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Methodological considerations and their application for evaluation of benefits from the conversion of even-age secondary Norway spruce stands into mixed uneven-aged woodlands with a focus on the Ukrainian Carpathians

Methodologische Überlegungen und deren Anwendung zur Evaluierung von Vorteilen der Umwandlung von gleichaltrigen sekundären Fichtenbeständen in gemischte ungleichaltrige Waldbestände am Beispiel der Ukrainischen Karpaten

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Keywords: forest ecosystem services, DPSIR conceptual model, extended cascade model, Wilcoxon signed-rank test, cost-benefit analysis, impact matrix of forest conversion

Schlüsselbegriffe: Wald-Ökosystemleistungen, DPSIR-Modell, erweitertes Kaskadenmodell, Wilcoxon-Vorzeichen-Rang-Test, Kosten-Nutzen-Analyse, Wirkungsmatrix, Waldumwandlung

Summary

This paper examines the integration of three approaches towards developing a transdisciplinary framework for the evaluation of benefits from the conversion of even-aged secondary Norway spruce stands into mixed uneven-aged woodlands. To pre-

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sent a whole nexus of causal relationships in social-ecological interactions inherent for the conversion processes in a systemic and condensed way and to provide a common point of reference for decision-makers we develop a conceptual model based on the DPSIR (Driving forces – Pressures – States – Impacts – Responses) approach. The Ukrainian Carpathians are used as a case study. An extension of the cascade ecosystem service model through integration of societal processes is proposed to strengthen the functionality of the model and to make it more applicable for addressing adaptive forest management and ecosystem-based forest governance. A non-parametric analysis of the stated stakeholders' preferences with a high statistical significance shows that the flow of ecosystem services from mixed forests is considered more valuable than that from spruce monocultures. For the valuation of benefits from forest conversion we propose an impact matrix that reflects existing dichotomies both in valuation techniques and among beneficiaries. This matrix could serve as a checklist for an appraiser. We conclude that a proper integration of several methodological approaches may assist researchers to overcome limitations of a narrow disciplinary perspective, to take advantages of quantitative as well as qualitative research methods and may allow a wider involvement of stakeholders in a more participatory decision-making in order to tackle the challenge of spruce stands decline.

Zusammenfassung

Dieser Artikel untersucht die Integration von drei Ansätzen die das Ziel verfolgen eine transdisziplinäre Perspektive in den Entscheidungsfindungsprozess bezüglich der Umwandlung von gleichaltrigen sekundären Fichtenbeständen in gemischte, ungleichaltrige Waldbestände zu bringen. Im Interesse einer ganzheitlichen Betrachtung wird ein konzeptionelles DPSIR-Modell (treibende Kräfte – Belastungen – Zustände – Auswirkungen – Reaktionen) am Beispiel der ukrainischen Karpaten vorgestellt. Um Interdependenzen zwischen biophysikalischen Strukturen wie Wald / Waldlandschaften, Prozesse innerhalb dieser Strukturen, Funktionen und Dienste, die menschlichen Leistungen und Werte, sowie Komponenten von Politik und Verwaltung der analysierten sozial-ökologischen Systeme darzustellen, wird ein erweitertes Kaskadenmodell vorgeschlagen. Dieses Modell integriert Elemente, die Politikentwicklungsprozesse beschreiben, in ein Wald-Ökosystemleistungen-Kaskadenmodell. Dadurch wird die Funktionalität des Modells und seine Anwendbarkeit für die adaptive Bewirtschaftung von Waldökosystemen verbessert. Die monetäre Bewertung der Effekte einer Waldumwandlung wird im Sinne einer Kosten-Nutzen-Analyse vorgenommen. Es wird vorgeschlagen, einen Matrix-Ansatz für die Identifizierung der Vorteile des Umwandlungsprojektes anzuwenden. Die Wirkungsmatrix der Waldumwandlung basiert auf der Literatur sowie auf einer Befragung von Interessensgruppen bezüglich ihrer Wahrnehmung von Ökosystemdienstleistungen, die von gemischten bzw. von Reinbeständen bereitgestellt werden. Es erlaubt den Umfang von bestehenden Dichotomien zu erfassen. Mit Hilfe der vorgeschlagenen Kombination von Methoden kann in einer

ganzheitlichen und kompakten Weise eine Reihe von kausalen, sozial-ökologischen Beziehungen bzw. Wechselwirkungen, die den Umwandlungsprozessen inhärent sind, aufgezeigt werden. Eine derartige Integration mehrerer methodischer Ansätze kann hilfreich sein, um die Grenzen einer engen disziplinären Perspektive zu überwinden und eine stärkere Einbeziehung von Stakeholdern in die Entscheidungsfindung betreffend Waldumbau zu ermöglichen.

