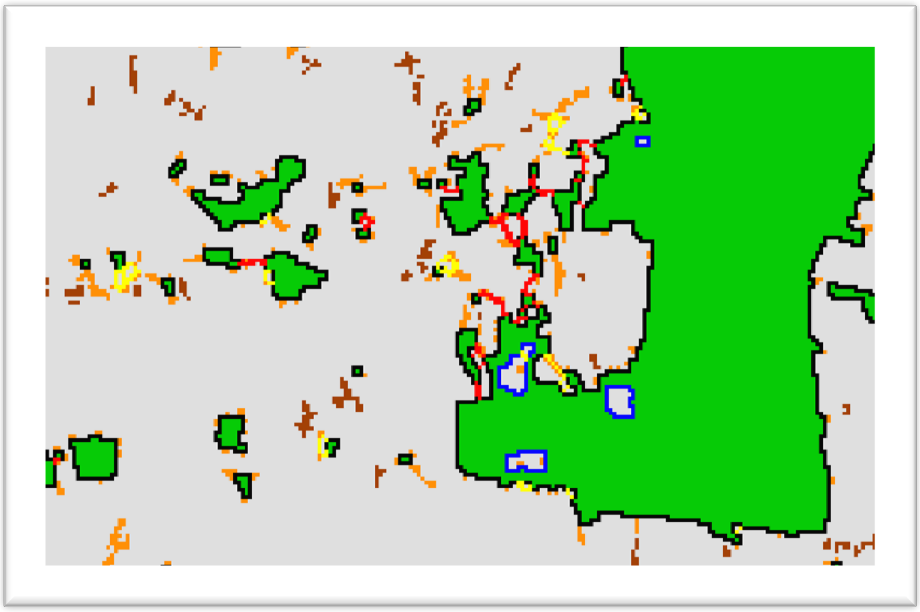
Role of forest certification in biodiversity conservation in Lithuania



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Swedish University of Agricultural Sciences
Master Thesis no. 232
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The picture is generated by MSPA model from the set aside areas in Lithuania.

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Summary

Forest Stewardship Council (FSC) certification scheme emerged as an instrument to notify well managed forests. There are endless discussions about the actual FSC certification contribution to biodiversity conservation. In this thesis Lithuanian FSC certified forests were assessed regarding biodiversity protection measures implemented on the ground. First, FSC Lithuanian standard indicators concerning biodiversity measures were selected and grouped according to the spatial scales of forest management that had to be performed in order to satisfy a certain indictor. Secondly, voluntary and formally set-aside areas for biodiversity conservation in FSC certified State Forest Enterprises (SFE) were compared. Lastly I examined structural habitat connectivity using morphological spatial pattern analysis tool. Lithuanian FSC standard indicators requirements were focused on the stand and landscape scales, while there were no indicators regarding ecoregion. The formally set-aside area was more than two times larger than voluntary. Structural habitat analysis showed that the most set-aside patches were smaller than 10 ha and had a small fraction of old forests. I discuss that FSC standard focuses on species with small habitat requirements. Moreover formal forest protection, due to several protection levels does not provide the same conservation measures, while voluntary set-asides are treated evenly. I conclude that to understand a role of FSC certification in forest biodiversity conservation it is important to evaluate formally and voluntary set-asides from protected species perspective to see functionality of the protected areas.

Key words: FSC, state forest enterprises, structural connectivity, set-aside area

Abbreviations used in the text

CoC - Chain of Custody

DG - the Directorate General of state forests

SFE – State Forest Enterprise

FSC - Forest Stewardship Council

HCVF - High Conservation Value Forests

GIS – Geographic Information System

LSFC - Lithuanian state forest cadastre

MSPA - morphological spatial pattern analysis

SFI - Stand-wise Forest Inventory

PEFC - Programme for the Endorsement of Forest Certification

WKH – woodland key habitat

WWF - World Wildlife Fund

EU – European Union

Contents

Introduction

During the last decades forest related issues have been, and are still, widely discussed among scientists, stakeholders and policy makers (Bernstein and Cashore, 2003). Concerns are related to a rapid loss of forest cover and ecological values of forests (FAO, 2010; Hansen et al., 2010; Butchart et al., 2010). Continuous forest cover decline increases species habitat loss and fragmentation that in turn was identified as one of the greatest threats to forest dwelling taxa (Fahrig, 2001). According to FAO (2010), every year 13 million hectares have been deforested since 1990. The intergovernmental attempts to find satisfactory measures to combine forest management for wood production with biodiversity conservation has not led to any binding global treaty as yet (Bernstein and Cashore, 2003). In 1993 the Forest Stewardship Council (FSC), a non-profit organization, together with various stakeholders, endorsed the first forest certification scheme to promote and implement responsible forest management (Gulbrandsen, 2004). The FSC forest certification is a market driven tool (FSC, 2014a). During the past two decades FSC certified forest area has reached 181 million hectares globally (FSC, 2014a). FSC claims that the certified forest management should be socially beneficial, economically viable, and environmentally appropriate (FSC, 2014a).

From the very beginning this scheme has had a strong support from environmental NGOs (Gulbransen, 2004; Cashore et al. 2004; Sasser et al. 2006) and the scientific community, which both recognized FSC as a potential system to improve the environmental performance of forest practices (Gullison, 2003; Putz, and Romero, 2001; Alves et al. 2011). However, there are still endless discussions whether the actual changes induced by forest certification lead towards better biodiversity conservation (Bennett, 2001; Johansson and Lidestav, 2011; Dias et al. 2013). This debate is fuelled by several factors: lack of confidence in certification as a conservation mechanism, conceptual and practical difficulties of assessing biodiversity in production forestry and standard implementation variations across countries (Ghazoul, 2001; Rametsteiner and Simula, 2003; Prakash and Potoski, 2012). Furthermore, various authors have voiced an urgent need to gain better understanding about the contribution of forest certification to biodiversity conservation on the ground (Gulbrandsen, 2005; Rametsteiner and Simula, 2003; Elbakidze et al. 2011).

This study focuses on Lithuania, one of the recent members of the European Union (EU) and the former member of the Soviet Union, which is located in a hemi-boreal forest zone (Ahti et al. 1968). There are clear distinctions remaining in terms of ecological values of forests between former Soviet countries and the western European countries with market economy (Angelstam et al. 2001; Brukas et al. 2013). Past top-down system of governance, including zoning approach in management and use of forest resources, in the Soviet Union often helped to retain greater biodiversity values in comparison to Western Europe. However, since Lithuania regained independence in 1991 market-economy has been introduced that led to fundamental changes in many sectors of society. Rapid forestry sector development, including intensification of forest management, raised concerns about the possible negative impacts on forest biodiversity (Angelstam et al. 1997; Lazdinis et al. 2009; Kurlavicius et al., 2004). On the other hand Lithuania was striving to become a member of EU. This process highly influenced the country's environmental ambitions expressed in various national policies e.g. Forest law, Lithuanian strategy for sustainable development. Biodiversity conservation has been announced as one of the focus areas in the Forestry policy and strategy (Ministry of Environment, 2002). These policy goals are related to continuous cover methods' propagation and phasing down pesticides usage in the forestry operations. In the program for forestry sector development 2012-2020 (Ministry of Environment, 2012) the current protected areas networks are regarded as sufficient and only minor upgrades in the regulation of these territories recommended.

In Lithuania the forests are divided between the state (50%) and the private forest owners (39%); the remaining 11% is temporarily managed by the state for ongoing land restitution (Ministry of Environment, State forest service, 2013). All state forests are being managed by the state forest enterprises (SFEs), which are under the supervision of the directorate general of state forests (DG) (Directorate general of state forests, 2007). With an increasing globalization of Lithuanian forestry products (Pekarskienė and Susnienė 2012) foresters have been exposed to market-driven voluntary certification standards. The forest certification process began in 2001 (Directorate general of state forests, 2013). The FSC forest certification was employed and in 2001 the first two SFEs got certified by the UK firm Société Générale de Surveillance (SGS) QUALIFOR (Ruževičius, 2008). The later certification process was taken over by DG and subsequently a new auditing company - the Danish registered non-profit organization NEPCon (Directorate general of state forests, 2013) was appointed. All 42 state owned forest enterprises were certified by the year 2005 (Ruževičius, 2008).

The certification of private forests against FSC in Lithuania was supported by the World Wildlife Fund (WWF) and IKEA Group. The WWF had led a project to stimulate a private forest certification from 2002 to 2005 (Lithuanian Fund for Nature, 2014). Only one private forest group certificate was issued to Stora Enso's Lietuva managed group in the year 2005 (Ruževičius, 2008). Currently this group has dissolved and a single SFE certificate is given to Stora Enso's Lietuva company for 463 ha of forest land (Scientific certification systems, 2011). An attempt was made to stimulate private forest certification through the other scheme – Programme for the Endorsement of Forest Certification (PEFC). The Lithuanian PEFC council formation was initiated by the Lithuanian private forest owners association in 2002 (PEFC Lietuva, 2008), but the process didn't gain a support from private forest owners. Currently there are 8 Chain of Custody (CoC) PEFC certificate holders and no forest management units have been certified against this scheme (PEFC, 2014). Consequently, FSC is a monopolist in Lithuanian forest certification, which imposes requirements on certified forest management. There are not many publications in Lithuania about the FSC certification. The published articles by Brukas (1998), Brukas et al. (1999) and Ruzevicius (2008), about forest certification are more exploratory in nature.

The aim of this study is to analyse the role of FSC certification in biodiversity conservation on the ground in Lithuania. The main research questions are: What are spatial scales of forest management for biodiversity conservation considered in the FSC standard that is used in Lithuania? How much forested area is protected following the requirements of the FSC standard within the forest management units? Do formally and voluntary protected forest stands form structurally functional networks? Using the approach proposed by Elbakidze et al. (2011), the study was organized in three steps. Firstly, I analysed the indicators related to biodiversity conservation requirements in the Lithuanian FSC standard. Secondly, I compared the areas of formally and voluntarily set-aside forests for biodiversity conservation in 40 (95%) of SFEs in Lithuania and, thirdly, I applied a morphological spatial pattern analysis to explore the structural connectivity of forest habitats set aside for biodiversity conservation in the state forests.

Forests in Lithuania

Forests in Lithuania are hemi-boreal, mixed species dominated (Laasimer et al. 1993). Approximately 2.17 M ha (33.3%) of the total country territory is accounted as forested land (Ministry of Environment, State forest service, 2013). Since World War II the forest area has increased by 13.6% and still continues to grow (Ministry of Environment, State forest service, 2013). Approximately 29% of the total forested land is under different types of protection (Ministry of Environment, State forest service, 2013).

Scots pine *Pinus silvestri* and Norway spruce *Picea abies* cover the largest area – 0.7 M ha (35.1% of the total forest area) and 0.3 M ha (20.9%) respectively. Coniferous species take up to 57% of total growing volume. The main deciduous tree species according to the growing stock volumes are birch *Betula sp.* (16.5%), black alder *Alnus glutinosa* (8.4%), grey alder *Alnus incana* (4.3%), aspen *Populus tremula* (6.3%) and oak *Qurecus robur* (2.8%) (Ministry of Environment, State forest service, 2013).

