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Planning for Viable Forests with High Biodiversity

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CONTENTS

Abstract

In recent decades, the rate of extinction of species is increasing due to human use and refinement of nature. This has resulted in a large amount of research throughout the world.

Forestry today is mostly based on clear cuts, and many natural forests have been cut down and replaced with monocultured forests. This is the major reason to the loss of species. Research has increased the knowledge about alternative forestry methods and measures are being taken to create nature conservation laws. This has resulted in a small amount of changes from even-aged to continuous forestry. At the same time the interest for more intensive forestry has grown due to increasing need of wood products. Thus, the cost-effectiveness and production orientation are becoming increasingly important. Increased protection of forest biodiversity often implies reduced income from timber and pulp production both for society, companies and forest owners. Swedish County Administrative Board have occasionally stopped forest harvesting because of red-listed species. This has begun a debate about restricted freedom for owners, even though only 5% of 54000 notifications regarding violations of conservation protected forests have been stopped.

Forest owners have a major responsibility for the forest's present and future health. For effective management, it is important to understand ecosystem responses to disturbance. Therefore, more measures must be done to inspire foresters to new forms of forestry. Cross-disciplinary cooperation between economic science, natural sciences, political work and legislation must be established with forestry in the center, because knowledge create motivation. There is also a need to provide forest owners with a value for biodiversity for their forest property. To estimate biodiversity climax and carrying capacity for an area, a biodiversity index describing the *abiotic basic Prerequisites for Biodiversity (APB)* is needed. To make such an index, you can use available data in databases such as Sweden's geological survey (SGU) and Geographical Information System (GIS). Such index could then be accompanied with guideline describing what is needed in the area to build for future high biodiversity. More research is also needed to find out if it is possible to manage even-aged-forestry in some land areas and at the same time be able to save guard biodiversity only by leaving patches with old trees connected with corridors for wildlife connectivity.

A Forestry sector information and knowledge system that more strongly incorporates biodiversity issues is needed. Within such a system services such as soil tests, economic and ecologic advices and tools as APB-index could be provided helping landowners plan their forest to higher biodiversity.

Introduction

Natural forests are rare today. Most forests are cultivated for production of wood commodities. Therefore, forests often consist only one tree species, often referred to as monoculture forestry. When it is time for harvesting it is done with total deforestation. The loss of biodiversity due to monocultured forest and the extreme intervention on nature because of clear cuts play an important role in the ever-increasing loss of species (Kindvall, 2006; Sample, 2005). Endangered species are a driving force for protecting the diversity of forests today (Haddad, et al., 2015).

Sweden signed the Convention on Biological Diversity (CBD), which entered into force in 1993(Council Directive 92/43 / EEC and Natura2000). It emphasizes that we shall maintain biodiversity through sustainable use of the Earth's resources. Sweden is committed to halving the loss of important natural environments and thus reducing the loss of biodiversity. According to the Nature Conservation Association, this work should be done through increased protection and with silvicultural methods without clear cuts (Widman, 2015). However, current forestry policies and legislation are not enough to safeguard the values of forests and meet the challenges to preserve biodiversity. One of the main reasons for that is because the world market has a huge need for pulp and other wood products. Pulp industry is for Sweden an important contributor to the global trade balance (Gladys, et al., 2018). Of total production in the world, Sweden accounted for 6 percent of pulp and almost 3 percent of paper production. Of Swedish paper and pulp production, about 70 percent are exported. In 2016 the net export value was about SEK 125 billion and Sweden was the third largest exporter of paper pulp and other wood products (Heinsoo, 2016). In order to ensure the resilience of ecosystems and the ability to deliver ecological basic values to human societies, measures must be taken to conserve biodiversity (Perrings, et al., 1992).

In a natural system, biodiversity increases over time to a certain level when the area has achieved carrying capacity. Different places have different basic conditions for the biodiversity climax. A frame methodology for valuation of potential biodiversity in an area is therefore needed.

Demarcation and aim of this study

In this paper an index for *abiotic basic Prerequisites for Biodiversity (APB)* will be introduced. This index could be used for basic valuation of biodiversity climax level in an area. Such index can be combined with abiotic factors and put in a mathematic formula to translate it further to values that is comparable between different ecosystems in the world. Such method could be used as a tool for research. But, due to the limited scope of this work, only some factors, that can be used to produce such an index, will be mentioned. Mathematical methods needed to transfer the index to values useful for comparisons in research, will not be presented. The methodology required for creating the APB index will not be listed. Nor will examples from fieldwork be presented as it requires special equipment, special laborations and a wide range of different areas of knowledge and expertise that is impossible to survey for one person. Nor, will the methodology for the use

Concepts

Biodiversity is describing the variety of living things, in different levels, as for example: genetic-, species- and ecological diversity. Ecological diversity specifies everything within the system as for example trophic levels, number of niches, individuals, groups, species, functional groups, ecological processes, capturing energy systems, sustaining food webs, recycle of materials, climate and much more (Cunningham & Cunningham, u.d.; BritannicaAcademic, 2018; Begon, et al., 2014)

Ecosystem functions:
"Ecosystem functions are ecological processes that control the fluxes of energy, nutrients and organic matter through an environment." For example, primary production" (Cardinale, et al., 2012).

Ecosystem services are advantages that ecosystems provide to humanity. For example, the production of renewable resources as for example, food, wood, fresh water.

Regulating services are those that lessen environmental change, as climate regulation and pest control (Pohjanmies, et al., 2017).

Succession:
"Ecological succession is the process by which the structure of a biological community evolves over time (Thompson, 2018)"Primary succession occurs in lifeless new areas, such as a new volcanic island or after a retreating glacier. Secondary succession occurs when vegetation recolonizes an area after a disturbance such as storm or fire. In the second succession the composition of species shifts over time in a chain of stages.

of Geographic information system (GIS) as a tool to create the index be mentioned. Here, only one first fundamental description of this index value will be introduced.