1. Introduction

Multifaceted challenges caused by environmental and social changes (MA, 2005) put at a threat a time-proven, traditional forest management. Recent investigation of climatic, biological and geochemical indicators of human activity impact (Waters et al., 2016) suggest that the era since the mid-20th century should be recognised as a geological epoch distinct from the Holocene. A more holistic framework instead of a narrow commercial vision has to be developed and adopted in the Anthropocene context to manage forests more effectively and efficiently in conditions of transcending planetary boundaries (Rockström et al., 2009; Steffen et al., 2015).

Mounting losses of forest ecosystems' resilience and productivity in the Ukrainian Carpathians root in transformations that occurred in the region during the 19th century, when 178000 ha of native beech (*Fagus sylvatica* L.) and mixed coniferous-broadleaved forests were converted, for commercial reasons, to Norway spruce, (*Picea abies* (L.) Karst.). Norway spruce was native to the region, but it was too intensively planted all over the place, using non-local genetic varieties (Krynytskyy and Chernyavskyy, 2014; Keeton and Crow, 2009).

Nowadays, under changing climatic conditions and increasing pressure of human praxis, such modified forest ecosystems have been rapidly losing their vitality and resistance against destructive abiotic and biotic impacts (Stoyko, 1998; Klimo et al, 2000; Spiecker et al., 2004). These changes have been undermining welfare of local communities and prosperity of the whole fragile mountain region (Krynytskyy et al., 2014; Soloviy, 2011; Soloviy and Melnykovych, 2014). At the present time a decline of secondary Norway spruce forests is made visible on the area of 19300 hectares of forest (3% of whole spruce in the Ukrainian Carpathians) with a wood volume near 6 million m^3 (Parpan et al., 2014).

Conversion of an even-aged secondary Norway spruce into uneven-aged mixed stands in the Carpathian Mountains, as in whole Central Europe, is internationally thought as a main challenge of recent mountain forest management and an effective way to tackle the abovementioned problems (Spiecker et al., 2004; Wolfslehner et al., 2005; Vacik et al., 2007; Soloviy et al., 2011; Lavnyy and Schnitzler, 2014; Krynytskyy and Chernyavskyy, 2014). Furthermore, conversion becomes internationally recognised as a necessary precondition for sustainable forest management and the well-being of forest-dependent communities (Bravo-Oviedo et al., 2013; Zahvoyska, 2015).

According to experts' estimations the conversion process induces a broad range of benefits, namely:

- Higher resilience and resistance of forest ecosystems to natural and anthropogenic disturbances and their better adaptation to climate change (Parpan et al., 2014; Soloviy et al., 2011; Roessiger et al., 2013);

- Increase of biomass productivity of forest ecosystems: in mixed stands of Norway spruce and European beech a forest stand productivity increases on average by 20% in comparison with pure stands of the same species (Piotto, 2008; Pretzsch et al., 2014);

- Better resistance to a drought (Merlin et al., 2015);

- Improved soil conditions (Brandtberg et al., 2000; Prescott, 2002);

- Reduced risk of landslides, windfalls (Schutz et al., 2006) and fires (Gonzalez et al., 2006);

- Improved hydrological regime and increased water supply (Kulchytskyy-Zhyhaylo and Kulchytska-Zhyhaylo, 2011);

- Reduced risk of pathogens' impacts (Parpan et al., 2014);

- Enhanced biodiversity and improved habitats for biodiversity (Lindenmayer and Hobbs, 2004; Carnus et al., 2006; Krynytskyy et al., 2014);

- Increased recreational value and personal perceptions of mixed forest landscapes (Grilli et al., 2014; Grilli et al., 2016) and a higher value of a neighbour real estate;

- Decreased financial risks due to forest species diversification (Hildebrandt and Knoke, 2009; Roessiger et al., 2013) etc.