According to Šaudytė et al. (2005), 85% Lithuanian forests are semi-natural. This indicates that forests are affected by economic activities (FAO, 2002). Lithuanian forest statistics gives very limited reference to naturalness, classifying stands by origin into either natural (74.6%) or planted (25.4%). Since the 2000s Natura 2000 and woodland key habitat (WKH) networks have been established (Ministry of Environment, 2007). The WKH concept came from Sweden and was adopted in Lithuania in early 2000s (Timonen et al., 2010).

Methods and material

Study area

40 SFE comprise the study area, which cover 0.98 M ha, or 45% of the total forest area in Lithuania. SFEs manage forests over all of Lithuania and the state managed forest land is intermingled with private forests (Figure 1). Each SFE manages their forest land under the supervision of Directorate general (Directorate general of state forests, 2007).

Figure 1
The state forest enterprises in Lithuania as the study area. Two marked SFEs were not included in the study area.

Analysis of the FSC standard's indicators related to biodiversity conservation

SmartWood Interim Standard for Lithuania SW-STD-FM-LIT-18MAR08 (hereafter the Lithuanian FSC standard) (Rainforest Alliance, 2013) was used by Lithuanian SFEs and

NEPCon auditing company undertake forest management certification. I used this standard to select the indicators directly related to biodiversity conservation following the methods presented in Elbakidze et al. (2011). First of all, I read the FSC standard several times and selected those indicators that requested direct actions for biodiversity conservation, for example such as: retention of biodiversity trees in a harvesting site; protection of threatened, rare and endangered species together with sensitive soils, ecosystems or habitats; prevention of pest outbreaks or spreading of invasive species; creation of buffer zones by the water bodies and preservation of dead wood. When all indicators had been selected, I grouped them according to the spatial scale of forest management that had to be performed in order to fulfil each selected indicator. Four spatial scales of forest management towards biodiversity conservation have been used, such as: (1) the scale of „trees“ encompasses individual trees or a group of trees (Eriksson and Hammer, 2006); (2) „stand“ scale corresponds to the scale traditionally used in forestry, where stand represents a forest area with similar age, height and tree species composition (Eriksson and Hammer, 2006); (3) “landscape” scale covers a spatially explicit mix of ecosystems and land-use types (Forman, 1995). (4) lastly “ecoregion” is regional/continental scale units of biodiversity (Olson and Dinerstein, 2002).

The reason of grouping FSC indicators according to the spatial scale was that the level of ambition for biodiversity conservation is linked to the spatial scale of forest management for biodiversity conservation (Elbakidze et al. 2011). Thus, following Angelstam et al. (2004a) at least four levels of ambition can be indicated: (1) compositional elements of biodiversity are maintained; (2) viable populations of more generalist forest species are present; (3) communities of all naturally occurring species of the representative ecosystems are maintained; (4) resilient forest ecosystems with a whole range of natural dynamic processes are preserved.

If FSC indicators require actions at the scale of “trees”, then species with small habitat requirements could persist (the first level of ambition according to Angelstam, 2004a). FSC indictors for the “stand” scale might contribute to sustaining viable populations of small habitat requiring species (the second level of ambition). Indicators that prescribe actions at landscape scale could help to sustain viable resident populations of the most demanding and specialist species (Angelstam 2004b; Tscharntke et al. 2012). And finally, presence of indicators relevant for the scale of "ecoregion" in the FSC standard require actions that potentially contribute to maintaining of "functional landscapes" that share majority of their species, dynamics and environmental characteristics (the fourth level of ambition).

The implicit link between spatial scale of prescribed forest management in order to fulfil a certain criterion and biodiversity conservation ambition level makes possible to draw conclusions about FSC standard conservation stringency and strategic orientation.

Materials

In order to perform this study I had to develop GIS database. The database of voluntary set-aside forests was constructed from the compartment lists provided by SFEs. All SFE had been asked to identify the forest compartments where some management restrictions were introduced according to the FSC requirements. 40 SFEs responded providing the lists of set-aside forest compartments, but two SFEs provided insufficient spatial information about the compartment location and consequently were not included in further analysis. Boundaries of the listed forest compartments were stored in a GIS database copying them from the official State forest service database from March, 29th, 2014 of the Lithuanian state forest cadastre (LSFC). The polygons of protected areas according to the national legislation (or formally set-asides) were available in the LSFC as well. The first WKH inventory database was used, because the new WHK inventory (2013) database hasn't been available. WKH database was not compatible with LSFC, therefore I overlaid the WKH database with LSFC and cut out the overlapping compartments. In the final database the mean size of a polygon was 1.6 ha with the standard deviation of 3.5 ha.

As the LSFC is an open and dynamic system, as well as it is based on the information originating from the Stand-wise Forest Inventory (SFI) , which is done annually on 10-15% of the country's area, - thus, I detected numerous mismatches between the forest stands identified in the lists from the SFEs and LSFC Thus, for 7 SFE raw data from recent SFIs were used which were not incorporated yet in the LSFC (Radviliškis, Kėdainiai, Kaišiadorys, Alytus, Jonava, Dubrava and Šakiai) (Figure 1).

Assessment of FSC outcomes for biodiversity conservation on the ground

Area proportion of set-aside forests

To identify how much was set-aside within the SFEs according to the FSC requirements I selected all polygons that represented formally and voluntary set-side areas separately. According to the FSC standard's principles (FSC, 2012a) forest management has to comply with the national legislation and protection measures (Principle 1). Following this principle 1 selected all formally protected forests from the developed database. According to the Law on forests of the Republic of Lithuania (1994), all Lithuanian forests are divided into four forest groups according to the predefined objectives and allowed economic activities, such as: (1) the group I forests, representing strict nature reserves, where all economic activities are prohibited; (2) the group II forests that have protective, restorative and recreational functions with prolonged rotations; (3) the group III has the aim to protect soil, air, water in combination to forming productive forest stands; (4) the group IV consists of economic forests. Thus, to the group of formally set-asides I selected the polygons of forests belonging to group I and group II. To the group of voluntary set-asides I included; (1) woodland key habitats (WKHs), forest areas with a significantly higher occurrence of protected species (Andersson et al., 2005); (2) high conservation value forests (HCVF) that contained "representative samples of existing rare and/or endangered ecosystems" (Rainforest Alliance, 2013). Several polygons of formally and voluntary set-asides overlapped with each other. To avoid double counting of set-aside areas, the polygons with the stronger protection status were only counted. For example, if a voluntary set-aside had a stronger protection status than the forest of group II, this polygon was moved to the group of voluntary set-aside and its area was withdrawn from the area of formally set-aside group. The two set-aside groups (formally and voluntary set-asides) were separately estimated in the GIS-database to calculate forest area proportion, which was set-aside for biodiversity conservation within the studied SFEs. In this analysis single trees and small stands (less than 0.1 ha) that were set-aside according to FSC requirements were not considered due to its very small size.

Assessment of structural habitat connectivity

According to Kindlmann and Burel (2008) there are two sorts of connectivity: structural, where connectivity is based entirely on landscape spatial arrangement, with no direct link to targeted species; and functional, which describes species' behavioural responses to separate landscape elements and to entire landscapes.

Formally and voluntary set-asides were analysed using the morphological spatial pattern analysis (MSPA) (Ostapowicz et al., 2008; Soille and Vogt, 2009; Vogt et al., 2007a, 2007b, 2009). The applications for MSPA are: quantifying the structural (Ostapowicz et al., 2008; Vogt et al., 2007a, 2007b) and functional (Vogt et al., 2009) connectivity, and landscape fragmentation (Ostapowicz et al., 2008). It processes the input pattern and segments into a series of categories revealing information about forest pattern size, shape, and connectivity (Soille & Vogt, 2009). As Siolle & Vogt (2009) proposed, seven size dependent and mutually exclusive pattern categories were used (Figure 2).

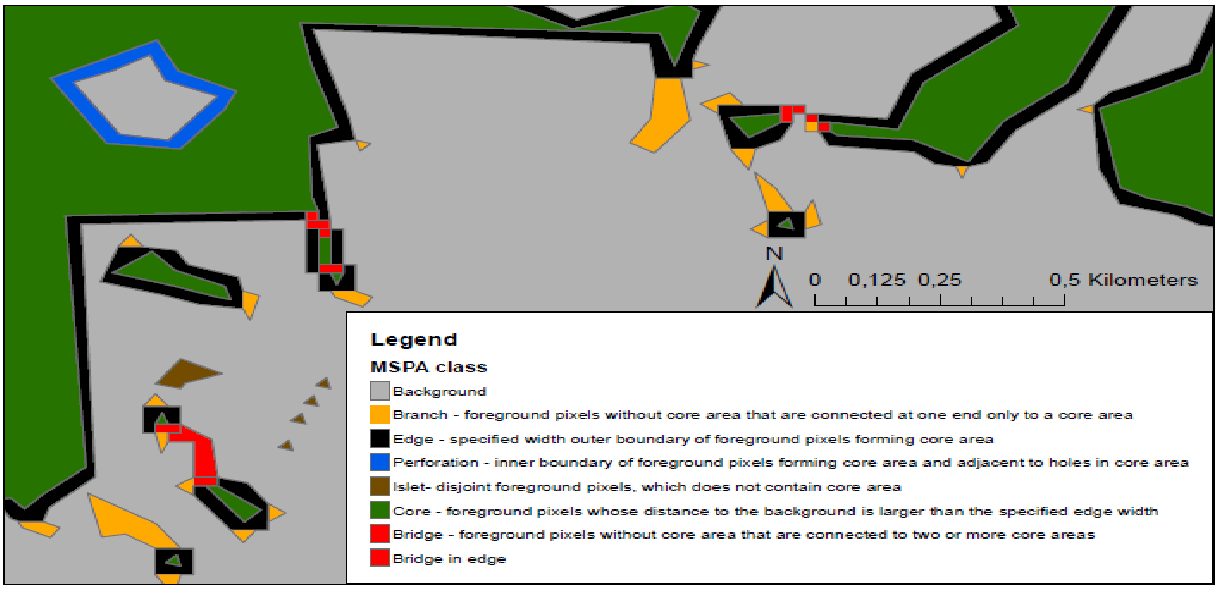

Figure 2
Characterisation of binary patterns used for MSPA categories. The foreground is represented by set-aside forest pixels as the background is represented by the production forest and all other land cover types (Soille and Vogt, 2009).

The assessment of structural habitat connectivity was carried out for all voluntary and formally set-asides that represented different forest types based on tree species composition and age (Table 1). In this study set-aside (foreground) area pixels were set to be 8-connected and therefore all other land use types (background) area pixels were set to be 4-connected. Size parameter used in the MSPA model and pixel size of the input data defines the output maps categories (Soile & Vogt, 2009). Conversely conditions in the forest patches are affected by proximity of an edge (Murcia, 1995). Numerous studies on boreal forests biotopes (Roberge et al., 2011; Aune et al., 2005; Esseen & Renhorn, 1998) display evidence about different species sensitivity to the forest edge created environment. They generally indicate that edge effects deviate among species, but stretch more than 25 m and probably reach even 100 m (Roberge et al., 2011). Accordingly GIS maps as input information for MSPA model were converted into 25-m pixel raster data. GIS raster maps were converted into binary input the maps compatible with MSPA model, which accepts two data groups – foreground (voluntary set-aside forests and formally protected forests) and background (other areas). Lastly, the structural connectivity was calculated using edge widths of 25, 50 and 100 m, which was represented by 1, 2 and 4 pixels in MSPA model.