Although some factors are of fundamental importance for biodiversity, it will not be further investigated or described in this work. Examples of that is: The level of geologically or anthropogenic induced toxicity in the soil, decomposers, mycorrhizae or trophic levels in the ecosystem with key species and key functions. Ecosystem of water is highly connected to surrounding terrestrial ecosystem and there is a floating limit between terrestrial and aquatic ecosystems. Even though there often are life holding interactions between species of land and water, the focus in this work will be on the terrestrial area. Aquatic ecosystems will be taken under consideration only as the percentage of open water or water-soaked land as an abiotic factor. Analyzes of the effects of climate change on forests, forestry and biodiversity and vice versa will not be made in this work. Critical meta-analysis of quantitative effects on biodiversity of different silvicultural methods will not be carried out in this work, even though it can be used as arguments to foresters. In this work the focus is only to suggest some fundamental solutions that could serve as a basis for solving the contradictions between society's demand for pulp and society's need for biodiversity.

It is not possible under the current limitation to investigate economic conditions, legal problems or social and organizational problems important to consider when incorporating proposed index. It is important to investigate and develop methods in order to succeed in inspiring forest owners to take responsibility for biodiversity. Thus, there is a need to modernize the Swedish Forestry act and adjust it to scientific results about biodiversity.

Forests has a lifespan of several hundred years, and silvicultural methods as even-aged forestry are new. In addition, many virgin forests have been cut down in the last two hundred years and most forests in Sweden today have not reached a mature age. These conditions make it a challenge to prove the negative effects that loss of biodiversity in forests has or show the benefits that virgin forests have. Therefore, scientific support for biodiversity is taken from biotopes all over the world, for example grasslands or tropical forests. But research from boreal forest in Sweden, Scandinavia, Canada, Russia has been prioritized.

This document proposes to inspire landowners to take more responsible for current and future biodiversity. This can be done by developing a multidisciplinary organization with tools and services that help forest owners evaluate their forests and plan for future high biodiversity. With this paper I like to point out that it is possible and not too late to recreate nature forest environments with high biodiversity even though the problems in the way are huge and many. The range of this study implies that a large amount of work and research is needed to secure biodiversity. One reason to the choice of subject to this paper, is because there is an acute need for more focus on this topic in Sweden. If you feel a commitment to this topic, I urge you to write about it. Don't be intimidated by the fact that it is a huge and voluminous widely-spread society problem. Every contribution of attention from an environmental, legal or even psychological perspective in this subject contributes to an increased understanding. Attention is required to the environmentally damaging aspects as opposed to the economic benefits because of intensive forestry today. Intensive forestry is not sustainable.

The aims of this study are 1) to present a background showing that biodiversity has a strong impact on the function of ecosystems and that even-aged forest managements with clear-cuts has a destructive effect on biodiversity. 2) Suggest measures that can be done to broaden the efforts to combine forest management and conservation of biodiversity. And 3) introduce an index value for abiotic prerequisites. This paper is compiled by literature studies and analyzes.

FORESTRY VERSUS BIODIVERSITY

Concepts

Intermediate disturbance:
Not too much and not too little disturbance. In a natural system, disturbance is a part of the natural pendulum. Minor disturbance can be grassing or predation that lower populations and give space to individuals from other species to exploit the biotope. (Dimitrakopoulos & Schmid, Jul2004 ; Cunningham & Cunningham, u.d.)...

A Climax ecosystem community
Is referred to ecosystems where the succession has reached a stable equilibrium for the prevailing circumstances and basic conditions (Thompson, 2018)

Keystone species
Keystone species are species that has a disproportionately large effect on biodiversity (Huston, 1997; Loreau & Hector, 2001)

Key functions
are key functions with large influence on productivity for the entire ecosystem**.**

Loss of trophic levels:
Loss of trophic levels, especially loss of higher levels, can reduce plant biomass (Duffy, et al., 2007) and transform versatile plant composition into monoculture (Cardinale, et al., 2012). Researchers argue that higher productivity are dynamics driven by competition within a functional group of the ecosystem. An ecosystem is also more resilient to environmental changes when there are species that can take over a function when a species in the same functional group has weakened (Gonzalez & Loreau, 2009; Zhang, et al., 2015,). Loss of predators can thus change vegetation structure, fire frequency and increase the risk of disease epidemics (Estes, et al., 2011).

Mycorrhiza plays a decisive role in the development of the ecological community. Mycorrhiza creates a cohesive network in the soil, stores carbon dioxide and helps trees and plants absorb water and nutrients from the soil.

Background

Loss of biodiversity

In the late 20th century The United Nations Conference on Environment and Development (UNCED) was summoned, also known as the Rio de Janeiro Earth Summit 1993. In this meeting it was declared that human actions are eliminating species at an alarming rate. This led to research and mounting evidence that ecosystem processes are negatively affected by loss of diversity. Biodiversity has a strong impact on the functioning of ecosystems, biomass production and nutrient cycling, meaning that ecosystem processes is negatively affected by loss of diversity. There is, for example, a positive correlation between biodiversity and the efficiency by which the ecological community produce biomass. (Cardinale, et al., 2012; Doak, et al., 1998; Naeem, et al., 1995; Knops, et al., 2001; Tilman & Downing, 1994). Loss of biodiversity changes not only the functioning of ecosystems but also its ability to provide the goods and services vital essential benefits to humanity (Cardinale, et al., 2012; Daily, 1997; Perrings, 1993). To maintain high functional ecosystems biodiversity is required (Cardinale, et al., 2007; Mueller, et al., 2013; Stachowicz, et al., 2008; Tilman, et al., 2012). A variety of species implies synergy effects that allow more nutrition and solar radiation to be absorbed and more moisture to be retained in soil and air (Cunningham & Cunningham, u.d.; Forrester, 2015). It is important to avert a further biodiversity loss within the European Union (Schoukens, 2016). In Sweden approximately 900 species are threatened, and 1800 red listed (Artdatabanken, 2018).

