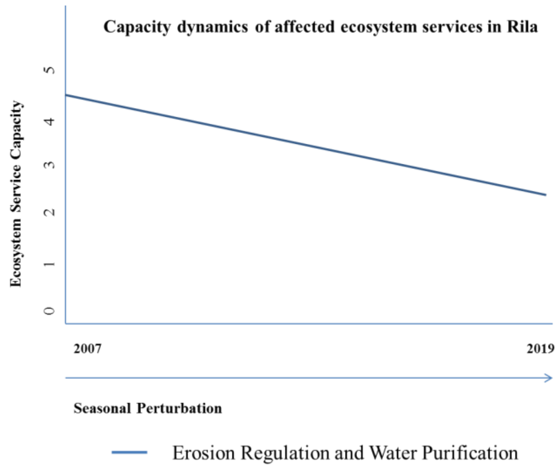
$$\boldsymbol{B\ avg}. = \frac{L\ 1 \times B\ 1 + L\ 2 \times B\ 2 + \cdots L\ i \times B\ j}{L\ 1 + L\ 2 + \cdots L\ i}\ meters\ (m)$$

Based on the data provided in the graph above**, B avg.** is estimated to be 5,95 meters or on average the intensively used trails in the Seven Rila Lakes valley are nearly 6 times wider in comparison to trails with not impacted by unregulated tourism in the national park. It is important to note that unregulated hiking tourism can hardly be traced and quantified. Various unregulated trails are not included in the current assessment along with other areas outside of the paths, which are often accessed by tourists. According to the Rila NP, in the zone for limited human impact, it is prohibited to visit areas outside the regulated hiking trails.

Capacity Dynamics of affected ecosystem services caused by anthropogenic impact

The perturbation in the catchment area of the Seven Rila Lakes is continuous and on seasonal basis, during summer months when snow cover is not present. In this assessment the initial and current state are assessed assuming territories had high to very high relevance to generate erosion regulation and water purification before the start of the perturbation. The use of 2007 as a base year can be arbitrary due to the fact that anthropogenic pressure was present before this point in time, however the anthropogenic pressure was not classified as unregulated and intensive. The spatial extent comprises the buffer areas around the footpaths. Due to the existence of the footpaths some of the area is generally without vegetation cover. The seasonal footpath trampling resulted in ongoing and continuously degenerative capacity of ecosystems services expanding the territory of non-vegetated surface. The spatial extent does not provide the ability to assess further and disseminate the capacity scale.

FIGURE 10: CAPACITY DYNAMICS OF AFFECTED ECOSYSTEM SERVICES IN RILA



Based on the field assessment, it can be concluded that affected territories in the buffer zones have relevant capacity to prevent erosion and purify water. However, ongoing erosion resulted in complete removal of top soil lair and no relevant capacity is observed in many locations. Over time grassland habitats are losing their resilience to return to original state before the next seasonal perturbation. The gradual decrease in soil stability and vegetation density causes the inability of grass species to naturally re cultivate the affected area, which is a major threshold for generation of regulation services.

8.5.4 Cultural Services

National Heritage

Cultural services of Pirin and Rila mountains stem from historical events dating back to the Neolithic age. Human presence on the territory of the mountains is described through preserved evidences from Thracian, Roman and Slavic settlements, cultural and language relicts (Raduchev, 1988). In more recent history bound to the preservation of Bulgarian culture through the centuries of ottoman rule between 14 and 19 century, the mountains are considered a protector of the nation. Rila and Pirin mountains provide shelter for haiduks (freedom fighters) and revolutionists. The remoteness of the mountains was able accommodate secret meetings and gatherings during the planning and preparation of the Bulgarian uprising (Dushkov, 1982). These circumstances result in a number of historical battles and events leading to the establishment of monuments and historical sites with national heritage value.

Recreation

Bansko ski resort is located within "Vihren" regional department of the national park. The regional department is characterized by the highest number of annual visitors in comparison with the rest of the park. Monitoring of tourist flow shows varying numbers per years, mostly affected by weather conditions but with tendency of growth of visitors on the territory of the park. According to the proposed management plan, approximately 140000 ski tourists visit Bansko annually. Accommodation in the region accounts for 18274 beds and lift capacity is 21000 persons per hour. Based on the given capacity and demand for ski sports, the present ski infrastructure is underutilized. In comparison to other European resorts which have 5 times more visitors per available accommodation, Bansko ski resort would reach similar ratio with 670000 annual visitors (WWF, 2018).

The tourist flow has been more extensively monitored in Rila national park. The average visitors of the park per year are 100000 for the period between 2000 and 2014. Between 2000 and 2007 the annual visitors rate is stable and remains unchanged over time. After the year 2007, the amount of visitors marks a sharp increase from approximately 50000 per year to nearly 250000 in 2012. Based on park regional departments, the most visited park showing considerable increase is Dupnitsa where the 7 Rila Lakes valley is situated. Approximately 45000 people visit the regional department of the park for the period between 2000 and 2014. In 2015, an assessment on tourist flow in the Seven Rila Lakes area has been conducted by the Sustainable Mountains NGO. The assessment estimated an average of 1858 visitors per day with number varying between 900 and 3300 daily visitors during the summer season.

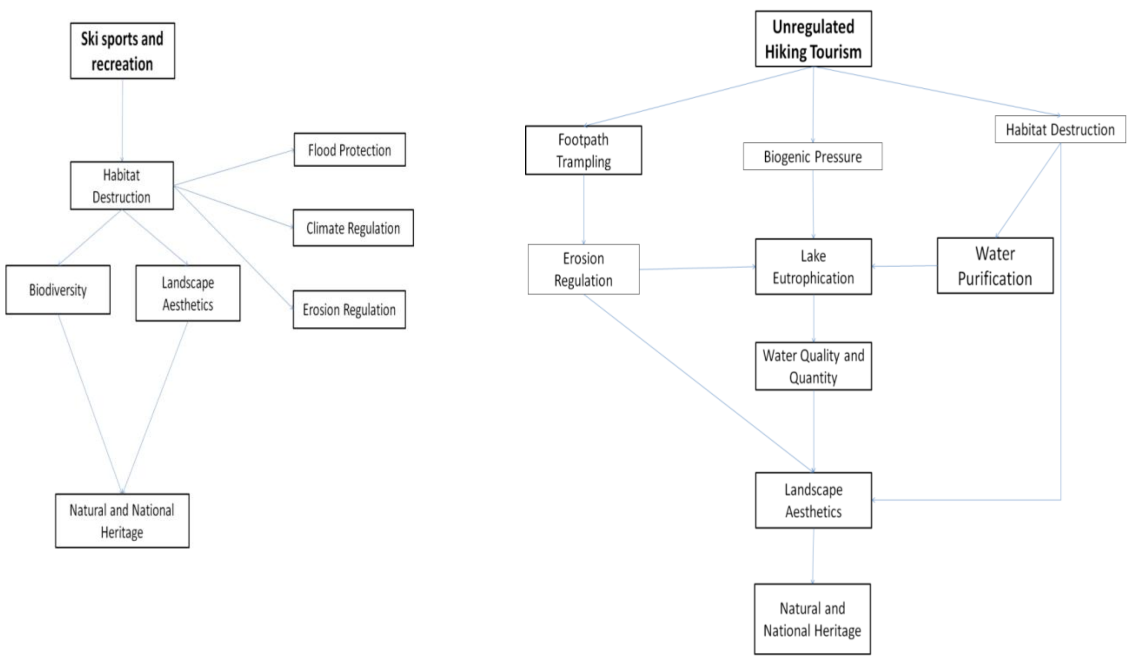
Natural Heritage

And while the human influenced cultural services develop during the last 14 000 years, the development of biotic and abiotic environment of the mountains as seen today originates during the Pleistocene era. Both Rila and Pirin experienced glaciations covering the areas between 1300m and above leading to formation of various types of cirques, glacial lakes, moraines and trough valleys (Tonkov, 2011). The geological processes shaped up typical but diverse aesthetical landscape features. The landscape heterogeneity of Rila and Pirin is considered an important determinant for the biodiversity of the mountains (Tews Ju, 2004). The territory of the mountains holds considerable part of the flora found in the country, consisting of nearly 1400 vascular plants, several hundreds of mosses, lichens and fresh water algae species. The fauna is represented by nearly 50 species of mammals, hundreds of bird species, nearly 3000 species of invertebrates, hundreds of which are considered endemic.