Table 1
Classification of forest stands based on their age and tree species composition. The forest stands were defined based on the main tree species and on their age (Bohn et al., 2000). Each cell shows the possible diversity of forest stand categories and an identification code based on combination of tree species and age classes

Forest stand classified according to the main tree species		Forest stands based on age class				
		Young 10-40	Middle age 41-70	Mature 71-110	Over mature 111-140	Old 141-…..
Scots pine	>70%	11	12	13	14	15
Norway spruce	>70%	21	22	23	24	25
Oak	>70%	31	32	33	34	35
Other broadleaved	>70%	41	42	43	44	45
Birch	>70%	51	52	53	54	55
Other pioneer deciduous	>70%	61	62	63	64	65
Deciduos-coniferous	>60% coniferous	71	72	73	74	75
Coniferous-deciduous	>60% deciduous	81	82	83	84	85

Results

FSC indicators for biodiversity conservation

The Lithuanian FSC standard is based on FSC international guidelines for forest management - general Principles & Criteria (FSC, 2012a). In total I identified 36 indicators that prescribed different aspects of forest management for biodiversity conservation (Appendix 1 and Table 2).

Table 2
Examples of indicators in the Lithuanian FSC standard relevant for biodiversity conservation at different spatial scales

Spatial scale of forest biodiversity conservation	Lithuanian FSC standard indicators
Trees	5.2.2. Economically valuable hard leave trees depending on their viability should have reached maturity during logging operations.
Stand	6.3.5. Thinning and harvesting operations shall favour the development of mixed stands (a, b, c).
Landscape	6.4.1. Large FMO-s: FMO shall leave representative samples of existing rare and/or endangered ecosystems for natural succession in their natural state covering at least 5 % of the total forest area. Strict nature reserves located inside or bordering to the FMO may be included in the estimation of the 5 %.
Ecoregion	Not found

The aforementioned indicators span through different spatial scales (Figure 3). Most of the indicators were related to the scales of Stands in a landscape (20 indicators) and Landscape in ecoregion (20 indicators). There were no indicators relevant to the scale of ecoregions. Some of the indicators clearly prescribed actions related to one spatial scale while the other bridged several of them. In the standard it was also specified that at least 5% of managed forest land has to be set aside for natural succession, which calls upon separate evaluation regarding the proportions of set aside areas in different forest classes and its structural connectivity.

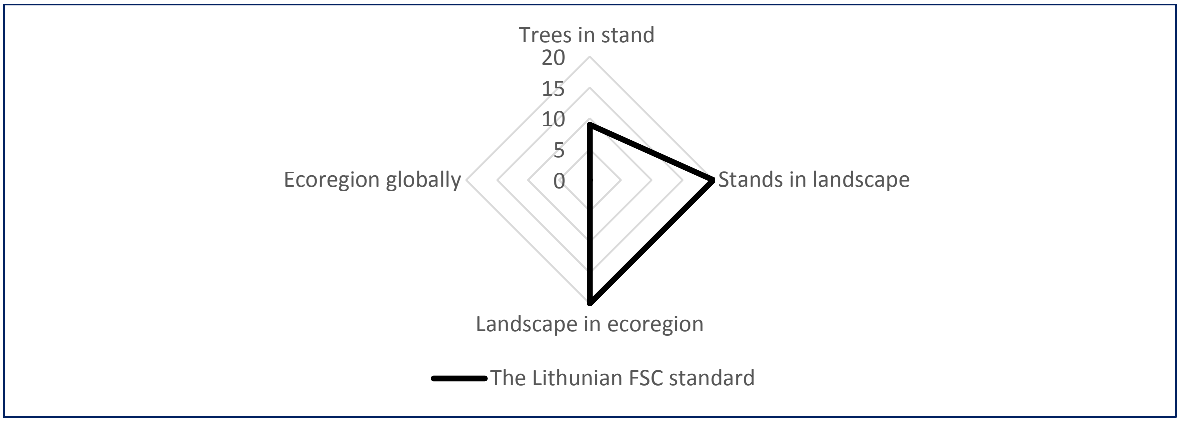

Figure 3
Indicators relevant for biodiversity conservation on different spatial scales in the Lithuanian FSC standard. The axe shows total number of indicators concerning biodiversity on each spatial scale

Assessment of FSC certification outcomes for biodiversity conservation

Area proportion of set-aside forests

In total set-aside area amounted to 18.6% of state managed forest land, from which 13.7% was formally and 4.9% voluntary protected (Table 3). Formally set-aside forests incorporated in strict nature reserves (group I) occupied 1.2% and protective forests (group II) occupied 12.5% of the aggregated study area. On a voluntary basis set-aside forests, including WKH and HCVF, occupied 1.8 % and 3.1% of total managed forested land respectively. All set-aside forest classes included non-forest habitats and elements: swamps, meadows, roads, ditches etc., which took distinctly different proportions of each class's total territory. Voluntary protected HCVF included the most non-forest areas that equalling 24% of the total area of HCVFs. In total all non-forest habitats occupied 21114 ha, which amounts to 11.6% of the entire protected territory.

Table 3
Total area and types of formally and voluntary set-aside forested land in the Lithuanian SFEs

	Types of set-aside forested land	Total area (ha) of land set-aside for biodiversity conservation and its proportion from total managed area (%)	Total area of non-forest habitats (ha) and its proportion from total set-aside area (%)	Frameworks
Formally set-aside area	Group I strict nature reserves	11939 1.2	2164 1.1	Forest law of Lithuanian Republic
	Group II protective forests	124122 12.5	10660 6.0	
Voluntary set-aside area	WKH (woodland key habitat)	17789 1.8	747 0.4	Lithuanian FSC standard
	HCVF (high conservation value forest)	30299 3.1	7542 4.1	
Total set-aside area		184149 18.6	21114 11.6	

Set-aside forested land is unevenly distributed among SFEs and forms a very fragmented pattern in the study area (Figure 4). Most of the formally protected areas were in SFEs that contained National and Regional parks (for example, Švenčionėlių and Telšių). The very same SFEs had the least amount of voluntary set-aside areas (Figure 5). Thus, voluntary and formally set-aside forested land extremes are intertwined: SFEs that had many formally protected areas set aside less on the voluntary basis, and opposite SFEs that had less formally protected areas had to “leave representative samples… at least 5% of total forest area” (Rainforest Alliance, 2013) voluntary.

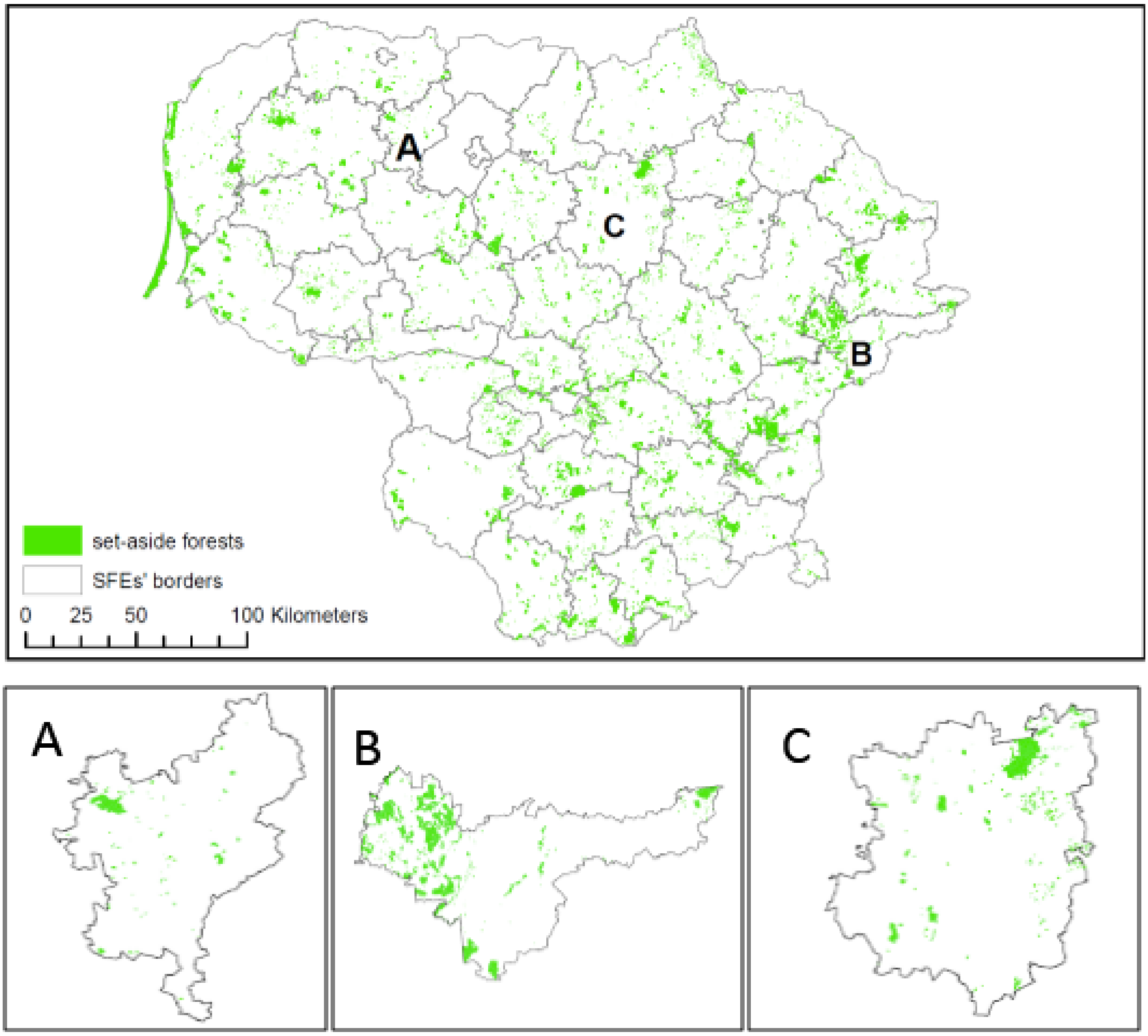

Figure 4
Distribution of formally and voluntary set-asides in the SFEs. A, B, C maps show minimum (1400 ha), maximum (11100 ha) and average (6900 ha) set-aside areas in Kuršėnų, Švenčionėlių and Panevežio SFEs accordingly