The responsibility of the landowners

Sweden's total area of land is approximately 41.0 million hectares. Of this, 22.6 million hectares is productive woodland. This implies that forest owners have the greatest responsibility for preserving biodiversity in Sweden. A large number of studies have been carried out regarding the current Swedish forest management system (Kleinschmit, et al., 2012). Landscape planning induced by new laws implies problems as those affect landowners unevenly (Zabel, et al., 2018). Therefore, several studies discuss voluntary instruments on the Swedish forest model (Appelstrand, 2012; Widman, 2015)

Disturbance and periods of recovery

In a forest there are interactions at all levels from bacteria with a living time of a couple of days to lichens that can grow very old. New interactions are created continuously, some disappear, and some persist. Higher diversity in forestry can increase ecosystem functions and stability (Amazonas, et al., 2018; Pohjanmies, et al., 2017). Higher diversity increases the possibility for interactions between species and this is stabilizing ecosystem functions. Such stability increases through time. (Campbell, et al., 2011; Cardinale, et

al., 2012; Cottingham, et al., 2001; Hector, et al., 2010; Ives, 2007; Jiang & Pu, 2009). It is important to understand ecosystem responses to disturbance for effective management of biodiversity (Gosper, et al., 2013). Disturbance regime is a frequency of disturbance followed by a period of recovery. The disturbance can for example be fire, storm or flood. When nature is able to recover between the disturbances and the disturbance is giving room for new species and new interactions, the disturbance is called *intermediate disturbance* and such processes have positive impact on biodiversity (Walker, 2012). However, an excessively high level of disturbance as clear-cut management every 80-120 years, has a negative impact on biodiversity. After a clear cut, fire or other major disturbance the forest start a recovery process called secondary succession. The appearance of the chain of a secondary succession depends on the basic conditions of the soils, bedrock and the climate. Then the species that take hold in the area modify the habitat and make changes that allow other species to adapt better. Interactions between plants, animals, and environment influence the pattern and rate of successional change (Thompson, 2018).

A forest regenerates in a succession chain after a disturbance. It takes, in the best case, approximately 200 years for a forest to balance interactions in an ecosystem and reach a biodiversity climax after a severe disturbance (Gosper, et al., 2013). How the forest recovers depend on the conditions given. First, it depends on what basic conditions exist in the area, as for example, the composition of soil and bedrock, pH of the soil (Sjödin, 2016), the water permeability of the soil and bedrock and the accessibility to and amount of water in the area. Other things that affect forest regeneration are the types of shrubs, trees, microorganisms, mycorrhizae and what kind of animals and insects that are available. By carefully studying basic prerequisites and enhancing ecological and biological knowledge the forester can increase the possibility to recovery of the forest and its resistance to extreme events.

Important factors for maintaining, or restoring biodiversity

In order to maintain or restore biodiversity, there are some factors that are more important. Here follow some examples listed:

Heterogeneity

Due to intensifying forest utilization the proportion of old forest has substantially declined, while young forests have increased (Kuuluvainen & Gauthier, 2018). An absence of old trees and the lack of differences in the age classes can be a threat to biodiversity because of decreasing environmental heterogeneity. Increased environmental heterogeneity increases the possibility to biodiversity (Finke, 2008; Kuuluvainen & Gauthier., 2018; Lichtenberg, et al., 2017; Tylianakis, et al., 2008). Suitable habitats for different kind of species are of great importance for biodiversity to flourish (Dahlberg, 2011; Pohjanmies, et al., 2017) . Different species have greater opportunity to exploit different kind of niches with increased environmental heterogeneity (Dimitrakopoulos & Schmid, 2004). Thus, the resistance to harmful organisms (predators, parasitoids and pathogens) increases with increased heterogeneity in the cultivation landscape (Lichtenberg, et al., 2017; Zhang, et al., 2015).

The summer 2018 Sweden experience extreme drought with forest fires as a result. Approximately 250 km^2 (100 sq mi) of forest burned down (Nilsen, 2018). Monoculture forests promote fire as they often consist of flammable coniferous trees which are planted in dense rows, factors that make it easier for fire to spread and complicate fire extinguishing work (Hessburg, 2016; Lundmark, 2018).

A research group in Canada has studied succession after forest fires. Their research showed that high biodiversity of the understory vegetation greatly contributes to the functioning of the ecosystem in a boreal forest. The overall results highlight the importance of heterogeneity, substrate specialization and growth dynamics at different levels of the ecosystem (Kumar, et al., 2018).

Trophic levels

In order for biodiversity to establish, it is important with substrate specialization and growth dynamics at different trophic levels in the ecosystem (Kumar, et al., 2018). If all species at a certain trophic level disappear, the ecosystem's key functions disappear. (Dobson, et al., 2006; Layman, et al., 2007). Trees at different ages provide different spatial levels of habitat within an ecosystem. The energy flow between trophic levels is affected both by the trophic structure of food web and the diversity of species within the trophic levels (Srivastava, et al., 2009).

Continuity and connectivity

In addition to heterogeneity, Continuity and connectivity have correlation to biodiversity. Continuity is a longer time-interval without major disturbance. Connectivity is a cohesive larger area (Campbell, et al., 2011; Cardinale, et al., 2012; Cottingham, et al., 2001; Hector, et al., 2010; Ives, 2007; Jiang & Pu, 2009). There must be possibility of dissemination and or establishment within an area (Dahlberg, 2011; Pohjanmies, et al., 2017). Today, anthropogenic land use means that a continuity for species movement patterns, patterns of diffusion, patterns of food-search are cut off. For example, roads and fences is a hindrance for animal movements in their search for food. Seeds, roots and mycorrhizae are prevented from spreading due to cities, monocultured areas and infrastructure. Insects such as for example, bees are lacking food for a long time when there is no continuity in flowering because of monoculture landscapes. Absence of continuity and connectivity are a threat to survival of almost all species (Begon, et al., 2014; Cunningham & Cunningham, u.d.). Research has often underestimated the minimum levels of biodiversity and area size required for ecosystems (Cardinale, et al., 2012).