Linkages between cultural and regulation services

The cultural services can be disaggregated in two categories based on their relation to anthropogenic impact and ecosystem condition. The first are the recreation purposes involving human presence and intervention in ecosystems developed for economic and social benefits. The second involves the regulation of human presence and interventions in ecosystems characterized by environmental laws and procedures on local, regional, national and international level aiming to preserve values of natural and national heritage. These two categories have specific effects on other ecosystem services and vary between the two case studies in Rila and Pirin.

FIGURE 11 LINKAGES BETWEEN CULTURAL AND REGULATION SERVICES



The construction of the ski resort caused destruction of forest habitats and land use change to grasslands on ski routes and chairlift. The habitat destruction led to loss of biodiversity and aesthetic value of the area. Additionally the anthropogenic impact of ski infrastructure led to changes in ecosystem services but also affected the value of natural and national heritage. The impacts from anthropogenic impact of unregulated tourism caused a more complex process in ecosystem services and functions. Tourism cased pressures like footpath trampling, biogenic pressure and destruction of grassland and heath habitats. Lake trophic levels, quality and quantity of water resources have combined effects from fluctuating ecosystem services and biogenic pressure. Loss of habitats and erosion processes affect landscape aesthetic value and the value of biodiversity of ecosystems, respectively has negative effects on the natural and national heritage.

CHAPTER 9: ANTHROPOGENIC IMPACT ON SOIL LOSS IN THE CATCHMENT AREA OF THE SEVEN RILA LAKES

The following analysis on soil loss and its effects on lake ecology aims to complement results from other studies and disciplines. Therefore, the approach builds on previous findings for trophic levels of lake waters, effects of ongoing erosion, climate change effects on the environmental components and monitoring of tourism in the study area. Through the performed desk study, the field work and the ecosystem service capacity results, areas prone to erosion and footpath trampling are identified. The characteristics and effects of tourist flow on the environment are related to the specifics of the lake system and the water accumulation in particular. Based on these interactions the link between footpath trampling and lake ecology can be identified. Modelling of soil loss risk is performed to locate areas prone to erosion and relate these areas to the footpath routes.

The ecological state of the Rila Lakes has been recorded through several studies in the past decades focusing on seasonal changes of biochemistry of lakes and biochemical properties of phytoplankton, zooplankton and bacterioplankton communities in relation to environmental changes and anthropogenic impact. Based on previous conclusions, a tendency for increasing air temperatures result in degenerative processeses like eutrophication and increased sedimentation in the catchment area, which is further stimulated by intensive anthropogenic impact (Kalchev et al., 2004, Ognjanova-Rumenova et al., 2009, Nikolova et al., 2012, Ilieva et al., 2015, Ognjanova-Rumenova et al., 2019). The lakes are characterized by medium to predominantly low productivity due to the considerably low temperatures and poor nutrient availability, therefore rising surface temperature or a small nutrient increase from the catchment area caused by enhanced rock weathering and soil erosion can disrupt the environmental balance and cause changes in composition of species and biodiversity. Air temperature has been considered to be the crucial factor for the ecological state of the lakes. It has been observed that depth of the lakes is influenced by surface temperature, rather than from precipitation. This would lead to increase of lake water temperatures, thus higher evaporation during dry periods. The lakes differ in their ecological characteristics based on their altitude, the catchment area and water depth and volume. Water temperature decreases as the altitude increases. The lakes influenced by eutrophication are the ones with the lowest depth and situated at lower altitude, namely Dolnoto, Ribnoto and Trilistnika. However, eutrophication has been observed in Bliznaka as well, which has a shallow portion of its surface area (approx. 3.78 ha.) resulting in a mean depth of 6.5 m. Regarding the structure of the lake system, Salzata, Okoto and Babreka are not linked, their discharged waters flow directly to Bliznaka and the lower lakes form a connection with each other. Bliznaka has been classified as mesothrophic lake meaning it has medium productivity, which is higher than oligothrophic or low productive lakes like Okoto or Babreka.

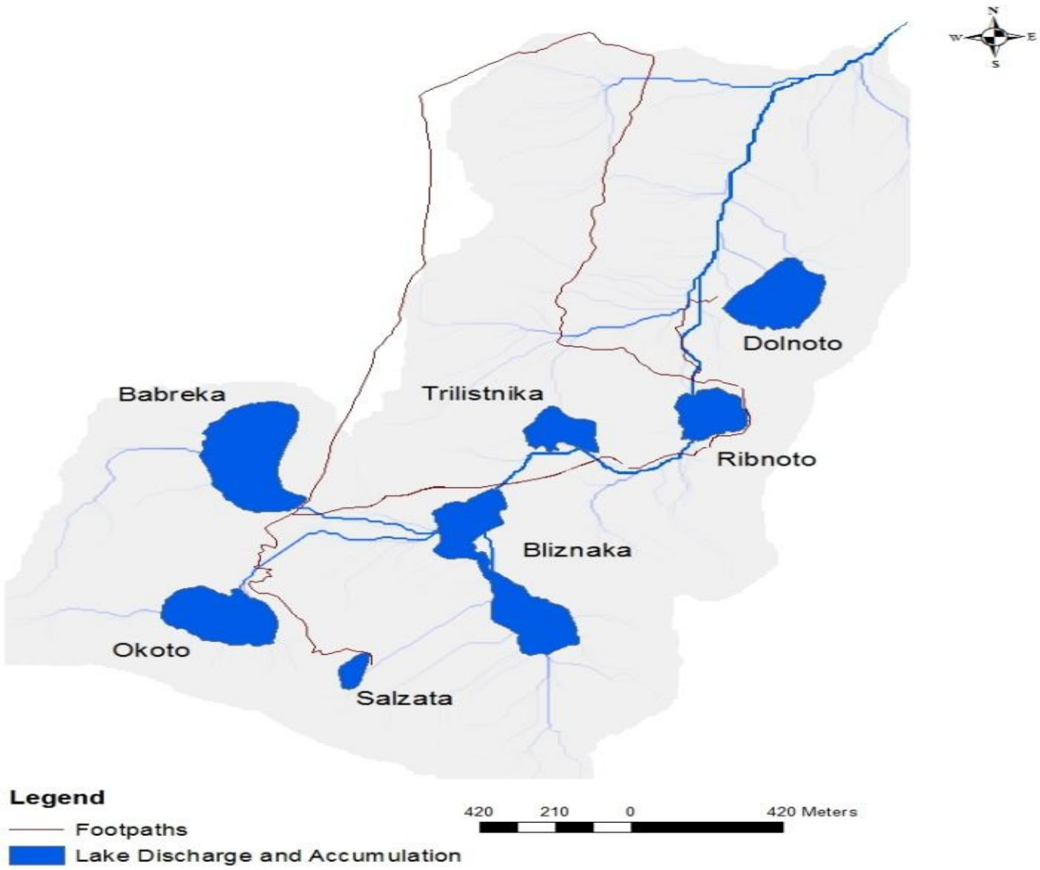
TABLE 15 MORPHOMETRIC CHARACTERISTICS OF THE SEVEN RILA LAKES (BOTEV, 2000)

Lake	**Altitude (m)**	**Depth (m)**	**Catchment Area (ha)**	**Water Volume (m3)**	**Surface Area (ha)**	**Average Surface Water Temperature**
Salzata	2535	4.5	18	15 000	0.70	9.7
Okoto	2440	37.5	36	860 00	6.80	10
Babreka	2282	28	56	1 170 000	8.5	10
Bliznaka	2243	27.5	210	590 000	9.10	12.5
Trilistnika	2216	6.5	228	54 000	2.60	12.7
Ribnoto	2184	2.5	273	38 000	3.50	12.8
Dolnoto	2095	11	300	240 000	5.90	14.5

The increased productivity, which was formed during the second part of 20 century, is characterized by higher bacterioplancton and significantly higher phytoplankton abundance (Kalchev et al., 2004). According to the same study, Bliznaka is classified as a lake with high anthropogenic impact, which is seen as major cause for increase in bacterioplancton in lake ecosystems. Boteva (2006) reports increase in both diversity and abundance of bacterioplankton over the course of the summer, while Boteva et al. (2013) results show decrease in diversity but increase in abundance from July to September. The results show varying indicators for biodiversity of bacterioplankton species and suggesting for higher biodiversity markers before the construction of the chairlift.

The most visited lakes in the summer of 2015 were Salzata, Okoto and Babreka (Sustainable Mountains, 2015). Based on the previous mapping of footpath extent, the effects of unregulated tourist flow may pronounce itself elsewhere in the watershed based on accumulation of rainfall, lake discharge and areas prone to soil loss. Based on the constructed buffers, the area with intensive erosion processes is situated between Babreka and Okoto. This area does not fall within the catchment area of those lakes despite that tourist flow is concentrated there, rather than it falls within the catchment area of Bliznaka and the connected lake system below. Increased soil loss and sediment transport has been seen as factor for delta formation in the vicinity of Bliznaka (Nikolova et. al. 2012).