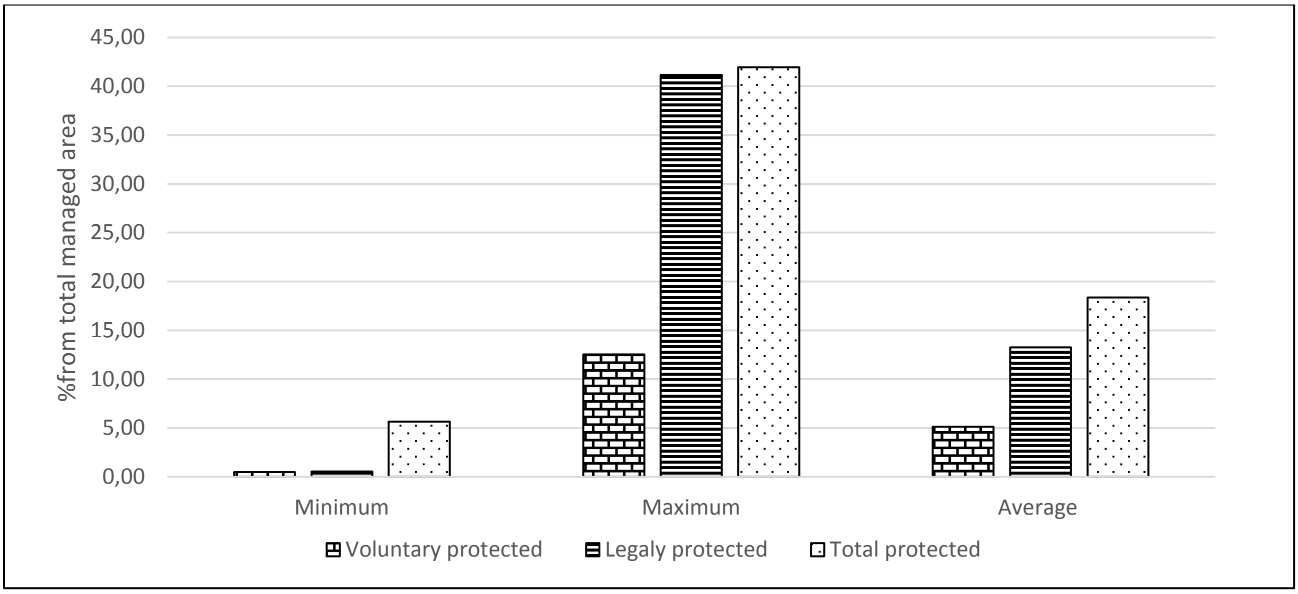

Figure 5
Examples of total set-aside areas and proportions of set-aside area from a total area of a respective SFE, including the extreme values

Structural habitat connectivity

Forest pattern classes of set-aside forests were influenced by the edge width settings (Figure 7.). A dominant pattern class at an edge width of 25 m was core; and comprised by more than 80% of all set-aside area for biodiversity conservation. Edge was well represented in overall pattern as well and accounted for 14% of total set-aside area (Table 4). When edge width was set to 50 m the core area decreased by 11% and the pattern class that gained the most was edge (from 14.3% to 20.2%). Even with an increase of the edge width to 100m the core class was dominant. It accounted for more than a half (55.1%) of set-aside forests, while edge and islet classes together occupied 35% of the total set-aside forests.

Table 4
Total area of the main pattern classes set-aside for biodiversity conservation

Pattern class	Pattern class (ha and % of set-aside forest area)		
	25 m	50 m	100 m
Branch	2571 1.5%	5007 3%	7857 5%
Edge	24155 14.3%	33385 20.2%	43023 27.4%
Perforation	1129 0.7%	1531 0.9%	1437 0.9%
Islet	1236 0.7%	5626 3.4%	11937 7.6%
Core	138573 81.8%	115872 70.2%	86475 55.1%
Bridge	1198 0.7%	2353 1.4%	4013 2.6%
Loop	571 0.3%	1368 0.8%	2293 1.5%
Total (ha)	169433	165143	157036
%	100%	100%	100%

Coniferous forests were the dominant forest type, occupying more than a half of all set-aside forest area (Figure 6). The second most prevalent forest types were mixed coniferous-deciduous and deciduous-coniferous forests occupying more than 28% of total set-aside area together. The least represented forest types were broadleaved forests that took less than 5% of total set-aside area.

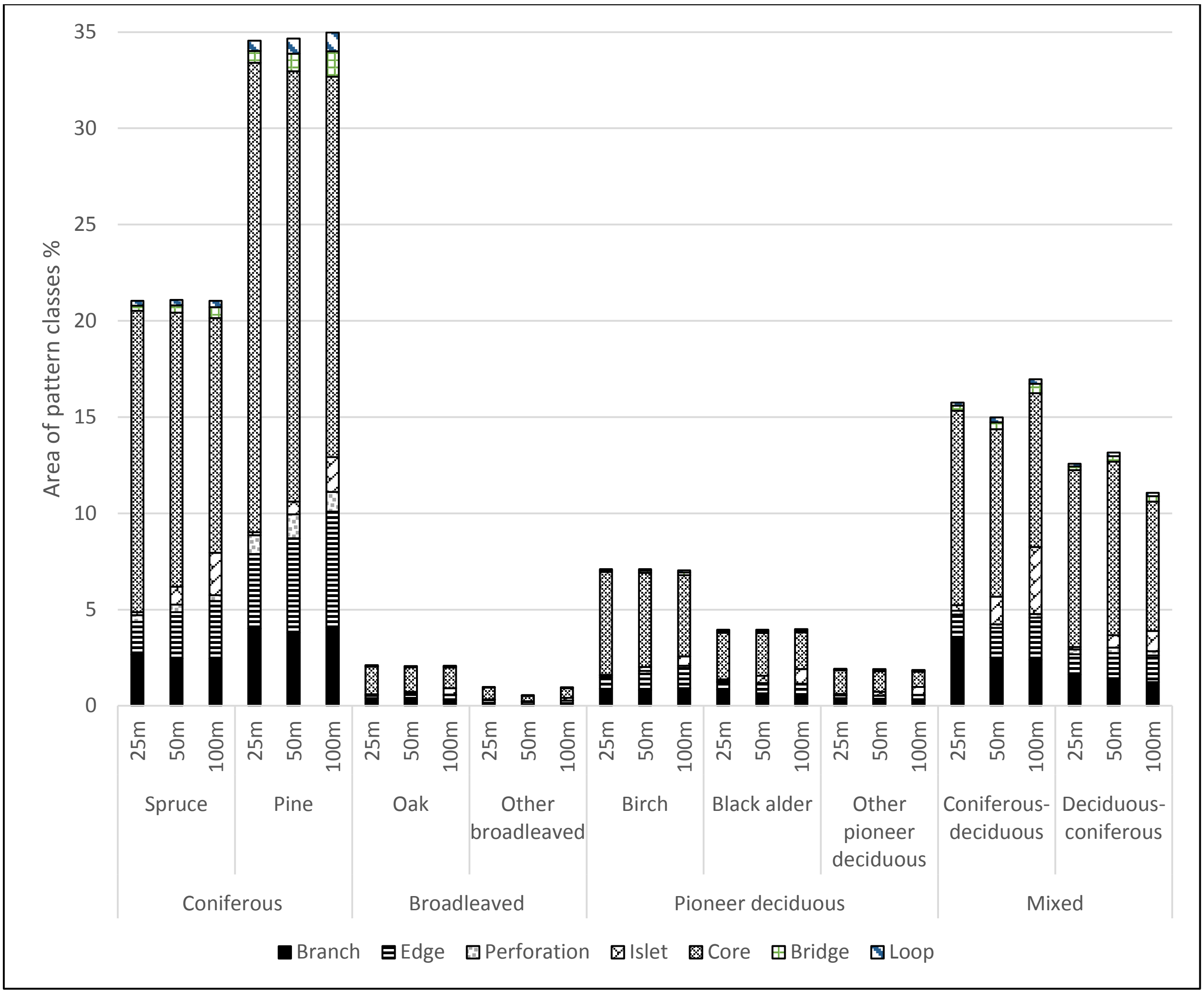

Figure 6

Area proportion of main pattern classes in different set-aside forest types for biodiversity conservation

Forest pattern classes were regularly distributed among all forest types with a predominant core class (Figure 6). An edge width increase from 25m to 100m the core proportion decreased 27%. It diminished almost by the same proportion (20%) in all forest types while edge and islet classes increased.

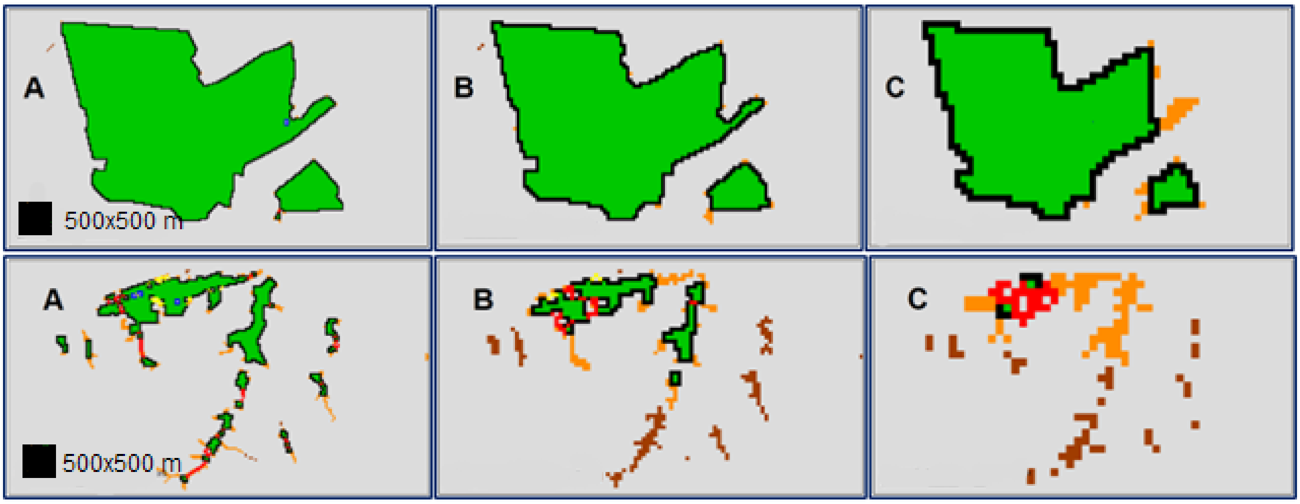

Figure 7
Examples of changes of set-aside forest area pattern when edge width increases from 25 m (A) to 50 m (B) and 100 m (C) in coarse (upper) and fine (bottom) structures

Larger core areas were not greatly altered by the increasing edge width (Figure 7), but small cores were converted into the other pattern classes or completely disappeared from the map.

The majority of cores (with edge width 25 m) in voluntary and formally set aside forest occupied less than 1 ha, while the most of the area (≥70%) was located in cores that ranged from 10 to 1000 ha (Figure 8). In both forest set-asides total number of cores, in less than 1 ha decreased twice with an edge width increase to 100m. On the other hand the area proportion of cores ranging from 10 to 1000 was not significantly affected by the edge increase. The least number of cores were more than 1000 ha large (less than 1% in both set-aside classes). They took less than one tenth of total voluntary protected area, but in formally set-aside forests largest cores accounted for more than one fourth of the total area.