Nutrition cycles

Biodiversity also require access to degradable materials and access to decomposers that contribute to transporting and recycling nutrients. Mycorrhizae and decomposers have a supporting role for a functioning ecosystem. There is a correlation between biodiversity and the efficiency in how the ecosystem decompose and recycle biologically essential nutrients (Balvanera, et al., 2006; Cardinale, et al., 2012; Cadotte & Cardinale, 2008; Flynn, et al., u.d.; García-Palacios, et al., 2011; Loreau, et al., 2001; Srivastava, et al., 2009; Quijas, et al., 2010;). Monoculture forests are poorer habitats for plants and animals than natural forests are. The paucity of naturally occurring wild plants and dead wood is the same as the absence of nourishment for many species. The amount of deadwood has decreased in the forests and it has a major negative impact on biodiversity. Deadwood is life supporting to decomposers. There are many different kinds of species and trophic levels within the level of decomposers. Decomposers and the substances that are decomposed, is a life supporting foundation for the entire food chain (Pohjanmies, et al., 2017).

The number of initial species

Silvicultural methods based on a mixed tree species are promoting biodiversity. Number of initial tree species increase ecosystem services such as, soil carbon storage, berry production, game presence and biomass production. Biomass production after five years is approximately 50% greater in a plantation with five tree species compared to a plantation with one tree species (Gamfeldt, et al., 2013). A literature study which compiled 44 research reports has shown that multicultural ecosystem produces an average of 1.7 times more biomass than monocultures and are more productive than the average monoculture in 79% the experiments (Cardinale, et al., 2006). A variety of species implies synergy effects that allow more nutrition and solar radiation to be absorbed and more moisture is kept to soil and air (Cunningham, u.d.; Forrester, 2015). Higher diversity in forestry also increase ecosystem functions and stability (Pohjanmies, 2018; Amazonas, et al., 2018).

Forestry

Approximately half of Sweden's land area covers is productive forest land. The productive forest land is mainly used for production of timber and pulpwood. Half of the productive forest land is privately owned small estates and the other half is owned by a few large companies and the state (Nilsson, et al., 2017). The dominating silvicultural method in Sweden is even-aged forestry (Vestin, 2017). 4% of productive and 7% of all forest land in Sweden is formally protected (Svensson, et al., 2018). To maintain ecosystem functions, it is important to maintain or restore biodiversity (Anderson-Teixeira, et al., Jul2013; Chiang, et al., 2016).

Even-aged versus continuous cover forestry

Even-aged silvicultural forestry methods aim to keep the area free from biodiversity. Firstly, one tree species is planted, and secondly the bushes and plants are thinned out to make the planted tree species grow better. Most of the Swedish silvicultural are based on even-aged methods. Even-age forestry management have different stages of management, including soil preparation, planting, clearing, thinning, fertilization and final harvesting. The method to plant only one species of trees is to increase the accessibility and income. Ecosystem management for maximizing provisioning services can cause declines in ecosystem services and loss of stability and resilience (Pohjanmies, et al., 2017). When the forest has reached the appropriate harvesting age, deforestation takes place. Then the cycle restart with soil preparation and deployment of new plants. Deforestation has a destructive influence on the sustainability of different habitats of the forests and it is a huge encroachment on nature (Cardinale, et al., 2012; Naeem, et al., 1995). Clear cuts involve large areas that have negative effects on forest values. Forestry with clear cuts is Sweden's dominant method since the 1950s (Ekstrand, et al., 2017). The interest in alternative forestry methods has increased in Sweden the last decades and different actors, including the Swedish Agricultural University (SLU), are conducting research to increase the knowledge about alternative forestry methods and their effects[1] and measures are being taken to reduce environmental damage (SkogsSverige, 2017).

Continuous cover forestry

Continuous cover forestry (CCF) is sustainable management of forests that are maintained in a permanently irregular structure through selection and harvesting of individual trees (Kerr, 1999). CCF is a collective name for different types of forestry, where you do not cut down all the trees at once. CCF means working with different ages of trees. Mature trees are harvested successively (SkogsKunskap, 2016). On behalf of the government, the Swedish Forestry Agency started in 2005 the project Continuity Forests and Forestry without clear cuts. The intention was to compile existing knowledge and build up expertise and knowledge in the field. The purpose is also to actively disseminate knowledge through various forms of information and education, both internally and externally (Dahlberg, 2011). This has resulted in the use of methods as for example shield forestry, which means that when harvesting, trees are left around water courses and other delicate areas in the surrounding (Skogskunskap, 2016). The Swedish Environment Protection Agency (SEPA) wants 20 percent of Sweden’s forests to be protected and that CCF management increase to around 30 percent of forestry management methods. SEPA also want that greater nature consideration are taken at harvesting so that the negative effects can be reduced. Work is being done to improve the conditions for increased biodiversity by combining various measures such as long-term forest protection, CCF and shield-measures at clear cuts. But, CCF do not always have to contain high natural values and high natural values can also be found in forests without long forest continuity. It is important to clarify what CCF is (Dahlberg, 2011). CCF usually have significantly higher natural values than forests that arise after clear cuts because promote continuity.

[1] Om miljöhänsyn på hygget här på SkogsSverige

Selecting and harvesting individual trees can be compared to a natural Intermediate disturbance which often result in increase of biodiversity and interactions between species (Begon, et al., 2014). Dense forest is not always the best place for thriving interactions, opening of canopies is giving space for light inflow. Promotion of biodiversity and multifunctional landscapes means in general maintaining landscape heterogeneity and reduced land-use intensity (Ekroos, et al., 2016).

Carbon sink and forest management

When the forest grows, large amounts of carbon dioxide are taken up. It is worth considering today when carbon dioxide emissions to the atmosphere have become a major problem. If the biomass is increasing the carbon dioxide in the atmosphere is decreasing. But forestry also means carbon dioxide emission in several other ways, for example due to machine emission at land preparation and transports of plants and the removal of wood. Thus, deforestation and thinning provide an increase in carbon dioxide emissions. It highlights the importance of taking into account the net effect of carbon dioxide when investigating forest management (Vestin, 2017).