FIGURE 12 WATER ACCUMULATION OF THE SEVEN RILA LAKES

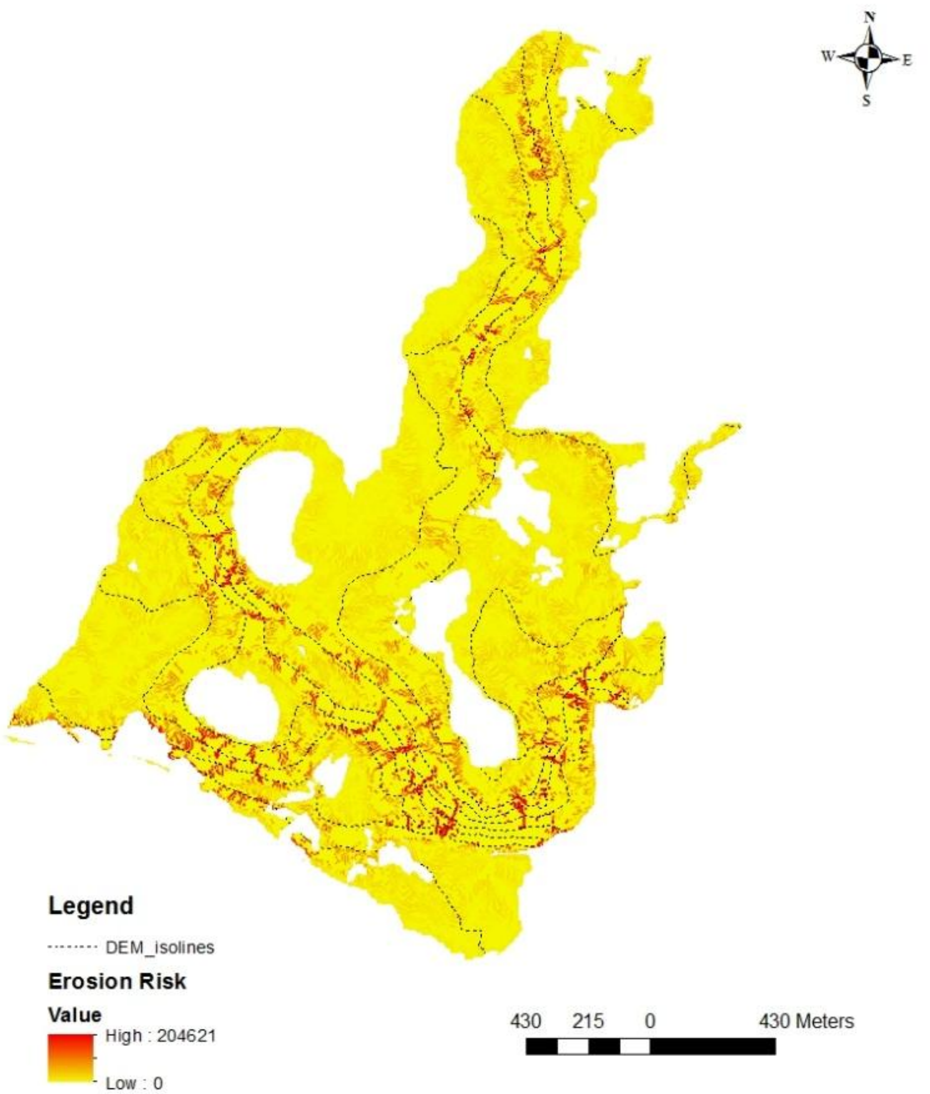


Data Source: Planet Labs (Rapid Eye 2015)

The increased soil loss above Babreka is not only due to intensive use of footpaths by tourists but due to a combination of topography and sensitive top soil lair. The area is situated at the foothold of the highest terraces of the cirque and is characterized by higher slope steepness.
A spatial approach is used to identify erosion risk areas through the application of RUSLE erosion model in GIS environment. The model consists of DEM data as input for slope length and steepness calculation. Rainfall erosivity data provided by ESDAC, soil erosivity calculated based on FAO data calculation of the Hazen–Williams equation. Land cover classification has been performed through NDRE estimation and classification based on the index values for

grasslands and heaths habitats and rocks. Land cover values for the calculations are assigned based on the results from Rozos, et al. (2013). The last component is conservation map which has been set as uniform value of 1, or no indication of conservation practices.

FIGURE 13 EROSION RISK IN THE CATCHMENT AREA OF THE SEVEN RILA LAKES



Based on the results and technicalities for the application of erosion modeling in the alpine region, it can be concluded that the main environmental factor for soil erosion risk areas is the slope length and slope steepness on areas with natural grassland and heath habitats. The RUSLE model is generally used for quantification of soil loss (tons/ha/year), however, making a precise estimate will be unreliable due to the varying snow cover and lack of weather stations and long term monitoring in the region. The model proved useful for identification of erosion risk areas in the catchment area, without specifying or quantifying the extent of these processes. Based on the spatially represented data, most of the regions with higher soil loss constitute on the steeper slopes in the valley.

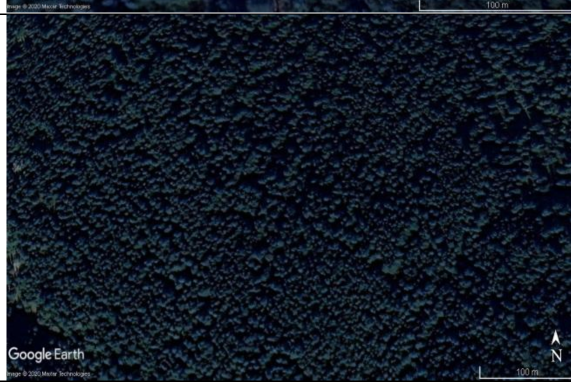
The identification of erosion risk areas can be related to the catchment areas of the lakes. Soil loss is particularly high in the catchment area of Babreka and Okoto, while it is the highest for Bliznaka. The results show that the tourist path with the largest estimate width of the buffer is within an area having a high risk of erosion.

CHAPTER 10: TIME SERIES OF FOREST CANOPY REFLECTANCE

10.1 Effects of Forest Density on NDRE pixel values

Both Pinus Heldreichii(PIHE) and Pinus Peuce(PIPE) are forming forests withvarying age of trees, structure and spatial composition. As previosly described forest density can be a result of forest age and natural hazards in areas not affected by anthropogenic impact. The density of the forests has a direct impact on NDRE pixel values. For the purpose of this study dense forests are of high importance since the value of each pixel will be comprised by a higher number of tree crowns. Forest with low canopy density will provide lower values due to a mix between tree crowns and forest understory, which is not desirable for the assessment of anthropogenic stress factors.

TABLE 16 FOREST DENSITY OF PIHE AND PIPE

Tree Species	Young Forests	Old Forests
Pinus Heldreichii		
Pinus Peuce		

In order to determine the ranges of these effects the NDRE values of sample sites of old and young forests will be compared. 8 sample sites with referenced age have been chosen for each of the two tree species. The objective is to collect the range of values that can characterise the least dense forest per tree specie and the most dense forest, which are mostly represented by homogenous young forests. Samples from both affected and unaffected territories by anthropogenic activities are selected for this comparison but are not reviewed separately. The resulting value ranges will serve as reference for the time series comparison.