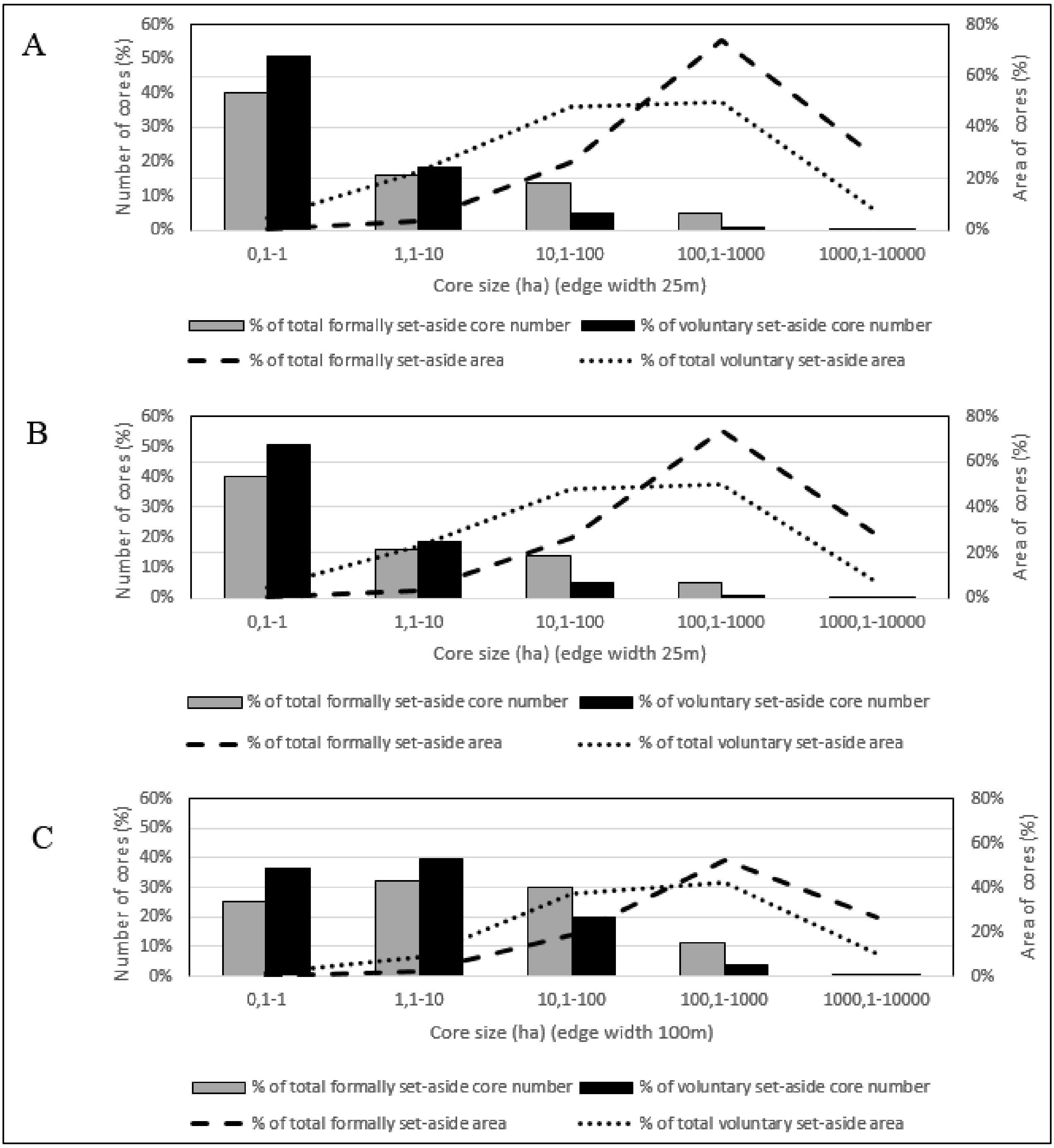

Figure 8
Area and core number distribution in formally and voluntary set-aside forests with edge width 25 m (A), 50 m (B), 100 m (C)

The old forest areas were scattered throughout the all set-aside area (Figure 9). It was especially apparent in a formally set-asides. Setting the analysis to 50% of the core area has to be older than 110 years decreased old forest area almost five times (from 6.4% to 1.3%).

Voluntary set aside area had decreased only one third (from 3% to 2.2%). Setting the analysis to old aged forest area proportion to 70% had decreased old core area even further.

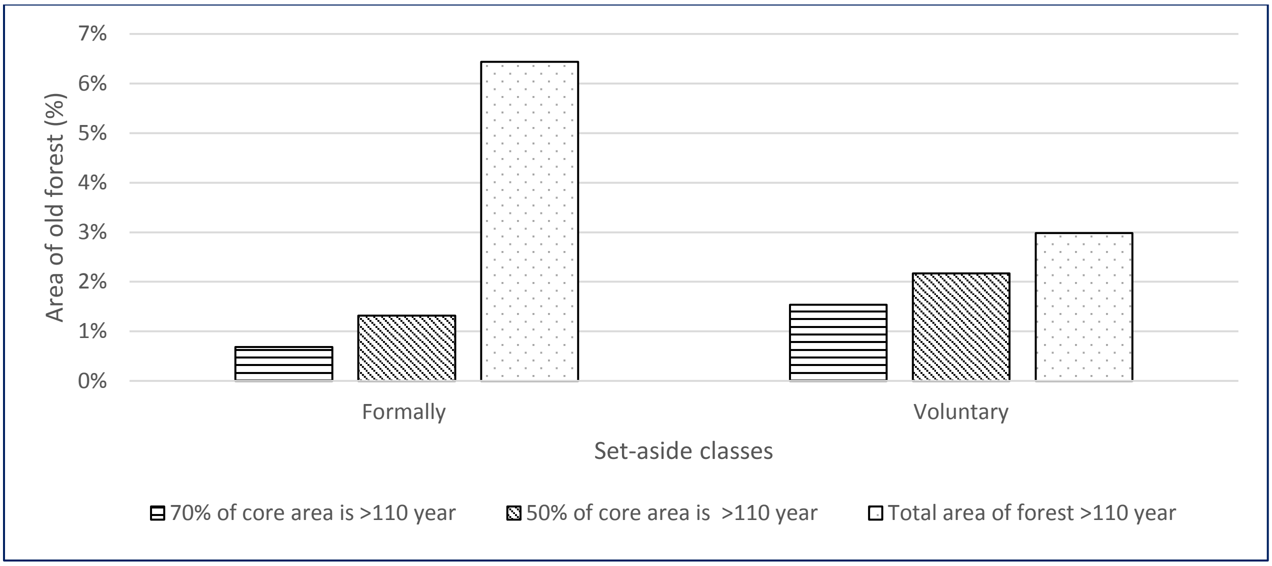

Figure 9
Area proportion of total old forest and old cores in formally and voluntary set-aside forest with edge width 25 m.

Discussion

Standard requirements for biodiversity conservation

The active measures in forest management according to the FSC requirements are imposed on three spatial scales ranging from single trees to landscape. However the coarsest scale - ecoregion is missing, which is acknowledged as being neglected in private conservation efforts (Poiani et al., 2000). In a comparison with indicators for biodiversity conservation in the national FSC standards in Sweden and the Russian Federation (Elbakidze et al., 2011) the Lithuanian FSC standard (if we consider only a number of indicators) focuses more on forest management on the level landscape in an ecoregion than the Swedish standard; however, the Russian standard contains more indicators for aforementioned scale of forest management than the Lithuanian and Swedish FSC standards. The only similarity between the Lithuanian and Swedish FSC standards is an absence of indicators for the scale ecoregion globally (Figure 9). Both Swedish and Russian standards have considerably more indicators on single trees and stands in landscape scales. In conclusion it could be assumed that FSC standard developed by the national initiatives have more implications on biodiversity conservation.

Considering the distribution of indicators among different spatial scales, I argue that forest management in the SFEs might be appropriate for generalist species with small habitat requirements, while the maintenance and protection of species with larger and more demanding habitats cannot be achieved with in the managed forests.

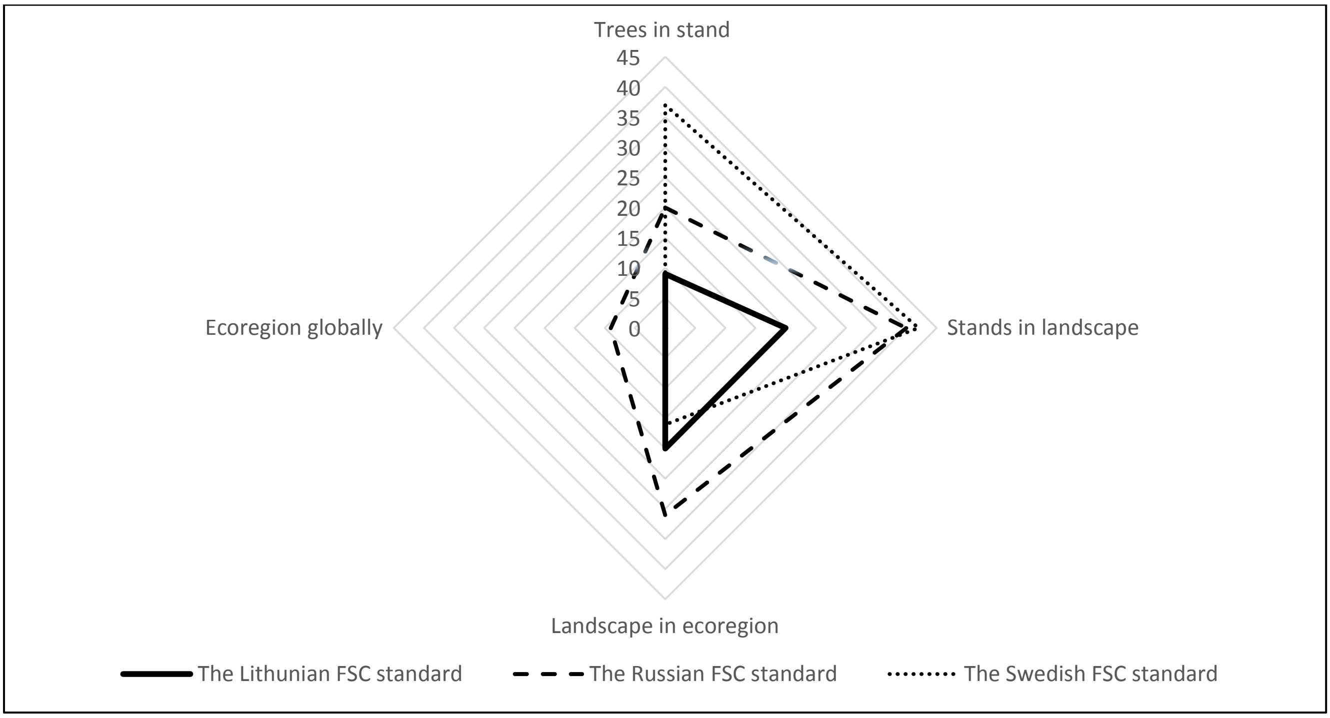

Figure 10
FSC standard indicators aimed directly at maintaining and protecting biodiversity in Lithuania, Russia and Sweden on different spatial scales

Assessment of FSC certification outcomes for biodiversity conservation

Area proportion of set-aside forests

The results of my study show that set-aside forest areas are mostly comprised of formally protected forests revealing a greater contribution to biodiversity conservation from national legislation than the market driven efforts. Nearly 70% of set-aside area in the SFEs managed forest in Lithuania belong to formally protected forests. However the Russian example shows that strong national legislation can enforce even higher protection level (Elbakidze et al., 2011). Voluntary set-aside area proportions varied between different SFEs, but clearly exhibited a trend to set aside non-forest habitats i.e. 450 ha of bogs, as HCVF. WHK had the least proportion of non-forest habitats; hence they were selected to preserve endangered woodland species. Thus, my assumption is that the contribution of FSC certification to biodiversity conservation in Lithuania is a result of requirements of the national legislation and not forest certification itself.