Intensive Cultivation

Intensive cultivation of forests is used as a collective term for management models that provide significant growth increase, such as fertilizing and the use of herbicides (Hamilton, 2010). Forest management have clear effects on GHG fluxes. Forest management contributes to the formation of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Vestin, 2017). Interest for more intensive forestry has grown lately, as cost-effectiveness and production orientation are becoming increasingly important (Skogsskötselserien, 2009). Intensive cultivation can increase the overall harvesting level. But there are many risks of intensive cultivation and fertilization. The biodiversity is decreasing using nitrogen fertilizer (Williams, et al., 2016). The risk of insect pest outbreaks also increases with fertilization (Ball, et al., 2000; Hamilton, 2010; Heiska, et al., 2007; Pirri, 1998). Increased fertilization in the forest also leads to an impact on other ecosystems adjacent to the forest, such as lakes, streams and seas (Georgiadis, et al., 2017). Statistics, measured in unit hectares per year, show that in the mid-1960s it became common to use nitrogen as fertilizer in forestry. During the 1970s it became very common, but during the 1990s, the use of nitrogen as a fertilizer in the forestry fell to low levels. After 2005 the interest in forest fertilizer has increased again (Lindkvist & Kardell, 2010).

Fertilization causes emission of greenhouse gases. Nitrous oxide gas (N_2O) is a strong greenhouse gas that is three hundred times (factor 298) stronger as greenhouse gas than carbon dioxide is. The risk for N_2O emission increases with lower pH as in boreal forests (Schmithausen, et al., 2018). In addition, N_2O depletes stratospheric ozone. A worldwide meta-analysis shows that N_2O is increasing exponentially to inputs of synthetic fertilizers. The emission of greenhouse gases from intensive forestry needs further research to be clarified (Wang, et al., 2018) and a global mitigation strategy according to synthetic fertilizers is needed (Shcherbak, et al., 2014).

Synthetic fertilization causes imbalance in the ecosystem making some species disappear and other species benefit so much that they develop into pests. A rapidly growing forest use energy at the expense of other species (Sukhdev, 2010). Wood ash as fertilizer has in contradiction to synthetic fertilization a positive feedback effect between for example fungi and trees (Peltoniemi, et al., 2016).

Conflicts between biodiversity and forestry

Forest Protection Act (1979: 429) 1 § "Forest is a national asset and a renewable resource to be managed so that it sustainably yields a good return while maintaining biodiversity. In the event of care, other public interests shall also be taken into account. Law (2008: 662)."

There is an inherent conflict between the industrial forestry and the protection of biodiversity. This is due to the fact that increased protection of forest biodiversity often implies reduced income from timber production both for society and forest owners (Bergseng, et al., 2012). Because of increased demand for timber products, the forest landscape has changed dramatically over the past two hundred years. Many natural forests have been cut down and replaced with monoculture forests. Humans have at a global scale refined ecosystem to maximize the production of food and raw materials with the result of severely disturbed and damaged ecosystem (Pohjanmies, et al., 2017; Triviño, 2017). Because of legislation and authorities' instructions in Sweden, practical application of intensive cultivation can be limited. It is recommended, with regard to intensive cultivation of forests, to be careful not to expose nature to unnecessary stress (Hamilton, 2010). At the same time it is recommended to manage the forest so that it yiels a good return, and the need for timber products increases constantly and the pressure to obtain more material from forests is very high. Therefore, the recommendations not to expose nature are often not followed. Protected forests have been harvested even though only 1.1 % of 1.3 million hectares forest land have formal protection. There are even cases when environmentally certified forest companies have been cutting down protected forests. The effects of such actions may extend far beyond the location both in spatial and temporal scale (Bennett, et al., 2009). Only 5% of 54000 notifications regarding violations of conservation protected forests have been stopped. According to Sebastian Kirpuu, Nature Institute of Nature Conservation, there are few countries in the world that affect their forest ecosystem as seriously as Sweden does at present moment (Härén, 2017; Jacobsson, 2017).

There are cases of forest-harvesting that have been stopped by the Swedish County Administrative Board because of red-listed species. This has begun a debate about restricted freedom for owners of forest property, and that biodiversity protection laws have major financial consequences for forest owners, and in its extension to Sweden's economy (Forsberg, 2016). Forest management need to find a way to deliver both economic and ecological values simultaneously (Strengbom, et al., 2018).

Challenges and opportunities

It is a challenge to create a bridge between a system regarding the economic values of the forest as cubic meters of wood and the insight that we must retain natural forests to biological, ecological, medical, economic, safety values that give survival ability. When attempting to change a system that are influenced by factors such as social organization and collective knowledge it is of huge importance to understand the complexity of political, social and scientific interactions (Klapwijk, et al., 2018). A disagreement between natural sciences and economic science about acceptable forest use affect the forester's uncertainties and uncertainties causes a strategic obstacle.

It is difficult to put an economic value on Ecosystem services because such services are part of complex systems where knowledge often is lacking. It is a challenge to prove connections in complex systems. It is also a challenge to transfer knowledge about ecosystems, geology, climate and biology from nature science experts to those who determine the forest future. Still, measures to avert further loss of biodiversity, has to be made (Schoukens, 2016).

Today, some measures to increase the biodiversity of forestry are already regulated under the Environmental Code. It is for example possible for the Forestry Board to designate forest areas as nature conservation area, supported by the Environmental Code. Nature conservation agreements can also be signed between forest owners and nature conservation authorities. In addition, forest owners can make voluntary provisions for protected forests. A certified forestry property[2] usually allocates at

[2] A forestry property can be certificated by FSC and PEFC.

least 5% of the productive forest land to protection from forestry management. Forest areas can be classified as key biotopes and other areas can be classified with high natural values or areas that can develop such values over time (SkogsSerige, 2017) .