However, the main difficulty associated with an assessment of benefits from the conversion process lies in the nature and features of these benefits. In a recent discourse of economic analysis of forest projects, the ecosystem services concept (MA, 2005; TEEB, 2008) is widely thought as the most relevant framework for identifying the benefits associated with a conversion project. However, the implicit nature of a significant part of forest ecosystem services (FES), non-rival and non-excludable in terms of ecological economics (Daly and Farley, 2010), causes market failures, resulting in the incapacity of a market to signal their scarcity and to provide market incentives to regulate their supply (Nijnik and Miller, 2014) or to adjust production and consumption to planetary boundaries (Steffen et al., 2015) and limited carrying capacity of the global ecosystem (Daly and Farley, 2010). This also makes it impossible to measure part of the FES value by means of traditional market instruments (Gregersen and Contreras-Hermosilla, 1992; Zahvoyska, 2014). Therefore, in the case of a market failure, economic valuation has the function to inform about all costs and benefits accruing to people now and in the future, and to enable decision-makers to reduce external costs and to maintain provisioning of public goods to the optimal extent, maximising human welfare taking into account all relevant costs and benefits (Grunewald and Bastian, 2015).

On the other hand, costs of the conversion are quite explicit. More intensive financial investments over a conversion period of around 100 years with a questionable commercial return in a long time perspective prevent a dissemination of this practice. The simulation of conversion strategies for a 62-year even-aged secondary spruce site located in Transcarpathian region of the Ukrainian Carpathians (the State Enterprise „Rakhiv forestry") using the growth simulator SIBYLA (Fabrika, 2005) revealed, that only the conversion strategy with an intensive target-diameter harvesting for spruce and selection thinning for beech and fir allows us to obtain a target (or native) trees species composition: 70% of spruce and 30 % of beech, and fir and sycamore with a sufficient diversity in terms of height and diameter (Pelyukh et al., 2016). Conversion means significant losses in increment and standing volume. Thus a trade-off between market and non-market values and between ecosystem services themselves in a long-term perspective brings additional difficulties into forest decision-making (Nijnik et al., 2012, Martín-López et al., 2014; Mosert et al., 2009; Rößiger et al., 2011; Rößiger, 2014).

As we see from the abovementioned simulation and from the scientific literature (Hanewinkel and Pretzsch, 2000; Krynytskyy and Chernyavskyy, 2014), possibilities to obtain a rich structure diversity on an initially even-aged forest stand using only "structuring measures" are limited. A success of a conversion strategy implementation highly depends on the quality of regeneration. Conversion strategies need more skilled design and implementation as well as monitoring under climate-changed and climate-changing conditions. A highly nonlinear behaviour of (forest) ecosystems, which demonstrate a weak response until they transgress the thresholds and their collapse becomes obvious and unavoidable (Scheffer et al., 2015), aggravate uncertainty and put a conversion dilemma into the focus of adaptive forest management.

Taking these reflections into consideration, the main objective of this paper is to review and advance existing approaches to identify and evaluate benefits from the conversion of secondary even-aged Norway spruce stands into mixed uneven-aged woodlands taking the Ukrainian Carpathians as a case study. A proper integration of analytical and participatory techniques as well as visualization tools is suggested for developing a holistic transdisciplinary framework for assessing the efficiency of forest conversion projects.

2. Material and Methods

To develop a transdisciplinary framework for evaluation of benefits from the conversion of even-aged secondary Norway spruce stands into mixed uneven-aged woodlands we propose to begin with three approaches: (1) systemic and holistic DPSIR approach (Driving Forces-Pressures-States-Impacts-Responses) to understand and communicate causal relationships in social-ecological interactions related to the conversion processes; (2) the ecosystem services approach to grasp and discover the fundamental link between biophysical structures like forest ecosystems or landscapes, human wants and needs and forest governance and (3) a framework of pure economic analysis of cost and benefits of the conversion projects in order to introduce a monetary perspective. The application of these approaches should answer such questions as "What should be considered in the framework and why?" The answer will suggest us relevant approaches and methodology to be used for the evaluation.