TABLE 17 DESCRIPTION OF SAMPLE SITE OF PIHE AND PIPE (ANNEX 3)

Sample Site PIHE	**Age Description**	**Lat/Long**
1	Mixed (100-1300 yrs.)	41° 46.020'N 23° 25.394'E
2	Old (300-600 yrs.)	41° 46.128'N 23° 25.234'E
3	Old (400-500 yrs.)	41° 46.484'N 23° 25.382'E
4	Old (400-500 yrs.)	41° 47.205'N 23° 25.328'E
5	Young (100 yrs. and single older trees)	41° 46.070'N 23° 25.471'E
6	Young (100 yrs.)	41° 46.441'N 23° 25.505'E
7	Young(100-150 yrs.)	41° 46.495'N 23° 25.805'E
8	Young (150-200 yrs.)	41° 46.572'N 23° 25.586'E

Sample Site PIPE	**Description**	**Lat/Long**
1	Mixed (100-600 yrs)	41° 45.972'N 23° 26.569'E
2		41° 45.602'N 23° 28.293'E
3		41° 45.928'N 23° 28.207'E
4		41° 46.658'N 23° 29.068'E
5	Young (100 yrs.)	41° 46.362’N 23° 26.242’E
6	Young (80-100 yrs.)	41° 46.298'N 23° 26.743'E
7	Young (100 yrs.)	41° 46.590'N 23° 28.235'E
8	Young(100 yrs.)	41° 47.293'N 23° 28.483'E

10.1.1 Forest Density Results

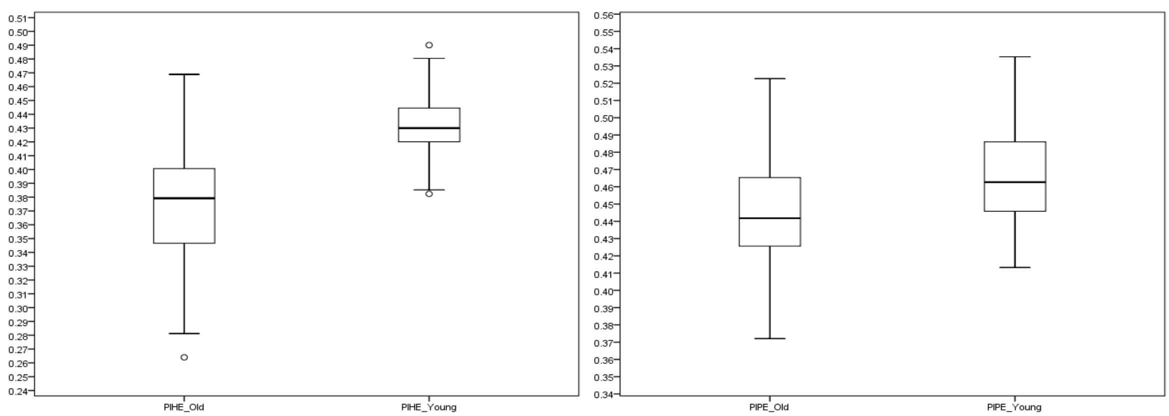
The resulting ranges of NDRE values involve samples from the 5 year time period of assessment and can represent the expected deviations that can occur from the multi-annual data. As expected old grown forest of PIHE observe the largest range of values and can be clearly separated from younger or even mid age forests. Old PIHE forests have mean NDRE value of 0.374, a maximum of 0.469 and a minimum of 0.264. The 25 percentile is estimated to be at 0.346 and the 75 percentile is 0.400. Young PIHE forests have mean NDRE value of 0.431, a maximum of 0.490 and a minimum of 0.382. The 25 percentile is at 0.412 and the 75 percentile is at 0.444.

The PIPE samples show slightly different outcomes. Old PIPE forest have a mean value of 0.447, a maximum of 0.522 and a minimum of 0.372. The 25 percentile is at 0.425 and the 75 percentile at 0.466. For young forest the mean value is at 0.464, the maximum at 0.535 and a minimum at 0.413.

Based on the results it can be estimated that low density PIHE forests are characterised by considerably lower values involving pixels with little to no trees. Up to 75% of the data on the territory of these forest is below 0.400, which is slightly above the minimum of young PIHE forests. This suggests that investigation of ecosystem health of old grown PIHE forest through remote sensing methods should be performed at much higher spatial resolution for other applications. Young PIHE forests have the majority of the NDRE values above 0.400 with slightly lower range of values in comparison to PIPE.

The margins between old and young PIPE forest is slim. A main distiction can be main between the lowest values of both samples. Young PIPE does not fall below 0.413, while 25% of the old PIPE data is below 0.425.

FIGURE 14 FOREST DENSITY RESULTS



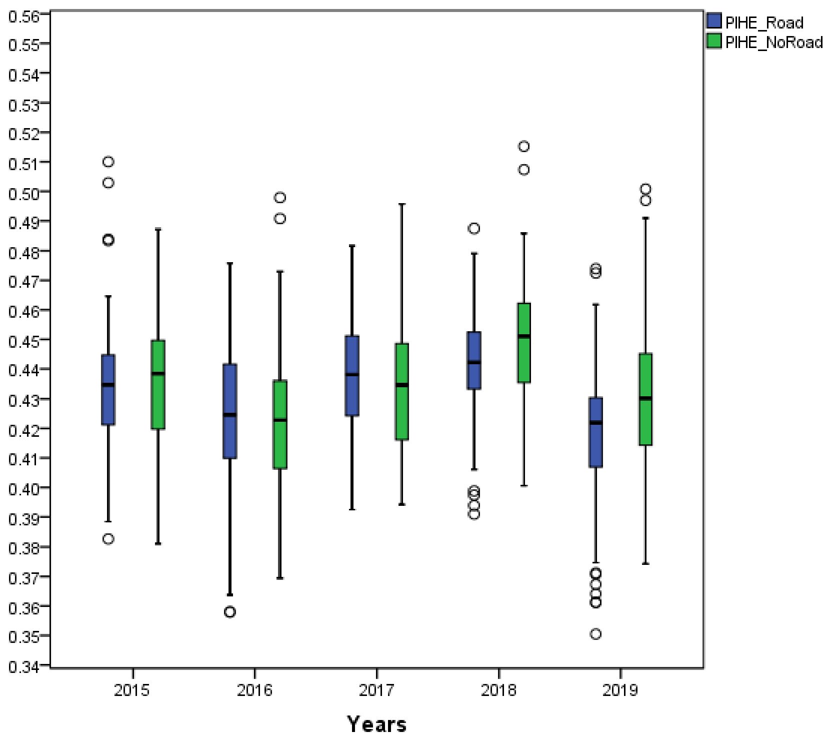
It can be concluded that older PIPE forests have higher forest density in comparison to old grown PIHE forests. The reference range of NDRE values for young forests time series reveals that values below 0.400 mark should be carefully evaluated and considered. Values above 0.550 should be excluded and marked as erroneus data.

10.2 Time Series of Young Forests

10.2.1 Pinus Heldreichii

Based on the previous analysis, a new set of sample site has been selected. Despite that PIHE forests have been subject to widespread logging practices in the past, the most prominent anthropogenic factor in recent years is the road connection between Bansko and Vihren hut. A total of 0.636 ha of young PIHE forests near the road has been selected and 0.606 ha in remote locations. The two sets of data have been compared for each year in the assessment period. It can be observed that both sets of data follow similar pattern in their values in the assessment period. Both sets of data do not show a pattern in their values which could suggest a notable change in their ecological condition. The 75 percentile of the forest near the roads is above the 25 percentile of the remote PIHE forests during all years of the assessment, suggesting that there isn't a considerable difference between the two sets of data.