One example of environmental measures is to leave ridges of trees and shrubs, so-called protection zones. Protective zones are provided by lakes and streams to protect water quality and aquatic plant and animal species (Kronnäs, et al., 2012). Replanting after clear cuts is legalized: According to the Forest Care Act, you are obliged to plant new forest no later than three years after harvesting. You have to use proven methods and species that match the soil. Even before a stock is harvested, you should make a regrowth plan, where you decide which tree species will replace the old stock and which method will be used for regrowth (1979:429). Other measures are to leave dead-wood material in the forest after deforestation. But it is of importance to leave such material in way so that the area is free for species to spread or move into the area. You can also leave live trees or reduce toxic substances in forestry to increase the chances for biodiversity to recover (Natursidan, 2015; Naturskyddsföreningen, 2011).

By harvesting some of the trees in the forest you open the canopy and the flow of sunlight to the ground will increase. This can intensify the probability of species to establish, flourish and create interactions. Thus, leaving old trees and taking out younger trees resembles natural disturbances. Understanding biodiversity and natural building of interactions is a necessity to manage the forest effectively and sustainably (Bennett, et al., 2009).

Forestry can be important sources of multiple ecosystem services. The provisioning of sustaining goods and services that we obtain from natural ecosystems is a strong economic justification for the conservation of biological diversity. Understanding the relationship between these goods and services and changes in the size, arrangement, and quality of natural habitats is a fundamental challenge of natural resource management (Dobson, et al., 2006).

SUGGESTED MEASURES -toward high biodiversity in forests

Important factors or needed measures for biodiversity

Because forestry has resulted in huge changes to very low biodiversity, it is recommended to plan the forests against the highest possible level of biodiversity, the so-called biodiversity climax. The level of future biodiversity climax for different areas depends on multiple factors. To be able to plan the forest to highest possible biodiversity the specific conditions of the area must be investigated. The basic abiotic factors are possible to merge into an index for a given area. Such index could be accompanied with guideline describing what is needed in the area to build for future high biodiversity. The concept is introduced in this paper and named *Abiotic biodiversity Index (APB)*. The factors included for such index are discussed in the following section. But first some important factors or needed measures will be listed.

Current condition of the forest and historical forestry investigation

The conditions of forests in Sweden today alter due to many aspects as for example the ecosystem that has evolved in the area, the forestry method that has been used and for how long this method has been dominant in the area. A method of validation that gives a comparable value is needed.

Easy access to soil samples

Mycorrhizae has a decisive role in terms of uptake of plant nutrition, for water uptake, for building a foundation for biodiversity and for ecosystem productivity. (Anwar, et al., 2008). Most plants and all trees in Scandinavia form mutualistic symbiosis with mycorrhizal fungi. (Olsson, 2018; Pallon, et al., 2007). Today it is a difficult process to take soil-samples and determine for example mycorrhizae. Only a few experts have access to both the knowledge and laboratory to get results from such samples. Such methods could be developed and used to investigate the site of a forest.

If an area has a history of industrial activities or forestry using pesticides, herbicides or fertilizers, there may be toxins left. Today there are 24,000 known sites that are poisonous due to anthropogenic activities in Sweden. Of these, 8,000 sites are in urgent need of remediation, as they involve a very high or high risk to man and environment (Fors, 2018). These are often covered and hidden, such as closed dump sites, dumped poison tanks or closed petrol stations. The degree of anthropogenic induced toxicity can be of importance to know. If the soil is very toxic, measures can be taken to isolate the area for future remediation. It is advisable to create or develop a soil sample analysis service for foresters. Many different biotic and abiotic factors are detectable in a soil sample. And the current state of the soil can indicate unbalances that can be adjusted with right measures or strengths possible to use when planning the silvicultural method best for biodiversity.

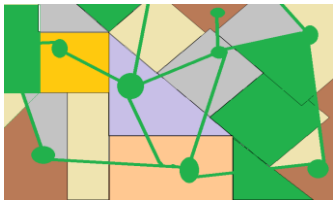

Figure 1: A Schematic picture describing patches of old trees connected with larger areas creating corridors and continuity for wildlife. Dark green: Nature reservation areas.

Patches with high diversity by continuity and connectivity

The Swedish Nature Conservation Association propose fewer clear cuts, regard to nature values at greater extent and long-term protected forests and CCF management. Those conditions could improve survival of species in the forest landscape. In order to further strengthen this work, a network of protected old trees and corridors that connect the various protected areas could be created. Such network could provide a connectivity and continuity for species in the area (figure 1). Old trees have a positive influence on biodiversity and are better suited to survive fires (Zemanová, et al., 2017).

The corridors between the patches could for example become a habitat for wild flowers more suited to, for example, different kinds of bees and at the same time be pathways for game. To enables such network of corridors and conservation areas an organization that bridges ownership borders is needed.

A cross-disciplinary organization to help foresters plan for higher biodiversity is needed

In order for change to take place, it is recommended that forest owners understand the importance and are motivated to make changes in forestry. A cross-disciplinary exchange between economic science, natural sciences, political work and legislation (Figure 2) could be established with forestry in the center. Knowledge create motivation. Such cooperation can result in synergies that make forestry benefit both owners, society and ecosystems.