Structural habitat connectivity

The structural habitat connectivity analysis provides contrasting views. Set-aside cores take a major part in the overall pattern. At the same time old forest cores occupy only 10% of total set-aside area and the majority of cores are represented by formally set-asides. However, most of formally set-aside areas in SFEs fall into group II forest, which has more lenient regulations. The lowest allowable cutting age for most of the species in group II forests does not reach over mature forest age (Ministry of Evironment, 2010), while in voluntary protected areas all final felling is prohibited. Nevertheless if the protection is aimed at old forest specialising species, most of the set-aside forests cannot provide large enough areas as potential habitats at present. Therefore the evaluation of only total set-aside forest area for biodiversity conservation might provide an overoptimistic view, due to a missing link to actual protected species requirements and habitat quality.

Tree species distribution calculated in the set-aside areas (Figure 7) is comparable to overall Lithuanian forest distribution (Table 5). However, set-aside areas have more coniferous species dominated stands and less pioneer deciduous. Broadleaved species are emphasized in the FSC standard (Rainforest Alliance, 2013), but they are less prevalent in set-aside areas that in average Lithuanian forests.

Table 5
Tree species distribution (%) in Lithuania (Ministry of Environment, State forest service, 2013) and in set-aside areas for biodiversity conservation

Dominant species groups	Species distribution (%)	
	Lithuania	Set-aside area
Coniferous	56	69
Broadleaves	4.4	3.5
Pioneer deciduous	39.6	27.5

In the studed SFEs set-aside forests were unevenly distributed and surrounded by the productive stands. Productive forests are considered to have insufficient resources to sustain target species for an extended period of time, due to continuous intensive management

(Niemelä, 1997). Yet they could facilitate inter-habitat matrix permeability and lessen the effects of set-aside forest fragmentation (Antongiovanni, and Metzger, 2005). The overall set-aside matrix had a significant area exposed to the edge effect and narrow elements (branch, bridge and loop) were prevalent as well, which can be easily transformed into islets in the future.

Furthermore it is very important to consider functional connectivity of set-aside forest in order to get a full view about the actual habitat functionality, but such requirements go beyond the scope of current Lithuanian FSC standard. In the revised FSC P&C there is a criteria (Criteria 6.4) referring to structural and functional connectivity, but this will become active only after international generic indicators are completed (FSC, 2012b). Moreover there is no national Lithuanian FSC standard, due to missing local initiative to develop national standard, which is a lengthy process, requiring expertise (FSC, 2014b). Hence it is not certain to which extent new requirements will be incorporated in the currently used interim standard.

Lithuanian forests are owned by the state and private individuals or organizations (Forest law of the Republic of Lithuania, 1994). The Lithuanian forests are made up from an archipelago of various sizes of state forest and small forest patches owned by non-industrial private forest owners, with an average holding covering <3ha (Ministry of Environment, State forest service, 2013). It creates a spatially complex pattern. The implementation of private and governmental biodiversity conservation tools on a landscape level in such an environment is bound to have many obstacles, thus cooperation between different stakeholders in order to protect or maintain forest biodiversity is of crucial importance (Cabarle et al, 2005).

This study has had some limitations. Firstly, I did not include all formally protected forests. Thus, formally protected forests that belong to group III were omitted, due to the weak restriction in foret management, which do not prevent final felling (Ministry of Environment, 2010). Secondly, small protection zones (biosphere polygons and rare birds' nesting zones, single protected trees) were not included due to the absence of spatial information. In evaluating the FSC indicators, a lenient approach was taken therefore, the total number of conservation measures imposing indicators and their spatial extent can be arguable.

Nevertheless there is a temporal link between voluntary set-aside areas and FSC certification. Such areas emerged only after SFEs became certified, before 2002 there were no voluntary set-aside areas. Moreover non-certified forests don't have such protected areas. Currently on-going project, to encourage private owners' to set-aside WKH that were identified in their forests, offers compensations (Lietuvos žemės ūkio konsultavimo tarnyba, 2013). Therefore it is hardly possible that the other direct drivers were involved beside FSC certification in voluntary set-aside areas emergence.

My study shows that the input of national legislation and policy for biodiversity conservation has the most important role in biodiversity conservation on the ground. Therefore to get a full picture about the actual consequences of market-driven biodiversity conservation efforts formally set-aside areas need to be considered as well. Overall FSC standard implementation is beneficial for biodiversity conservation in Lithuania, but it lacks coordination among SFEs and other concerned parties. Lastly, structural habitat analysis demonstrates only physical area distribution without considering different species requirements.

It could be proposed further set-aside for biodiversity conservation areas analysis in regards to functional connectivity to provide more accurate estimation of current set-aside network value. Such study would have practical implications showing the target species optimal habitats and possible improvements of functional connectivity.

References

Ahti, T., Hämet-Ahti, L. & Jalas, J. (1968). Vegetation zones and their sections in northwestern Europe. Ann. *Bot. Fennici,* 5, 169-211.

Alves, R. R., Jacovine, L. A. G. & Silva, M. L. (2011). Forets plantations and the protection of native forests in certifyed management units in Brazil. *Recista Arvore, Vicosa-MG*, *35*(4), 859–866.

Andersson ,L., Kriukelis, R., Skuja, S., (2005). *Woodland Key Habitat inventory in Lithuania* (In Lithuanian, Kertinių Miško buveinių inventorizacija Lietuvoje). VĮ Valstybinis miškotvarkos institutas, Kaunas, 121 p.

Angelstam, P., Boutin, S., Schmiegelow, F., Villard, M.-A., Drapeau, P., Host, G., Innes, J., Isachenko, G., Kuuluvainen, M., Mönkkönen, M., Niemelä, J., Niemi, G., Roberge, J.-M., Spence, J., Stone, D., (2004a). Targets for boreal forest biodiversity conservation – A rationale for macroecological research and adaptive management. *Ecological Bulletins* 51, 487–509.

Angelstam, P., Breuss, M., Mikusinski, G., (2001). Toward the assessment of forest biodiversity at the scale of forest management units – a European landscape perspective. In: Franc, A., Laroussinie, O., Karajalainen, T. (Eds.), *Criteria and indicators for sustainable forest management at the forest management unit level.* European Forest Institute, Nancy, 59–74.

Angelstam, P., Roberge, J.-M., Lohmus, A., Bergmanis, M., Brazaitis, G., Donz-Breuss, M., Edenius, L., Kosinski, Z., Kurlavicius, P., La¯¯rmanis, V., L_ukins, M., Mikusinski, G., Račinskis, E., Strazds, M., Tryjanowski, P., (2004b). Habitat modelling as a tool for landscape-scale conservation – A review of parameters for focal forest birds. *Ecological Bulletins* 51, 427–453.

Angelstam, P.K., Anufriev, V.M., Balciauskas, L., Blagovidov, A.K., Borgegard, S.O., Hodge, S.J., Majewski, P., Ponomarenko, S.V., Shvarts, E.A., Tishkov, A.A., Tomialojc, L., Wesolowski, T., (1997). Biodiversity and sustainable forestry in European forests: how East and West can learn from each other. *Wildlife Society Bulletin, 25,* 38–48.

Antongiovanni, M., and Metzger, J. (2005). Influence of matrix habitats on the occurrence of insectivorous bird species in Amazonian forest fragments. *Biological Conservation*, *122*(3), 441–451.

Aune, K., Jonsson, B.-J., Moen, J., (2005). Isolation and edge effects among woodland key habitats in Sweden: is forest policy promoting fragmentation? *Biological Conservation 124*, 89–95.

Bennett, E. L. (2001). The Joint Effort of Timber Certification. *Conservation Biology*, *15*(2), 318–319.

Bernstein, S., and Cashore, B. (2003). Nonstate Global Governance : Is Forest Certification a Legitimate Alternative to a Global Forest Convention ? In: Kirton, J. J. & Trebilcock, M. J. (eds.) *Hard Choices, Soft Law, Voluntary Standards in Global Trade, Environment and Social Governance*, (Rosenau), 33-64.

Bohn, U., Neuhäusl, R., unter Mitarbeit von / with contributions by Gollub, G., Hettwer, C., Neuhäuslová, Z., Raus, Th., Schlüter, H. & Weber, H. (2000/2003): *Karte der natürlichen Vegetation Europas / Map of the Natural Vegetation of Europe.* Maßstab / Scale 1: 2 500 000. Münster (Landwirtschaftsverlag).

Brukas, V. (1998). Green forest certification: future mirage or upcomming reality? (In Lithuanian: Žaliasis miško sertifikavimas: ateities miražas ar besiartinanti realybė?) *Mūsų girios*, *7*, 12-13.

Brukas, V., Felton, A., Lindbladh, M., & Sallnäs, O. (2013). Forest Ecology and Management Linking forest management, policy and biodiversity indicators – A comparison of Lithuania and Southern Sweden. *Forest Ecology and Management*, *291*, 181–189.

Brukas, V., Helles, F. & Tarp, P., (1999). Miško sertifikavimas: nestandartiniai standartai [Forest certification: non-standard standards]. *Informacinis biuletenis*, *2*, *7*, 15-20.

Butchart, S. H. M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J. P. W., Almond, R. E. a, … Watson, R. (2010). Global biodiversity: indicators of recent declines. *Science* (New York, N.Y.), 328(5982), 1164–8.

Cabarle, B., Brown, N. & Cesareo, K. (2005). Integrating Protected Areas, Plantations, and Certification. *Journal of Sustainable Forestry*, 21:4, 15-34.

Cashore, B., Auld, G. & Newsom, D. (2004). *Governing Through Markets: Forest Certification and the Emergence of Non-State Authority* . New Haven, CT, USA: Yale University Press.

Dias, F. S., Bugalho, M. N., & Cerdeira, J. O. (2013). Is forest certification targeting areas of high biodiversity in cork oak savannas? *Biodiversity conservation*, 22(1), 93–112.

Directorate general of state forests, (2007). Regulation. (In Lithuanian, Nuostatai) Accessed 2014.03.02 <http://www.gmu.lt/gmu_nuostatai/>

Directorate general of state forests, (2013). Forest certification. (In Lithuanian, Miškų tvarkymo sertifikavimas) Accessed 2014.01.29 <http://www.gmu.lt/misku_tvarkymo_sertifikavimas/>

Elbakidze, M., Angelstam, P., Andersson, K., Nordberg, M., and Pautov, Y. (2011). How does forest certification contribute to boreal biodiversity conservation? Standards and outcomes in Sweden and NW Russia. *Forest Ecology and Management*, 262(11), 1983–1995.