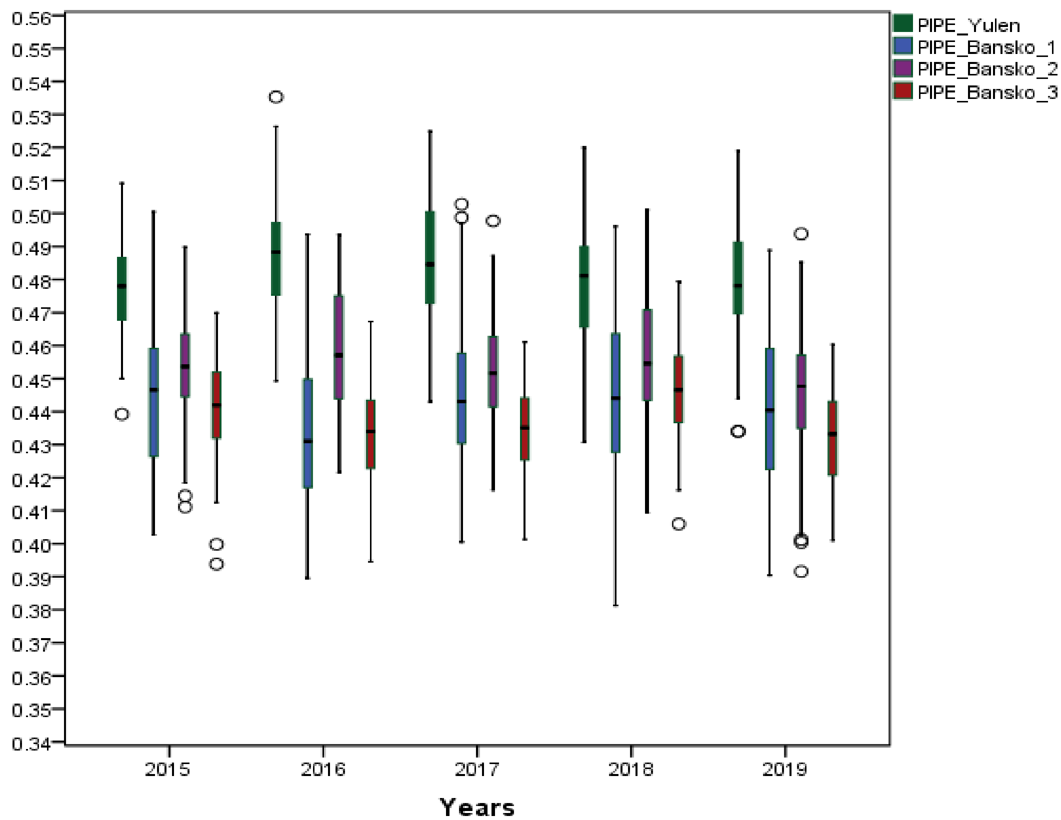
FIGURE 15 PIHE TIME SERIES



8.2.2 Pinus Peuce

The majority of forests above the altitude of 1850m in Bansko ski resort are PIPE forests and 4.362 ha have been selected for assessment. In comparison PIPE forest cover large forest territories in Yulen reserve at similar altitude and 4.518 ha have been selected for the assessment. In contrast to PIHE, here a more detailed approach is used to locate and described the results. The Yulen samples of all years have been added as a single reference class of values to which 5 samples of forests affected by ski routes are compared. The samples near the ski routes are buffered by 2 pixels, or 20 meters in order to avoid pixels with mixed habitats leading to the exclusion from the assessment of trees situated in the border between the forest and the ski routes.

FIGURE 16 PIPE TIME SERIES WITH SIGNIFICANT DIFFERENCE



The first set of samples represents 3 samples from affected territories by ski infrastructure. All of these samples represent forests which are segregated from the rest of the forest canopy by ski routes. Bansko 4 are forests located on the outer side of the ski routes, bordering the ski resort to the southeast only. Bansko 5 is a segregated forest section represented by a mixed forest of PIPE and Pinus Silvestris. The time series assessment reveals no considerable trends in ecological condition of all samples either affected or unaffected by anthropogenic activities. A notable difference is observed between the affected and unaffected territories in terms of range of NDRE values. The values of Bansko 1, 2 and tree fall below the 25% of the Yulen samples suggesting for significant difference between the two sets of young forests.

FIGURE 17 PIPE TIME SERIES WITH INSIGNIFICANT DIFFERENCE

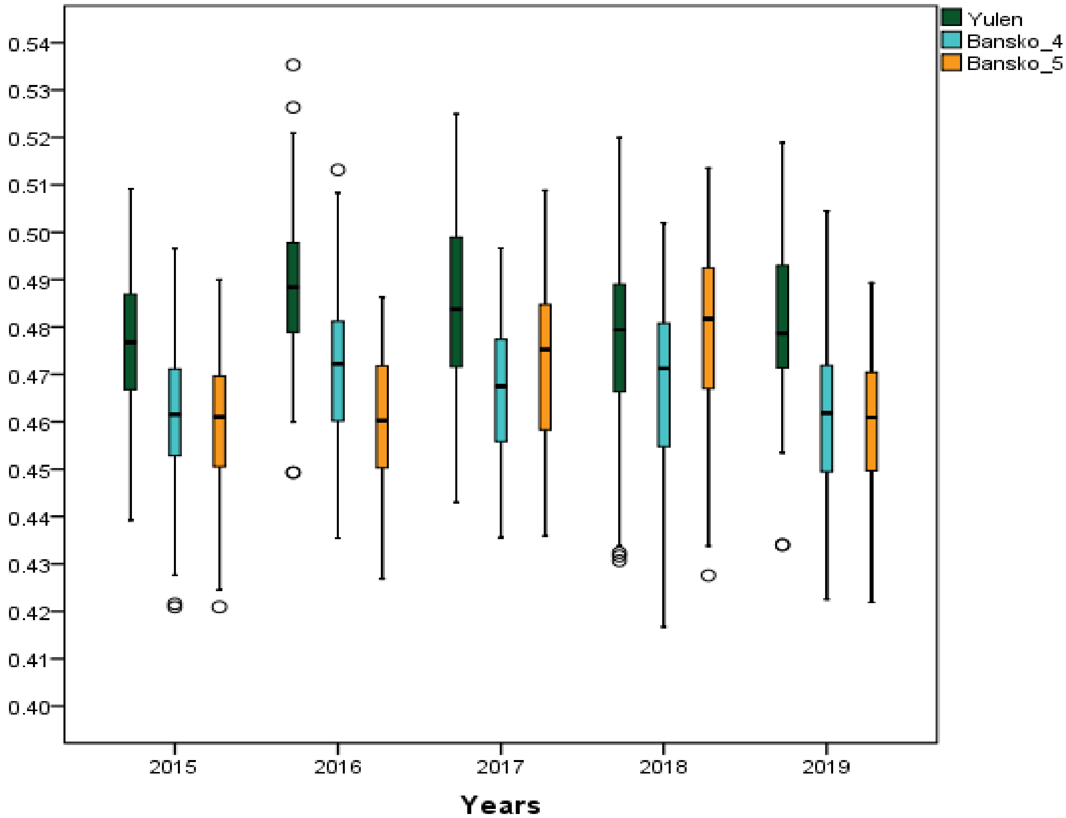


TABLE 18 PIPE TIME SERIES OF ECOSYSTEM STRESS RESULTS

Samples	**25 percentile**	**75 percentile**
Yulen Reserve	**0.471**	0.492
Bansko 1	0.425	0.458
Bansko 2	0.441	0.466
Bansko 3	0.427	0.448
Bansko 4	0.457	0.478
Bansko 5	0.453	0.477

Based on the implemented method for assessment of ecosystem stress, it has been observed that 3 of the 5 PIPE samples near the ski routes have 75% of their pixel values below the 25 percentile of Yulen reserve PIPE forests. Bansko 4 and 5 surpass the 25 percentile by a slim margin on average but also fall within the stress range in some years. The exact causes for the significant difference in the population of NDRE values cannot be estimated. The combination between in-situ data and spaceborne can be used to determine the cause for the lower index values.

8.3 Summary

The results from the time series of canopy reflectance properties revealed that forest density has a major role for the estimation of NDRE values. Forest density is affected by forest age and natural hazards, therefore excluding old forests and hazard prone areas in the assessment proved useful to diminish forest density effects on NDRE values. The PIHE results suggest that the intensively used road during summer months does not affect neighboring young PIHE forests as the two sets of data showed similar trends of annual values. The compared PIPE results however showed considerable difference based on the chosen methodology, although results can be arbitrary and require field assessment to determine the origin for the difference. The results suggest that isolated forest portions surrounded by ski routes have worse condition in comparison to unaffected forests in Yulen natural reserve.

The study showed positive signs for the application of spaceborne data in forest management due to the ability to assess forest on large scale in hardly reachable terrains. The application of geospatial approaches can navigate field research and even provide additional data on forest condition for the estimation of forest density and forest age as such data is currently lacking. Spaceborne data can be validated and coupled with in-situ measurements and areal assessments for precise and in-depth analysis of forest condition.

CHAPTER 11: SCENARIO ANALYSIS

11.1 Scenarios for the study area of the Seven Rila Lakes

The plausible scenarios in the study area of the Seven Rila Lakes reflect the possible future human interventions and governance regulations. The effectiveness of possible human interventions in the future are assessed based to the findings provided in Chapter 7, 8 and 9 related to past and current governance and ecosystem condition.

In February 2019 a project has been initiated by the directorate of Rila National park with the objective to limit the anthropogenic impact in the area of the Seven Rila Lakes. The project will be completed in 2023. The project aims to limit the amount of footpaths used and extract algae build up in the lakes and use the green mass rich in nutrients to aid recultivation of plant species in eroded areas near the footpaths. The project is expected to be completed until 2023. Previously, the environmental NGO coalition made an appeal to the directorate to limit the amount of daily tourist being able to visit the park in a single day. The chosen approach by the directorate differs from the requests made by the NGOs. Therefore, these two approaches can be seen as plausible scenarios in the coming decade. The baseline scenario is the current approach by the directorate, while the policy scenario considers limit in the amount of daily visitors.