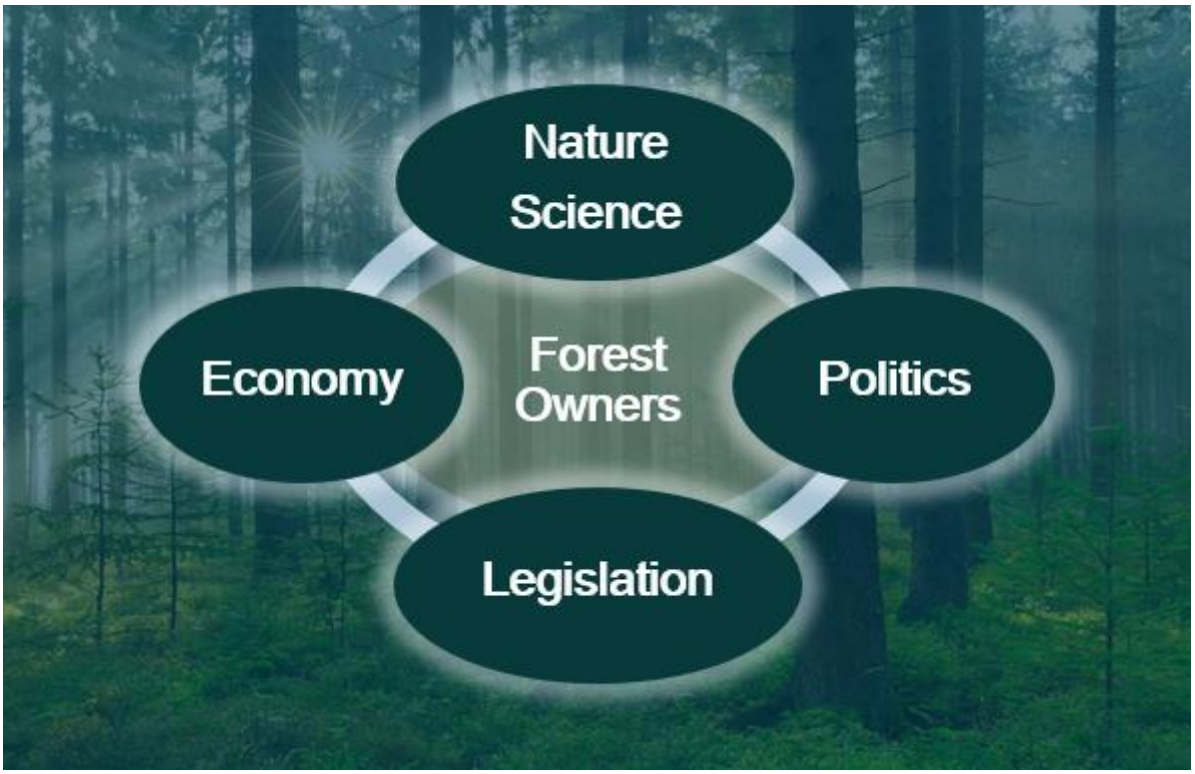

Figure 2: An organization with cross-disciplinary exchange between economic science, natural sciences, political work and legislation could be established with forestry in the center.
Source of the picture in the background https//www.svensktra.se/om-tra/hallbarhet

Abiotic basic Prerequisites for Biodiversity (APB-index)

To estimate biodiversity climax and carrying capacity for an area, a biodiversity index describing the *abiotic basic Prerequisites for Biodiversity (APB)* is needed. An index like this could be used as a foundation for forest planning towards ecosystems with high biodiversity. To make such an APB index, available data in databases such as Sweden's geological survey (SGU) can be used. In the geographic information system (GIS) existing information can be managed and analyzed and encourages the flow and input of new data from local up to international levels and vice versa (J. M. Scott, 1993). Thus, the Geographical Information System (GIS) can be used to calculate a single index based on different input layers. Such data can be abiotic factors as pH, amount of nutrients, soil and bedrock composition and percentage open water.

Scaling the value

For example, the APB value could be highest for the *best conditions that is in the middle between the extremes*. The scale of the APB-prefix could be fit to the grading one to ten, where a high value describes the best prerequisite for biodiversity, shown in the figure 3. Examples of factors building an APB-index need to point out balanced amounts of for example water, heat, minerals, Soil-pH and nutrients in the field. When there is too much or too little of these basic conditions, the possibility of biodiversity is lesser. Note, that this also applies to too much nutrient in the field and that fertilization of forest therefore reduces the value of the APB-prefix (Camenzind, et al., 2014; Kwak, et al., 2018; Siddique, et al., 2010).

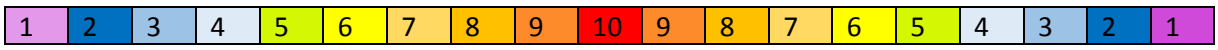

Figure 3: A value for *Abiotic basic Prerequisites for Biodiversity* (APB) could be highest for the best conditions that is in the middle between the extremes. 10 with the best prerequisites and the value 1 for worst scenario as extremes where it is too much or too little of for example nutrition or too high or too low value of pH.

Bedrock and soil

The composition of the bedrock can be a first guideline for how much nutrition or toxic substances present in the soil. The bedrock is an abiotic foundation for minerals potential nutrients or toxins in the soil and is therefore an important factor to the index. Then the anthropogenic previous use and methods give a second guideline. The level of toxicity in the soil that is anthropogenic induced, is also affecting the biodiversity.

Soil pH and soil nutrition

Soil pH stand out as the environmental factor that has the greatest influence on species riches of bryophytes and vegetation composition (Oldén, et al., 2016; Tyler & Olsson, 2016). It is an important variable to determine the future climax level of species richness. Soil nutrition is also an important factor. Too high or too low values of pH are negatively effecting biodiversity (Zinko, et al., 2006).

Water

Water conditions are a very important factors when it comes to the level of biodiversity. To keep the index uncomplicated the aquatic ecosystems could be taken under consideration from an abiotic point of view, by calculating the percentage of open water or water-soaked land.

Biotic values

Biotic values can be used in such a first index. For example, different vegetation regions and plant zones make naturally a varied range of forest types. But, with the goal to keep the index as clear as possible, it is preferable to leave the biotic conditions out at first. Then an index of basic factors can

easily be weighed against the biotic conditions in the investigated area. The instructions required for creating the foundation for high-diversity-forest from different conditions could then be listed for each index number, as for example which trees and plants best suited for given area, giving the forest planner a guideline.

To be able to use an index for forest planning, it is important to create indexes for smaller units as the abiotic and biotic conditions can vary greatly from hectare to hectare.