Eriksson, S. and Hammer, M. (2006). The challenge of combining timber production and biodiversity conservation for long-term ecosystem functioning—A case study of Swedish boreal forestry. *Forest Ecology and Management*, 237 (1–3), 208–217.

Esseen, P.-A., and Renhorn, K.-E., (1998). Edge effects on an epiphytic lichen in fragmented forests. *Conservation Biology*, 126, 1307–1317.

Fahrig, L., (2001). How much habitat is enough? *Biological Conservation*, 100, 65–74.

FAO, (2002). Second expert meeting on harmonizing forest-related definitions for use by various stakeholders. Accessed 2014. 06. 12 <http://www.fao.org/docrep/005/y4171e/y4171e00.htm#TopOfPage>

FAO, (2010). Global Forest Resources Assessment 2010, Main report. *FAO forestry paper*. Accessed 2014.01.29 < http://www.fao.org/docrep/013/i1757e/i1757e.pdf>

Forest law of the Republic of Lithuania (In Lithuanian, Lietuvos Respublikos miškų įstatymas) (1994). Vilnius. (Nr. I-671).

Forman, R. T. T. (1995). Some general principles of landscape and regional ecology. *Landscape Ecology*,10(3), 133-142.

FSC, (2014a). Fasts & Figures. Accessed 2014.01.30 <https://ic.fsc.org/facts-figures.19.htm>

FSC, (2014b). Process requrements for the development and maintenance of national Forest Stewardship standards. FSC-STD-60-006 (V1-2) en. Accessed 2014.09.10 < https://ic.fsc.org/national-standard-development.318.htm>

FSC, (2012a). Fsc international standard. Fsc principles and criteria for forest Stewardship. Fsc-std-01-001 (version 4-0) en. Accessed 2014.06.09 < https://ic.fsc.org/principles-and-criteria.34.htm>

FSC, (2012b). Fsc international standard. Fsc principles and criteria for forest Stewardship. FSC-std-01-001 (version 5-0) en. Accessed 2014.06.30 < https://ic.fsc.org/preview.revised-fsc-pc-v5-0-fsc-std-01-001-low-resolution.a-870.pdf>

Ghazoul, J. (2001). Barriers to Biodiversity Conservation in, *Concervation Biology 15*(2), 315–317.

Gulbrandsen, L. H. (2004). Overlapping Public and Private Governance : Can Forest Certiacation Fill the Gaps in the Global Forest Regime ? *Global Environmental Politics*, *4*(2), 75–99.

Gulbrandsen, L. H. (2005). The Effectiveness of Non-State Governance Schemes: A Comparative Study of Forest Certification in Norway and Sweden. *International Environmental Agreements: Politics, Law and Economics*, *5*(2), 125–149

Gullison, R. E. (2003). Does forest certification conserve biodiversity? *Oryx*, *37*(2), 153–165.

Hansen, M. C., Stehman, S. V, & Potapov, P. V. (2010). Quantification of global gross forest cover loss. *Proceedings of the National Academy of Sciences of the United States of America*, 107(19).

Johansson, J., and Lidestav, G. (2011). Forest Policy and Economics Can voluntary standards regulate forestry ? — Assessing the environmental impacts of forest certi fi cation in Sweden. *Forest Policy and Economics, 13*(3), 191–198.

Kairiūkštis, L. (ed). (2003*). Lithuanian forest annals XX century* (In Lithuanian, Lietuvos miškų metraštis. XX amžius). Vilnius: Petro ofsetas, p. 631.

Kindlmann, P., and Burel, F. (2008). Connectivity measures: a review. *Landscape Ecology, 23*, 879–890.

Kurlavicius, P., Kuuba, R., Lukins, M., Mozgeris, G., Tolvanen, P., Angelstam, P., Karjalainen, H., Walsh, M., (2004). Identifying high conservation value forests in the Baltic states from forest databases. *Ecological Bulletins*, *51*, 351–366.

Laasimer, L., Kuusk, V., Tabaka, L., Lekavičius, A. (Eds.). (1993). *Flora of the Baltic countries: compendium of vascular plants*, vol. 1. Tartu: Estonian Agricultural University, *Institute of Zoology and Botany*, 362.

Lazdinis, M., Carver, A., Lazdinis, I., Paulikas, V.K., (2009). From union to union: forest governance in a post-soviet political system. *Environmental Science and Policy, 12*, 309–320.

Lietuvos žemės ūkio konsultavimo tarnyba, (2013). Woodland key habitat inventory (In Lithuanian, Inventorizuojamos kertinės miško buveinės). Acesses 2014.09.11 <http://www.agroakademija.lt/miskininkyste/?SId=803>

Lithuanian Fund for Nature, (2014). Stimulation of private forest certification in Lithuania (2002 - 2005) (In Lithuanian, Privačių miškų sertifikavimo skatinimas Lietuvoje). Accessed 2014.02.05 <http://glis.lt/en/?pid=24&proj_id=35>

Ministry of Environment, (2002). Lithuanian forestry policy and strategy (In Lithuanian, Lietuvos miškų ūkio politika ir jos įgyvendinimo strategija). Accessed 2014.03.12 < http://www.am.lt/VI/index.php#a/4997>

Ministry of Environment, (2007). What is Natura 2000? (In Lithuanian, Kas yra Natura 2000?) Accessed 2014.02.27 <http://www.a m.lt/VI/index.php#a/6802>

Ministry of Environment, (2010). *Forest cutting rules* (In Lithuanian, Miško kirtimo taisyklės) Vilnius, Valstybės žinios, Nr. 14-676.

Ministry of Environment, (2012). The national program of forestry for year 2012-2020. (In Lithuanian, Nacionalinė miškų ūkio sektoriaus plėtros 2012-2020 metų programa). Ministry of Environment, Vilnius. Accessed 2014.03.10 < http://www.am.lt/VI/index.php#a/11003>

Ministry of Environment, State forest service, (2006). *Lithuanian statistical yearbook of forestry 2006.* Vilnius: Lututė.

Ministry of Environment, State forest service, (2013). *Lithuanian statistical yearbook of forestry 2013.* Vilnius: Lututė.

Murcia, C. (1995) Edge effects in fragmented forests: implications for conservation. *Trends in Ecology and Evolution*, 10, 58–62.

Niemelä, J. (1997). Invertebrates and Boreal Forest Management. *Conservation Biology*, 11(3), 601–610.

Olson, D. M., & Dinerstein, E. (2002). The global 200 : priority ecoregions for global conservation. *Annals of Missouri Botanical Garden,* 89, 199–224.

Ostapowicz, K., Vogt, P., Ritters, K., Kozak, J., Estreguil, C., (2008). Impact of scale on morphological spatial pattern of forest. *Landscape Ecology,* 23, 1107–1117.

PEFC Lietuva, (2008). PEFC Lithuanian (In Lithuanian, PEFC Lietuva). Accessed 2014.02.07<http://www.forest.lt/pefc/PEFC_Lietuva.htm>

PEFC, (2014). PEFC Council Information Register. Accessed 2014.01.29 <http://www.pefcregs.info/RESULT1.asp?COUNTRY_CODE=20&TYPE_OF_CERTIFICATION=_&ORGANISATION_NAME=&CERTIFICATION_NUMBER=&CERTIFICATION_BODY_NAME=_&fstatus=valid&B1=Search+now>

Pekarskienė I., Susnienė R. (2012). Baltic countries globalization sectorial analysis (In Lithuanian, Baltijos šalių atskirų ūkio šakų globalizacijos lygio vertinimas). *Economics and management*. *17*(2): 547–553.

Poiani, K. A., Richter, B. D., Anderson, M. G., & Richter, H. E. (2000). Biodiversity Conservation at Multiple Scales : Functional Sites, Landscapes , and Networks. *Bioscience, 50*(2), 133–146.

Prakash, A., & Potoski, M. (2012). Voluntary Environmental Programs : A Comparative Perspective. *Journal of Policy Analysis and Management, 31*(1), 123–138.

Putz, F. E., and Romero, C. (2001). Biologists and Timber Certification, *Conservation biology 15*(2), 313–314.

Rainforest Alliance, (2013). Lithuania Interim FM Standard. Accessed 2014.02.18 <http://www.nepcon.net/files/resource_1/documents/LITHUANIA/Rainforest%20Alliance%20Lithuania%20Interim%20Standard%20FM-32%20LIT.pdf>

Rametsteiner, E., and Simula, M. (2003). Forest certification—an instrument to promote sustainable forest management? *Journal of Environmental Management, 67*(1), 87–98.

Roberge, J.-M., Bengtsson, S. B. K., Wulff, S. and Snäll, T. (2011), Edge creation and tree dieback influence the patch-tracking metapopulation dynamics of a red-listed epiphytic bryophyte. *Journal of Applied Ecology*, 48, 650–658.

Ruževičius, J. (2008). Lithuanian forestry certification analysis (In Lithuanian, Lietuvos miškų sertifikavimo sistemos analizė). *Ekonomika ir vadyba,* 13, 834-841.

Sasser, E. N., Prakash, A., Cashore, B., & Auld, G. (2006). Direct Targeting as an NGO Political Strategy : Examining Private Authority Regimes in the Forestry Sector. *Business and Politics*, 8(3), 1-34.

Šaudytė, S., Karazija, S., & Belova, O. (2005). An Approach to Assessment of Naturalness for Forest Stands in Lithuania. *Baltic Forestry*, 11(1), 39–45.

Scientific certification systems, (2011). Forest management and stump-to-forest gate chain-of-custody certification evaluation report. Accessed 2014.02.07 <http://info.fsc.org/details.php?id=a0240000007pVmnAAE&type=certificate>

Soille, P., and Vogt, P., 2009. Morphological segmentation of binary patterns. Pattern Recognit. Lett. 30, 456–459.

Timonen, J., Siitonen, J., Gustafsson, L., Kotiaho, J. S., Stokland, J. N., Sverdrup-Thygeson, A., & Mönkkönen, M. (2010). Woodland key habitats in northern Europe: concepts, inventory and protection. *Scandinavian Journal of Forest Research*, 25(4), 309–324.

Tscharntke, T., Tylianakis, J. M., Rand, T. A., Didham, R. K., Fahrig, L., Batáry, P., Bengtsson, J., Clough, Y., Crist, T. O., Dormann, C. F., Ewers, R. M., Fründ, J., Holt, R. D., Holzschuh, A., Klein, A. M., Kleijn, D., Kremen, C., Landis, D. A., Laurance, W., Lindenmayer, D., Scherber, C., Sodhi, N., Steffan-Dewenter, I., Thies, C., van der Putten, W. H. and Westphal, C. (2012), Landscape moderation of biodiversity patterns and processes - eight hypotheses. *Biological Reviews*, 87, 661–685.

Vogt, P., Ferrari, J., Lookingbill, T., Gardner, R., Riitters, K., Ostapowicz, K., (2009). Mapping potential functional connectivity. *Ecological Indicators*, 9, 64–71.