Baseline Scenario
The first measure to limit anthropogenic impact requires the restriction of alternative and secondary footpaths. These paths have not being considered during the ecosystem analysis and erosion assessment in this study. While some sections of the main paths have alternative routes, other sections have no alternatives based on topographic features. The route between Babreka, Okoto and Salzata will not be closed since it does not have an alternative route. As mentioned inassessment of the extent of footpath erosion, the section between Babreka and Okoto is highly prone to erosion. It is expected that this area will receive focus from the new recultivation practices with the algae removal from the lower lakes. Whether the practice will be successful, it will depend on the anthropogenic pressure caused by tourism and the ability of plants to recover and reclaim their habitats. Based on the results from the pilot monitoring by Sustainable Mountains (2015), many visitors do not take the route between Babreka and Salzata but look for alternative routes. In case these routes are not available, the implemented restrictions in the new project can result in even higher tourist flow in highly eroded areas between Babreka and Okoto after 2023. The Project for the new management plan has not been revised yet making the future environmental regulations unclear at present time.

Policy Scenario
Based on data provided in the proposed management plan, approximately 20 000 people visited the area of the Seven Rila Lakes annually before the construction of the chairlift. Until that point in time, the anthropogenic impact has not been considered as significant. In comparison, the number of visitors rose to 100 000 in 2010 and 140 000 in 2012. Thus, the amount of visitors can increase sevenfold without imposed restrictions on the chairlift capacity. The first step for the estimation of the maximum amount of daily visitors that will not pose significant anthropogenic impact in the area of the Seven Rila Lakes is field assessment and dissemination of environmental impacts on ecosystems and anthropogenic sources.

11.2 Scenarios for the study area of Bansko Ski Resort

The new management plan proposed a number of alterations of the zone regulations for the national park in Pirin. The proposed alterations of the regulations regarding infrastructural development have not been assessed for their ecological impact yet. The positive decision of SAC for the necessity of EA on the alterations in the new management plan of Pirin National Park leads to the implementations of EA procedures. The procedures include report development, consultations with the public, interested bodies and third persons, inclusion of the consultation outcomes in the report, determination of the measures for observation and control of the implementation of the management plan. Based on the EA, the management plan will once again be evaluated for its coherence with national and European environmental regulations. This decision is the major time step for the governance of Pirin National park in the coming decade. There is great uncertainty and inability to estimate the exact point in time when the new management plan can be fully evaluated by the Council of Ministers. There isn’t any time limitations for the implementation of EA based on the ordinance for the conditions and the order for implementation of EA for plans and programmes. Various scenarios can develop based on the EA processes and the approval procedure after. Two scenarios seem plausible for analysis at the current point in time. The first scenario can be classified as baseline scenario, or scenario which does not account for policy alterations. The second scenario, which is seen as policy scenario will involve approval of the new zoning alterations of the management plan after the performed EA procedure. The effects on ecosystems from the two scenarios are evaluated based on the selected indicators from the DPSIR framework. The spatial extent of the two scenarios is compared to the total territory of the catchment area occupied by forests (2168 ha). For the baseline scenario the affected territory by anthropogenic impact remains unchanged. The climate regulation and flood protection spatial extent has been estimated previously. Both forests and grasslands share similar erosion and water purification capacity and their spatial extent is combined. On the other hand the proposed changes of the zoning of the park introduce a sub zone 4a – Special Buffer zone of Bansko Ski Resort reflecting the buffer zone set by UNESCO in 2011. The buffer zone has total territory of 1088, 4 ha comprising the territory of ski resort and the surrounding forest territory which is 883, 4 ha. The buffer zone uses the regulations specified for zones for tourism and zone for infrastructure. With respect to the total area of forests in the catchment area it can be estimated the spatial impact on regulating ecosystem services.

TABLE 19 PLAUSIBLE SCENARIOS FOR THE FUTURE GOVERNANCE OF NATIONAL PARK PIRIN

The Effects Of the Proposed Zoning Regulations (Table 5) Are Estimated Through Their Spatial Effects In The Catchment Area (Figure 6).

Scenarios	**Affected Area by Anthropogenic Impact (ha)**	**Total Climate Regulation and Flood Protection Spatial Capacity of Forests (% of forest in the catchment area)**	**Total Erosion and Water Purification Spatial Capacity of the Forest Territory (% of forest in the catchment area)**
Baseline Scenario	164	5.65%	7.56%
Policy Scenario	1088,4	40.7%	50.2%

CHAPTER 12: DISCUSSION

The DPSIR framework proved to be a useful tool to describe linkages between the environmental policies and the environmental state. The indicator selection based on the linkages between the components of the framework highlighted important variables for the effects of environmental policies and anthropogenic impact on ecosystem condition. These variables were spatially quantifiable, yet anthropogenic impact has been seen as difficult to estimate by the national park directorates and scientists. The national park directorates monitoring practices relate anthropogenic impact to spatial extent and tourist flow, while continuous quantifiable data about environmental state of affected areas is lacking. The inability to provide numeric information specifically for anthropogenic impact prevents the implementation of environmental policies and the development of new strategies although norms and standards for ecosystem condition do exist.

The spatial approach for the estimation of ecosystem capacity to generate regulatory ecosystem services presented pilot results, quantifying the effects of anthropogenic impact. The catchment area was used as spatial boundary condition and proved to be an easy estimate to group different habitats sharing common environmental resources, thus their contribution to ecosystem functions and services can be disseminated, if the catchment area is seen as a system with ecosystem services as outputs. The results for ecosystem capacity presented remote sensing and GIS data lacking input from other scientific fields and in-situ data. However, the innovative approaches of modern geospatial studies can fill the gaps which other disciplines and currently implemented research and monitoring practices fail to address. One of these gaps is the need to large scale continuous data availability which comes at low cost for implementation. A combination of multi-disciplinary approach for governance of environmental resources can address the current obstacles for the scientific data availability. The geospatial and modern approaches to ecosystem services quantification can complement well with other disciplines to further quantify environmental hazards and risks.

The assessment on erosion risk in the area of the Seven Rila Lakes proved to be a good example for combination of multidisciplinary approaches. Previous studies on lake ecology and biochemistry addressed changes in the ecological state of the lakes and accounted for both environmental and anthropogenic factors. Little spatial information was available to address the spatial extent of the anthropogenic impact and the cause and effects from tourism on lake ecology. The combination of erosion modeling and GIS approaches was able to identify prone areas and their effects on ecosystem services based on topographical features of the catchment area.

The time series analysis of PIHE and PIPE coniferous tree species provided a pilot research method for continuous monitoring of ecosystem condition on large scale. The method used a 5 year assessment period which proved to be short to assess for trends in forest condition based on annual vegetation maximum in July. A more detailed research with multiple annual measurements can reveal phenological variations providing more information on inter-annual variations.

Despite trends, the results were meant to evaluate differences in ecosystem condition of areas affected and unaffected of anthropogenic impact. While PIHE sample sites did not show either trends or differences between affected and unaffected sites, young PIPE forests used for the comparison showed considerable differences. A clear conclusion based on the remote sensing results cannot be made, which identifies the importance of in-situ measurements for precise estimation of the cause for the difference.

The estimation of future trends proved to be a difficult task due to lack of identifiable trends and lack of reliable scientific data available. There is great uncertainty in environmental policy making in terms of length of the process and its outcomes. There is lack of scientific papers which address future changes. Uncertainty is present for the environmental variables as well due to inability for continuous monitoring on large scale, the responses to global climate change are rather unclear. Due to these circumstances, the limitation to two plausible scenarios seemed reasonable to address identified ecological trends in the area of the Seven Rila Lakes and the effects of policy change on ecosystem protection in the new management plan of Pirin national park. A major time step for the governance of the Seven Rila Lakes will be the implementation of the project addressing the anthropogenic impact. Based on data from other scientific studies and the spatial approach used to identify sources of anthropogenic impact, the approach of the proposed project may provide both positive and negative impact.
The new proposed changes in the zoning of Natural Park in Pirin were analyzed based on the catchment area spatial extent used for the estimation of ecosystem capacity. In this way the current extent of anthropogenic influence and the possible future extent were compared. The proposed changes which will be evaluated for their ecological impact clearly show the change of environmental policy regulations for nearly half of the territory of the forested catchment area. The results show that nearly half of the catchment area will be subject to land use change, thus changes in ecosystem services, both regulatory and cultural.

CHAPTER 13: CONCLUSION

The study used approaches from social, environmental and geospatial disciplines to address the complex interaction between the human and the natural environment. The linking component has been the anthropogenic impact characterized by two case studies in Rila and Pirin Mountains.

How are ecosystems in Rila and Pirin National Parks influenced by anthropogenic activities and infrastructural expansion?