Discussion

In recent decades, an ever-increasing rate of extinction of species due to human use of nature has spurred a large amount of research throughout the world. Forests with high biodiversity have greater resistance to extreme events and multicultural ecosystem produce an average of 1.7 times more biomass than monocultures. Thus, there are more ecosystem services in system with high biodiversity. (Anderson-Teixeira, et al., 2013 ; Cardinale, et al., 2012; Chiang, et al., 2016; Daily, 1997; Knops, et al., 2001; Naeem, et al., 1995; Perrings, 1993; Tilman & Downing, 1994). In view of all the research findings presented, insufficient measures have been taken to counteract the impacts on forests.

In order to strengthen human benefit from the forests, it is important to strengthen the possibility of a high number of interactions between different species. This can be done by laying a heterogeneous foundation with the aiming toward highest possible biodiversity for an area. In order for biodiversity to develop, there must be suitable habitats and the possibility of dissemination and or establishment within a particular area. It is of importance to lay a foundation for temporal and spatial continuity. (Dahlberg, 2011; Maguire, 2005; Pohjanmies, et al., 2017). To forbid the silvicultural even-aged method *thinning* shrubs and bushes would be a start, giving the area food for game and protection for all animals and allowing plants to establish. Thus, such act would lower the risk for forest fires.

In a natural system, intermediate disturbance contributes to a greater and greater biodiversity until a climax is reached (Cunningham & Cunningham, u.d.). This fact can be used in continuous forestry. An excessively high level of interference, as clear cuts, has a very negative impact on biodiversity. Cutting down trees is a disturbance to the ecosystem. But intermediate disturbance has a beneficial effect on increasing biodiversity. By setting the disturbance regime at the level that increases biodiversity, wood can be harvested at the same time as contributing to an increased biodiversity. It is therefore important to investigate the area and set a silvicultural disturbance regime that promote biodiversity. In addition, the forest owner would get a more even financial dividend on the forest.

Today, there are arguments against forestry for high biodiversity. For example, that such methods are not economically justifiable. It is easier to have monoculture-based forests with a total deforestation. A natural economic consequence of an easier methods is a greater percentage of investments. Protecting forests and biodiversity could also mean that the availability of wood products would decrease on the world market. A reduced asset of pulp can have a positive effect on market forces and development. Ideas for new types of solutions increase when shortcomings arise. Such solutions may, for example, be technology and organizational solutions for recycling, technologies for producing other types of materials, methods of extracting biomass from other kind of biomass in a forest. Sweden could become a precursor for such development by safeguarding the biodiversity of Swedish forests and legalizing a limited harvesting.

Swedish export market of pulp contributes to the national budget balance. But, in the other hand society is depended on a healthy nature. This contradiction needs to be solved. Suggestable this can

be made by, as mentioned before, changing forest management and harvesting methods. But it can also be done by development of …
… New materials that can replace timber
… Recycling technique and processes
… Services that can be exported, for example recycling methods
… The management and methods that support foresters in their planning toward biodiversity

One alternative could be to introduce more laws and regulations and raise sentences regarding nature conservation laws. But a limiting organization has both pros and cons. In order for a change to take place, knowledge must be incorporated into forestry. Knowledge can motivate forest owners to make measures to conserve biological values. By offering the landowners tools for forest planning, knowledge and methods you may motivate instead of forcing. But often you have to do both to make changes.

After a deforestation, or for example wildfire, it is time to plan the forest for the future. A forester who replants a forest will not see the result within his or her lifetime. What is most important to plan for? Is it cubic meters of timber or a forest that is resilient towards climate change that can provide species richness? A forest of biodiversity is a survival site with great potential for known and unknown ecosystem services. A forest of biodiversity has greater *potentials* for economic advantages compared with monoculture forestry. In two hundred years, people may appreciate herbal medicine, berries or game more than pulp and wood. Nature has a self-generating aspect that constantly creates an abundance. One seed grows to ten in one season, and the sunlight constantly creates biomass together with the ecological systems. From this creation the civilizations of humankind have arisen. It is important to take care of and maintain such foundation of richness.

CONCLUSION

It is of huge importance to protect the biodiversity by finding bridging solutions between the two opposites; the need for high biodiversity and the need of high-effective forestry. Today forestry most often means highly disturbed forests with loss of biodiversity and an ecosystem that after clear cuts need long time recovery periods species (Kindvall, 2006; Sample, 2005). In order to make it possible to control the forest's recovery path it is important to create a preventive forest composition (Hérault & Piponiot, 2018). Loss of biodiversity not only make the forest more fragile to extreme events, but also changes the functioning of ecosystems and consequentially weakens its ability to provide the goods and services vital to humanity (Cardinale, et al., 2012; Daily, 1997; Perrings, et al., 1993). When it comes to obtaining economic benefits (in industrial scale) from forestry, a new approach is needed. It is recommended to find a way of development of new techniques and methods for extracting material from heterogeneous forests. More research is also needed to investigate economic effects that different policy approaches have for forest owners (Bell, et al., 2016). More research is also required to investigate the economic benefits and disadvantages for a forester when changing to methods that benefits biodiversity.

Forestry Science today focuses on economic gain based on a measure that indicates cubic meters of timber in the form of wood or pulp. This approach is a one-sided economic focus which results in animal species are becoming extinct at an ever-increasing rate. Ecological systems need heterogeneity and continuity and most of the forests is lacking that today. In order to slow down the negative trend of extinction, more resources and methods must be introduced to the work of implementation of forest planning toward biodiversity in forestry. This can be done by development of a forest knowledge and information system that more strongly incorporates biodiversity. Such services could be valuation of an area and action plan that fits the conditions on the site. As forests are complex systems and the conditions for biodiversity change geographically an easy-to-use tool for forest planning can be created to help foresters plan for biodiversity. Such a tool could, for example, be an index value for the abiotic basic conditions for each area. Such an index could then be used with other values from the site. There is a need to raise the level of measures and solutions because current forestry policies and legislation are not enough to safeguard the vales of forests. It is important to work for increased awareness and changes within forestry towards systems and methods that promote viable forests with high biodiversity.

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