Vogt, P., Riitters, K., Estreguil, C., Kozak, J., Wade, T., Wickham, J., (2007a). Mapping spatial patterns with morphological image processing. *Landscape Ecology,* 22, 171–177.

Vogt, P., Riitters, K., Iwanowski, M., Estreguil, C., Kozak, J., Soille, P., (2007b). Mapping landscape corridors. *Ecological Indicators,* 7 (2), 481–488.

Appendices

Appendix 1

Lithuanian FSC standard (indicators)	***Scale***			
Direct positive impact of FSC stansard on biodiversity conservation in Lithuania	**Tree in stand**	**Stand in landscape**	**Landscape in ecoregion**	**Ecoregion globally**
5.2.2. Economically valuable hard leave trees depending on their viability should have reached maturity during logging operations.	1			
5.6.8. Large FMO: The overall proportion of pre-mature and mature stands shall not be bellow 20 %. If it is bellow, a long term strategy to improve situation shall be prepared.		1		
6.1.2. Measures to minimize negative environmental impacts of forest operations shall be followed in the field, e.g. wet soil types shall be handled with precaution to avoid soil damages, sensitive bird habitats shall not be intervened in birds nesting period, except means that were recommended by Forest Sanitary Protection Service, in case of potential mass spread of forest pests or disease, or if these are already spread.	1	1	1	
6.2.1. Large FMO-s: FMO shall have a written list and implement protection means of threatened, rare, or endangered species or ecosystems identified within their forest area.	1	1		
6.3.1. Large and medium FMO-s: Special efforts shall be taken to increase the share of native noble hardwoods (a, b).	1	1	1	
6.3.3. Selective logging or natural regeneration should be preferred on wet soil types (a, b, c), except all marshy habitats (P and U hydrotops), with top forest layer consisting more than 30 pct. spruce.		1		
6.3.4. Natural regeneration and local provenances should be preferred. (a, b, c).		1		
6.3.5. Thinning and harvesting operations shall favour the development of mixed stands (a, b, c).		1		
6.3.7. Hollow standing trees and trees with big bird nests shall be preserved.	1			
6.3.8. Biologically valuable dead wood (snags, lying dead wood) of various decay stages shall be preserved with consideration of national requirements on work safety as well as safety along major roads and recreational sites. The amount of dead wood should be at least 5% of existing wood volume in the stand. Cutting remainings (stumps, brances, etc.) that are generated during logging operation can be removed for economical purposes.		1		
6.3.9. At least 10 living biodiversity trees (7 in case of noble hardwood) per hectare shall be selected and left in final felling (including clear cutting, selective cutting and step wise cutting) and shall be left until natural decay (b). These trees shall be selected before logging operations.	1			

6.3.10. Biodiversity trees shall be chosen from wide variety of species with larger diameter among the most biologically valuable and wind stable trees. (6.3 b). Hollow standing trees and trees with big bird nests can be counted as biodiversity trees.	1			
6.3.11. Spatial location of biodiversity trees in final felling areas should promote their long term survival and benefit endangered rare biodiversity forms.	1			
6.4.1. Large FMO-s: FMO shall leave representative samples of existing rare and/or endangered ecosystems for natural succession in their natural state covering at least 5 % of the total forest area. Strict nature reserves located inside or bordering to the FMO may be included in the estimation of the 5 %.			1	
6.4.2. In case the same forest owner has got several FSC certified FMOs, then in some FMOs less than 5 % of area can be set aside (see 6.4.1.) while all together certified FMOs of the same owner fulfil the requirement of indicator 6.4.1. Set aside areas can be distributed unevenly with intention to select the most valuable and representative sites of certified forests.			1	
6.4.3. Selection of forest areas to be preserved as required in 6.4.1 shall be based on the identification of key biological areas identified through consultation with environmental stakeholders, local government and scientific authorities.		1	1	
6.4.6. No timber harvesting shall take place in areas protected as required in 6.4.1, unless specified in legal acts regulating management of these areas with intention to increase the value of protected habitats or species.		1		
6.5.5. Buffer zones in clear cuts shall be left along water bodies and open landscape to ensure stability for forest ecosystems and microclimate.			1	
6.9.1. Native forests shall not be converted to stands of exotic species.		1	1	
6.9.2. Exotic species should not be cultivated in the forest, except scientific and recreational purposes.		1	1	
6.9.3. The spread of invasive exotic species that have been historically introduced shall be monitored and if necessary, actions shall be taken to control or eliminate the species.		1		
6.10.2. Forest and forestland with high conservation values cannot be converted to non-forest land.		1	1	
7.1.2. Large and medium FMO-s: FMO management plan or other management documents shall include: g) General description of monitoring activities implemented to ensure conservation of protected areas and HCVF resources (f, g) h) Maps describing the forest resource base including protected areas, planned management activities and land ownership (h)			1	
8.2.1. Large and medium FMO-s: Monitoring plan shall identify/describe observed changes in conditions in terms of:environmental changes affecting flora, fauna, soil and water resources (e.g. erosion, outbreak of pest, spreading of invasive species, observed nesting sites for endangered bird species) (c, d)	1	1	1	

9.1.1. Information on officially protected areas and woodland key habitats shall be included on maps and protection reasons described in written.		1	1	
9.1.2. Large and medium FMO-s: FMO shall have written procedures for identifying and recording new HCVF areas.			1	
9.2.1. Large FMO-s: Local people and stakeholders including environmental NGOs shall be consulted to identify HCVF.			1	
9.4.1. HCVF shall be monitored on a regular basis to avoid activities such as illegal logging that might endanger the conservation values.			1	
10.2.1. Areas with natural vegetation shall be protected and taken into consideration when planning establishment of plantations.		1	1	
10.2.2. Streamside buffer zone with natural vegetation shall be established and/or protected.			1	
10.2.3. The scale and layout of plantations shall be consistent with natural forest vegetation in the landscape.			1	
10.4.5. In case exotic species are used, at least 20 pct of the stand shall consist of native species.		1		
10.5.1. Large and medium FMO-s: FMO shall set aside at least 10 pct of the area for natural vegetation.		1		
10.6.2. Water bodies within the plantation area shall be identified and buffer zones established (see also 10.2).		1		
10.9.1. The plantation shall not occupy land converted from natural forest since November 1994, unless clear evidence exist that the current manager/owner was not responsible.			1	
10.9.2. Primary, degraded primary and mature secondary forests shall not be cleared by current forest managers to create tree plantations.			1	
Total	***9***	***20***	***20***	***0***

Appendix 2

Pattern classes

Pattern class	Coniferous species						Broadleaved species						Pioneer deciduous species									Mixed						Pattern class % (of set-aside forest area)		
	Spruce			Pine			Oak			Other broadleaved			Birch			Black alder			Other pioneer deciduou			Coniferous-deciduous			Deciduous-coniferous					
	25m	50m	100m	25m	50m	100m	25m	50m	100m	25m	50m	100m	25m	50m	100m	25m	50m	100m	25m	50m	100m	25m	50m	100m	25m	50m	100m	25m	50m	100m
Branch	4479	4159	4218	6767	6428	6964	686	696	520	290	153	263	1499	1396	1566	1428	1114	854	675	624	533	5910	4226	4105	2747	2430	2101	24481	21225	21124
	2,7%	2,5%	2,5%	4,0%	3,8%	4,1%	0,4%	0,4%	0,3%	0,2%	0,1%	0,2%	0,9%	0,8%	0,9%	0,8%	0,7%	0,5%	0,4%	0,4%	0,3%	3,5%	2,5%	2,4%	1,6%	1,4%	1,2%	14,5%	12,6%	12,3%
Edge	2856	4065	5110	6503	8281	10313	213	326	422	218	180	205	970	1435	1803	633	778	1075	228	264	427	2070	2611	3737	1757	2214	2390	15448	20154	25482
	1,7%	2,4%	3,0%	3,9%	4,9%	6,0%	0,1%	0,2%	0,2%	0,1%	0,1%	0,1%	0,6%	0,8%	1,1%	0,4%	0,5%	0,6%	0,1%	0,2%	0,2%	1,2%	1,5%	2,2%	1,0%	1,3%	1,4%	9,2%	12,0%	14,9%
Perforation	584	661	525	1638	2089	1734	69	44	68	31	26	9	166	235	191	91	109	60	36	20	8	341	326	322	425	460	375	3381	3969	3292
	0,3%	0,4%	0,3%	1,0%	1,2%	1,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,1%	0,1%	0,1%	0,1%	0,1%	0,0%	0,0%	0,0%	0,0%	0,2%	0,2%	0,2%	0,3%	0,3%	0,2%	2,0%	2,4%	1,9%
Islet	284	1578	3763	259	1127	3106	49	171	561	20	51	245	81	337	840	155	636	1275	107	324	711	470	2422	5951	207	1088	1805	1632	7735	18258
	0,2%	0,9%	2,2%	0,2%	0,7%	1,8%	0,0%	0,1%	0,3%	0,0%	0,0%	0,1%	0,0%	0,2%	0,5%	0,1%	0,4%	0,7%	0,1%	0,2%	0,4%	0,3%	1,4%	3,5%	0,1%	0,6%	1,1%	1,0%	4,6%	10,7%
Core	26325	24035	20869	41040	37766	33807	2399	2138	1823	1038	465	865	8990	8264	7224	4094	3749	3252	2060	1816	1341	16993	14683	13693	15471	15240	11487	118408	108156	94361
	15,6%	14,2%	12,2%	24,4%	22,4%	19,8%	1,4%	1,3%	1,1%	0,6%	0,3%	0,5%	5,3%	4,9%	4,2%	2,4%	2,2%	1,9%	1,2%	1,1%	0,8%	10,1%	8,7%	8,0%	9,2%	9,0%	6,7%	70,4%	64,4%	55,1%
Bridge	448	629	966	1024	1515	2262	59	62	118	20	52	49	134	198	222	148	171	164	87	102	108	456	610	827	327	479	488	2703	3818	5204
	0,3%	0,4%	0,6%	0,6%	0,9%	1,3%	0,0%	0,0%	0,1%	0,0%	0,0%	0,0%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,3%	0,4%	0,5%	0,2%	0,3%	0,3%	1,6%	2,3%	3,0%
Loop	415	492	566	915	1330	1690	79	57	55	49	27	20	100	141	200	114	131	137	40	74	68	268	421	410	222	314	284	2203	2987	3430
	0,2%	0,3%	0,3%	0,5%	0,8%	1,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,0%	0,0%	0,0%	0,2%	0,2%	0,2%	0,1%	0,2%	0,2%	1,3%	1,8%	2,0%
Total	35391	35618	36016	58147	58536	59876	3553	3494	3567	1664	954	1656	11941	12007	12046	6662	6688	6816	3233	3223	3197	26508	25298	29047	21155	22224	18930	168255	168043	171151
%	21,0%	21,1%	21,0%	34,6%	34,7%	35,0%	2,1%	2,1%	2,1%	1,0%	1,0%	1,0%	7,1%	7,1%	7,0%	4,0%	4,0%	4,0%	1,9%	1,9%	1,9%	15,8%	15,0%	17,0%	12,6%	13,2%	11,1%	100,0%	100,0%	100,0%