Bansko Ski Resort

The development of the ski resort resulted in episodic but substantial land use change, loss of regulation ecosystem services and biodiversity. The analysis on the ecosystem capacity revealed the difficulties in recultivation practices of grasslands on the territory of the ski routes. The problem with erosion stems from the graded ski route construction methods which removed the root system of trees reshaped and destabilized the top soil lair resulting in inability of new cultivated grass species to reclaim the habitats. The results from the flood protection and climate regulation services revealed unsubstantial influences on both services in the catchment area, however in case of intensive rainfall and specific weather conditions, the loss of flood protection services of ecosystems on the territory of the ski resort may increase significantly the risks for flash floods downstream.

The Seven Rila Lakes

The construction of the chairlift resulted in seasonal and continuous anthropogenic impact with negative trends in ecosystem condition of grasslands, heaths and lakes. The negative trends are characterized by the cumulative effects from footpath trampling, erosion, sedimentation and increased trophic levels in the lake posing a risk on plankton biodiversity and water quality. The result on ecosystem capacity of grasslands for water purification and erosion regulation revealed substantial increase in the spatial extent of tourist footpaths, specifically between Babreka and Okoto lakes. The analysis on soil loss revealed that while these lakes are the most visited by tourists, the impact from footpath trampling, erosion and sedimentation affects the lower group of lakes and especially Bliznaka since the affected areas fall within their catchment area.

Are there similarities or differences in anthropogenic impact and infrastructural development between the two national parks? What are the reasons for the differences and the similarities?

Differences

The main difference between the two case studies is the type of anthropogenic activity. As previously noted construction of ski infrastructure is episodic but with substantial impact, while unregulated tourism is continuous and seasonal. The construction of ski infrastructure has direct impact on biodiversity and landscape aesthetics, which is directly linked to natural and national heritage value of ecosystems. Affected ecosystems show ability to recover their services to some extent after large scale construction of ski routes and chairlifts. Ecosystems affected by ongoing unregulated tourism show negative trends in their capacity to generate ecosystem services. The impact from unregulated tourism has direct impact on grassland and heath habitats but indirect impact on lake ecology, landscape aesthetics and natural and national heritage which are affected by cumulative effects from footpath trampling and habitat destruction.

Similarities

While the two case studies differ in their impact on ecosystems they have have similarities related to their governance and environmental policy making. Ecosystems in both mountains are within the NATURA 2000 framework, thus suffering from the effects from ineffective governance and non-compliance with the directives of the framework as stated by the report of BNAO (2019). Both national parks operate with outdated management plans, while new management plans suffer substantial delays due to gaps in their development. In both cases it is unclear when the new management plans will be approved and what regulations will be applied. Both case studies had significant involvement of the general public and environmental NGOs as required by national and international legislation. The new management plans for both national parks mark the first involvement of these new stakeholders in the policy making process of the national parks. While this has led to intense debates and delays in the management plans development, the NGOs and the general public acted as complementary informal institution. The persistent involvement of these stakeholders was motivated by the cultural ecosystem services, particularly the value of the natural and national heritage of Rila and Pirin Mountains.

What are the effects from the change of policies in the management plans?

The proposed management plan of Pirin National Park introduced new zoning regulations that contradict PAA and BDA regulations. The proposed management plan lacked EIA as required by EPA and PAA, thus failing to address the environmental impacts from the new regulations. The new zoning regulations provide an opportunity for logging and construction practices on nearly half of the territory of the national park, thus enabling future investment projects to pose substantial risk on the generation of all ecosystem services.

The proposed management plan of Rila National Park has been heavily criticized for gaps in its formulation and inability to address environmental and anthropogenic pressures through regulatory measures. The proposed management plan does not address the unregulated tourism in the study area of the Seven Rila Lakes by development of monitoring practices for the quantification of anthropogenic impact, thus developing regulations to limit and manage the impacts on ecosystems.

What recognizable trends from past to current ecosystem conditions can be found, based on the empirical analysis, which can serve as foundation for possible future scenarios?

The time series analysis of PIHE and PIPE forest canopy reflectance properties did not show recognizable trends in forest condition for the period between 2015 and 2019. The assessment period proved to be short to recognize trends, while the method to compare annual vegetation maximum is insufficient for trend investigation. However, the analysis showed substantial difference between affected and unaffected PIPE forests, thus provides an opportunity for further research on the anthropogenic impact on these forests.

What are the future risks from the effects of policies, anthropogenic activities and infrastructural expansion?

The future risks for ecosystems remain unclear for both national parks until present date due to lack of strategic monitoring and research practices. A substantial risk arises for the harmonization and implementation of European environmental policies. The rising interest in recent decades for recreation and tourism in the national parks pose a new risk for ecosystem condition and the lack of regulation practices causes inability to assess outcomes from anthropogenic impact in the future.

Chapter 14 Reccomendations

The study aimed to present methods for assessment of ecosystem condition and analyze the governance of protected areas. Both the methods and results from the research are meant for Balkani Wildlife society as well as any relevant environmental NGO and regional or state governmental bodies having interest in the governance of protected areas.

The proposed methods for geospatial assessment of ecosystem services can also be integrated in EIA and EA assessments of new and already implemented investment projects in protected areas. These methods can complement field studies from other disciplines and help in monitoring, educational and research practices to address data gaps and availability of continuous scientific information for large scale assessment on ecosystem condition. The concept of ecosystem services is gaining credibility at European scale and show potential for future applicability in environmental governance procedures. A determination of quantifiable indicators of anthropogenic impact can be achieved through spatial assessment on capacity of ecosystem services within defined spatial boundary in order to better understand environmental risks. A quantifiable data is currently lacking and geospatial methods can address the problem in efficient and effective way in conjunction with precise and reliable in-situ data.