2.1. Evaluation of benefits from the conversion process using DPSIR approach

The DPSIR framework was developed by the Organization of Economic Cooperation and Development (OECD, 1993) and the European Environmental Agency (EEA, 1995; EEA, 2007; EEA, 2013) as one of the original tools for adaptive management of social-ecological systems (Carr et al., 2007; Kagalou et al., 2012; Binder, 2013; Gari, 2015). This framework focuses on such aspects as Driving forces, Pressures, States, Impacts and Responses and postulates causal chains of links between them. Designed as a reporting framework (Eurostat 1999; Smeets and Weterings, 1999), the DPSIR approach is increasingly used as a decision-support tool to structure and condense a complex and diverse information into sets of indicators to track and analyse ongoing processes and to build quantitative models. The DPSIR model allows a researcher to reveal and understand in a holistic way the causal relationships in interactions between society and the environment and is sufficiently broad to allow a formalization of the whole procedure of decision making in the context of adaptive forest management (Chipev et al., 2008).

DPSIR indicator models serve as a reliable instrument and database for analytic hierarchical or network models for multicriteria decision-making (Wolfslehner et al., 2005; Vacik et al., 2007). In return, conceptual models usually are designed to disclose fundamental principles of processes or systems under consideration and to provide a common point of reference for model users.

Problems of secondary Norway spruce decline in the Ukrainian Carpathians are intensively examined in forestry literature (Stoyko, 1998; Kramarets and Krynytskyy, 2009; Krynytskyy and Chernyavskyy, 2014; Lavnyy and Schnitzler, 2014) whereas interdisciplinary investigations and stakeholders' involvement, essential for adaptive forest management (Holling, 1978), are weak and rare.

To fill this gap and synthesize a mosaic of disciplinary and stakeholders' perspectives into a holistic transdisciplinary view of conversion, relevant processes in social-ecological systems should be analysed integrating the DPSIR approach into the conceptual model of these systems coevolution. Such conceptual DPSIR model will explain a basic logic of social and ecological systems interaction and their interdependences, considering these processes from stakeholders' perspectives. Such model should allow an identification of driving forces, conflicts and synergies among stakeholders and facilitate their co-learning and co-search to tackle challenges in a sustainable way. To apply this model a real nexus of forestry-social-economic problems in the Ukrainian Carpathians was analysed by synthesising current knowledge and information out of dialogues with stakeholders.

2.2. Evaluation of benefits from the conversion process using the ecosystem services approach

The ecosystem services approach is increasingly applied to link biophysical structures like forest stands and landscapes with human well-being. Conceptualisation and classification of ecosystem services, originated by Costanza (1997), Daily (1997) and De Groot (2002), were enhanced in the MA (2005) and TEEB (2008) reports, further reassessed by Boyd and Banzhaf (2007), Costanza (2008), Fisher and Turner (2008), Fisher et al. (2009; 2011), Haines-Young and Potschin (2009; 2012); TEEB (2010; 2015), Gómez-Baggethun et al. (2010), Chaudhary et al. (2015), Daw et al. (2016) and many others. The value of multiple ecosystem services was conceptualised and valuation methods were analysed at appropriate scales. Knowledge of non-market valuation now has been extended (Krutilla, 1967; Gregersen et al., 1995, Hanley and Spash, 1998; TEEB, 2010; Costanza et al., 2014) and provides a solid background for operationalising ecosystem services.

However, a broad interdisciplinary scope of the ecosystem services framework predetermines a variety of their interpretations and classifications of ecosystem services per se (Daily, 1997; Costanza, 1997; 2008; MA, 2005; TEEB 2010; Fisher et al., 2009; Haines-Young and Potschin, 2009). Understanding of ecosystem services as ecosystems' contribution to human well-being (Fisher and Turner, 2008; Fisher et al., 2009; CICES, 2013) provided us with a proper framework for unambiguous identification and evaluation of the conversion process benefits. To avoid an ambiguity and a double counting in the ecosystem identification and valuation (Fisher et al., 2009; Haines-Young and Potschin, 2009) and to ensure a comparability of research we applied a trinomial hierarchical classification of ecosystem services as proposed in (CICES, 2013).