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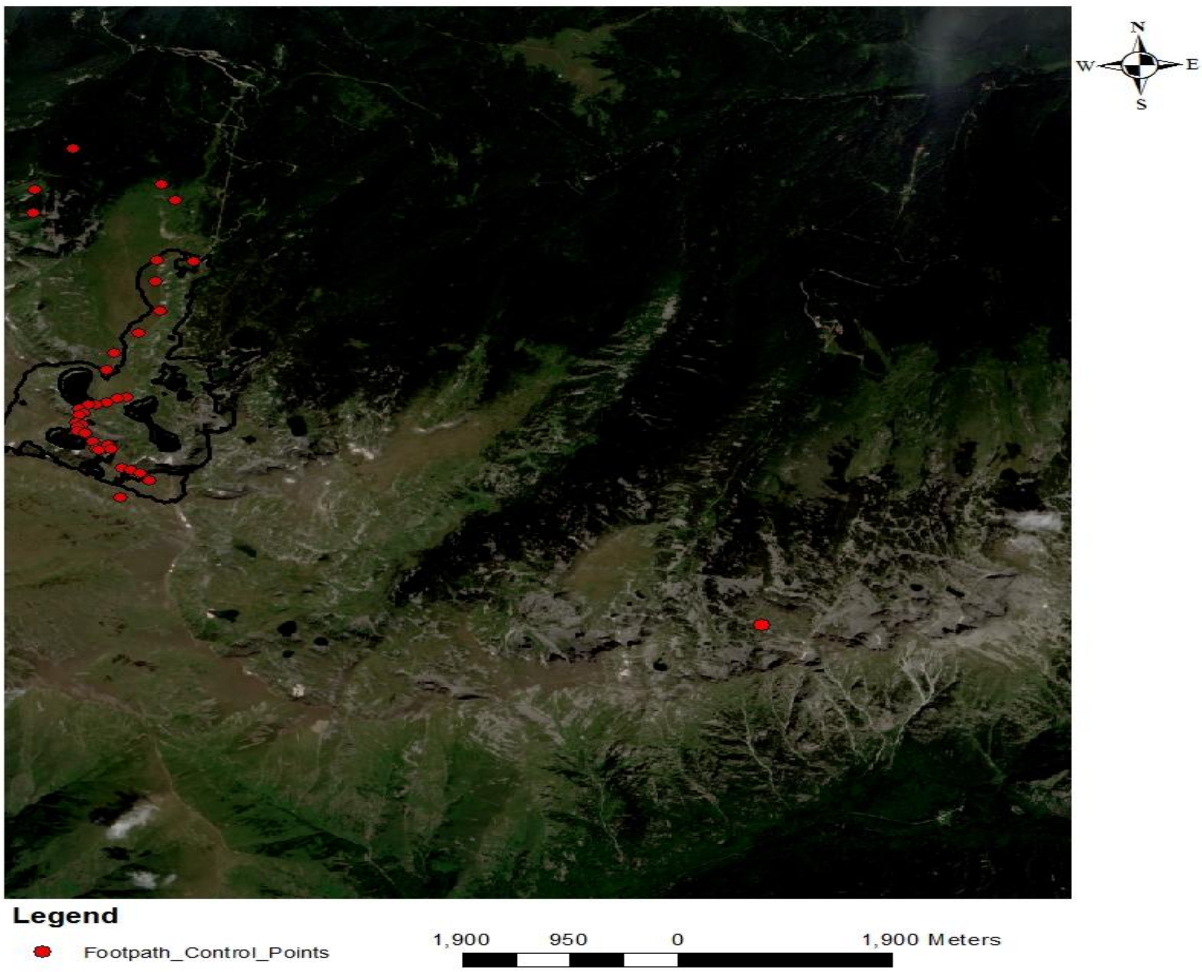
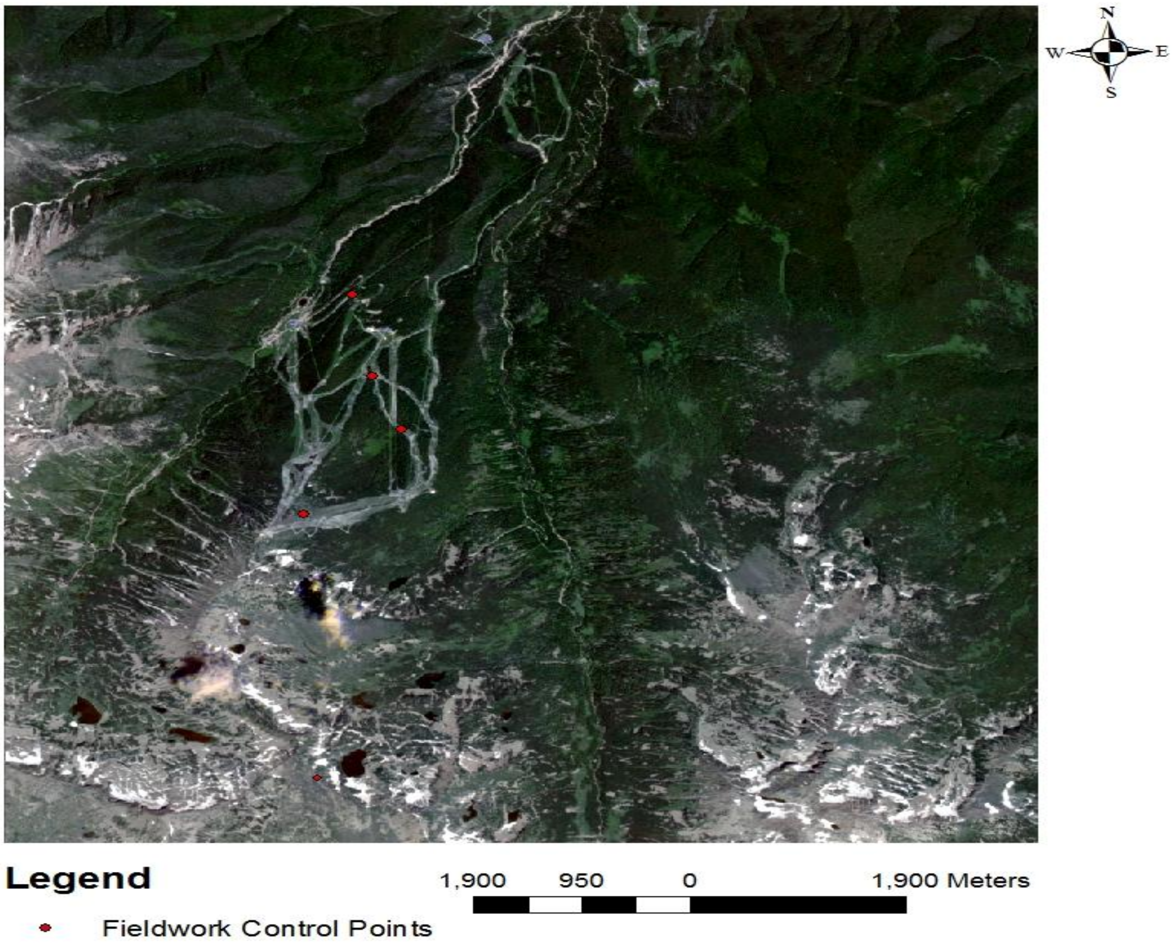
ANNEX

1. Ground Control Points in the study area of the Seven Rila Lakes

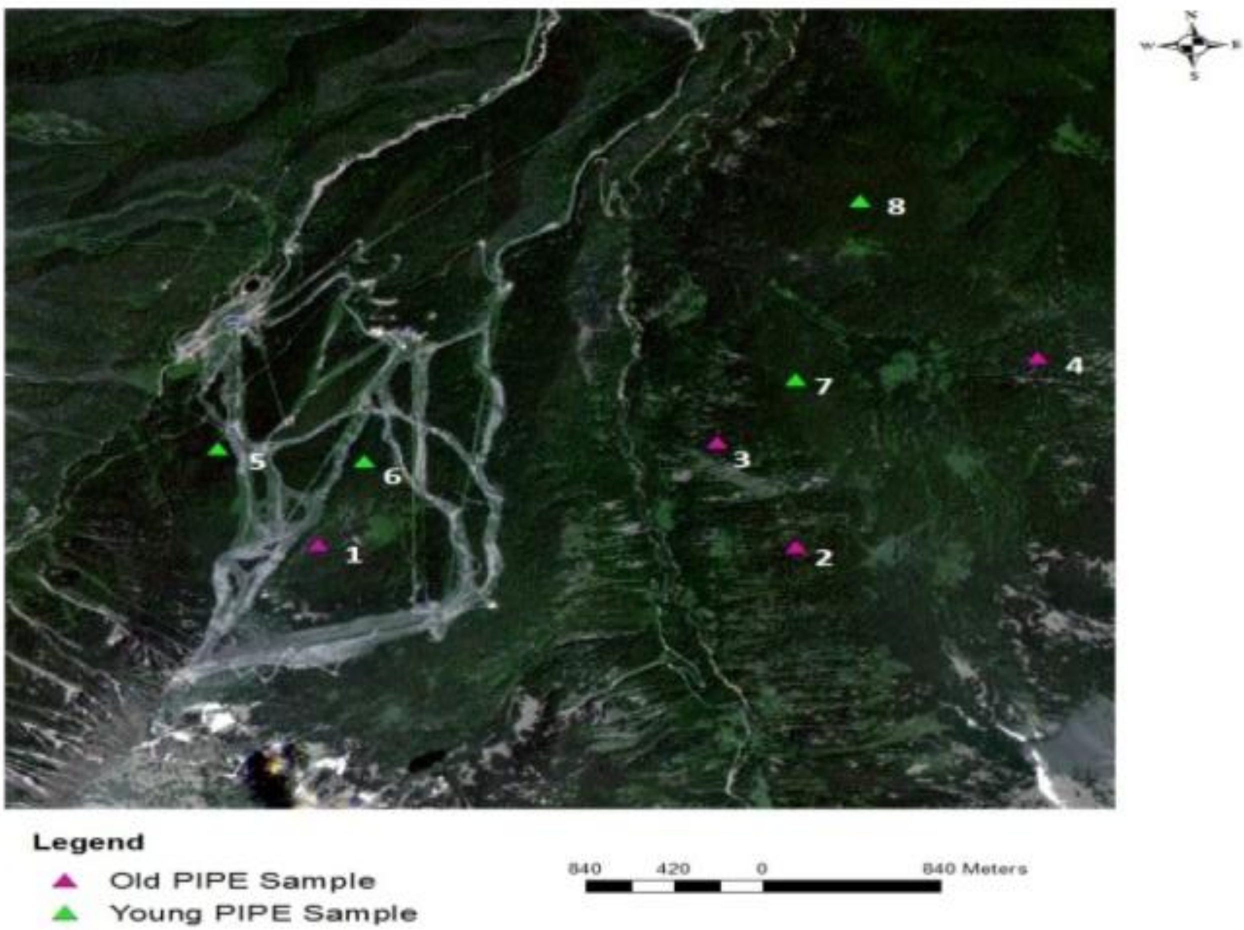


2. GROUND CONTROL POINTS IN THE STUDY AREA OF BANSKO SKI RESORT



3. Forest Age Reference sample sites

Pinus Peuce



PINUS HELDREICHII