The ecosystem service cascade model (Potschin and Haines-Young, 2011; Potschin et al., 2016) serves as a comprehensive framework for the identification of the links between ecological and social systems, which co-evolve at a range of spatial and temporal scales. This model reveals how changes in biophysical structures and processes within them cascade through ecological and social systems and result in subsequent changes in multidimensional human well-being.

However, the full cycle of ecosystem services generation and management remains unrevealed in the model (Spangenberg et al., 2014). To include a variety of societal processes into the cascade model we propose a backward link in order to explain how stakeholders' knowledge, perceptions, values and the prices cascade through the decision-making process and shape environmental policy, governance and institutions, which, in turn foreshadow the ecosystems' structure and quality (Zahvoyska, 2014).

To develop adaptive management of secondary Norway spruce stands it is important to understand stakeholders' perceptions of FES generated by pure vs. mixed forest stands to be able to identify relevant synergies and conflicts. With this aim we prepared a comparative questionnaire, based on the ecosystem service framework. This questionnaire consists of three sections: the first section includes questions about professional background of a respondent; the second section is dedicated to a respondent's assessment of the FES importance; and the third section deals with a comparative evaluation of the quality of FES provided by pure vs. mixed stands. To scale these values our respondents were asked to refer to a 5-point Likert scale (the higher value means the higher importance). CICES classification of ecosystem services (CICES v. 4.3) was applied in our questionnaire because it provides a researcher with a precise interpretation of FES essence and ensures comparability of the research results.

The survey was conducted in the Ukrainian Carpathians, a part of the Eastern Carpathians, namely in Lviv and Ivano-Frankivsk regions, which are featured by a high forest cover (app. 40%). The absolute height of the mountain system ranges from 120-400 m near the foothills up to 1500-2000 m along the main ridge. There is a temperate continental climate with a relatively high level of precipitation: 500-800 mm in the foothills and up to 1600-2000 mm on the highest ridges. Altitudinal landscape differentiation is clearly expressed: from deciduous (sessile and pedunculated oak (*Quercus petraea*, *Quercus robur*), beech (*Fagus silvatica*), sycamore (*Acer pseudoplatanus*) and hornbeam (*Carpinus betulus*)) to coniferous forests (Norway spruce (*Picea abies*) and silver fir (*Abies alba*)). An average altitude of a treeline is 1376 m asl, usually it is formed by spruce and beech forests in almost equal proportions (52% and 48%, respectively) and is related mainly to human activity (Sitko and Troll, 2008).

We approached two groups of stakeholders: Scientists and Forestry enterprise employees. The Scientists group was represented by researchers from the Ukrainian Research Institute of Mountain Forestry (Ivano-Frankivsk) and the Ukrainian National Forestry University (Lviv). Both institutions are closely related and have an intensive scientific collaboration.

The Forestry enterprise employees group was represented by a staff of the State Enterprise "Skole Forestry" (Skole, Lviv region) and the Municipal forestry enterprise "Halsillis" (Pustomyty, Lviv region). Both forest enterprises are located in Lviv region, but have a bit different ecological and economic conditions. The State Enterprise "Skole Forestry" is located in a mountain area, where secondary spruce forests dominate, while the Municipal Forestry Enterprise "Halsillis" is located in plain area, where oak and pine forests are common. However, in both areas a phenomenon of spruce and pine dieback occurs. Therefore, employees from both enterprises face the necessity and have some experience in forest conversion.

From an economic point of view, both enterprises operate in strained circumstances because of long-term market and institutional transformations as well as a hybrid war, which takes place in Ukraine. However, the State Enterprise "Skole Forestry" operates in a less developed economic region than Municipal Forestry Enterprise "Halsillis". Even average salary in Skole district is approximately 15% higher. An integrated assessment which involves soft and hard indicators ranks Pustomyty district in the very top position among 20 districts of the Lviv region, whereas Skole region was placed near the end of this list at the 17th position (Lviv, 2016).

Collected data regarding stakeholders' perceptions of importance and quality of FES provided by pure vs. mixed stands were elaborated using nonparametric methods, namely the Wilcoxon signed-rank test (Lowry, 2014), to check a statistical significance of the evaluations.

2.3. Evaluation of benefits from the conversion process using the economic approach

To gain insight into the process using a monetary dimension of the conversion benefits we analysed current economic approaches, elaborated by international schools of environmental economics such as cost-effectiveness and cost-benefit analysis (CBA). Cost-effectiveness analysis is often used in the field of public goods and focuses on identifying the best alternative (the cheapest option) to achieve the goal. It avoids a valuation of benefits if this exercise is inappropriate or non-straightforward (Layard and Glaister, 1996; Callan and Thomas, 2013; Tuominen et al., 2014). Thus, this is a rather fair technique in application, but the main question of the assessment "Does the conversion process pay?" is still left unattended.

Methodology of CBA is rather sophisticated. It is theoretically well grounded and has a long history and broad scope of application (Gregersen and Contreras-Hermosilla, 1992; Layard and Glaister, 1996; Hanley and Spash, 1998; Pearce et al., 2006; Cubbage et al., 2013; Sartori et al., 2014 etc.). It is an analytical tool for discovering attractiveness of an investment decision from the investor and society perspectives by comparing costs and benefits attributable to the proposal. The logic of the economic appraisal is presented in Fig. 1.

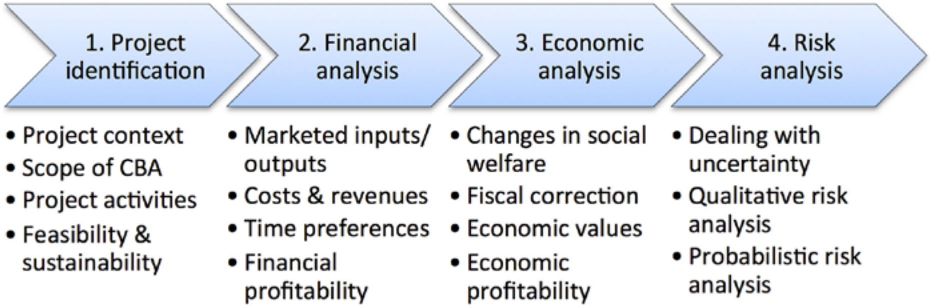

Figure 1: Main steps of cost-benefit analysis

Abbildung 1: Die wichtigsten Schritte der Kosten-Nutzen-Analyse

The analytical framework of CBA refers to a list of principal concepts as the total economic value (Krutilla, 1967) and opportunity costs, time preference rate and its social value, monetary indicators of economic performance and uncertainty. Relevant multidimensional welfare changes and associated economic values create a central focus of CBA.

Forestry projects constitute a special case of CBA because of features of forestry projects and difficulties in valuation of benefits, attributable to the proposals. These benefits often are public goods (pure or mixed), priceless but essential for human well-being. Therefore, FAO pays special attention to the economic assessment of forestry project impacts and the application of valuation methodology (Gregersen and Contreras-Hermosilla, 1992; Gregersen et al., 1995). The extensive body of literature on application of valuation techniques in forest project assessment (Gregersen et al., 1995; Hanley and Spash, 1998, Pearce et al., 2006; TEEB, 2010; Haines-Young and Potschin, 2009) proposes a variety of approaches and case studies, but at the same time stresses difficulties and pitfalls of economists' intention to assign a market price to priceless items.

A major drawback of CBA methodology is that it takes into account only those costs and benefits which have a monetary value. For long-term forest projects that have a significant impact on the environment and welfare of society, it is not easy to meet these requirements. CBA is reasonably criticised because of its fail to address multifaceted dimensions of human well-being, a whole continuum of values and the objective implications of spatio-temporal framing (Wegner and Pascual, 2011).

Over the last four decades environmental economists have taken significant steps in developing methods for the monetary valuation of benefits from improved environmental quality. Extensive databases of valuation case studies, their critical overviews and high volatility highlight the importance and complexity of the task and, as a result, raise questions about the validity of the CBA profitability indicators. For instance, recent estimations of economic damages from an additional ton of carbon dioxide emitted in 2015 varies from 37 $ worth of economic damages (US government estimation) to 220 $ according to Moore and Diaz (2015). Another example is a prediction of changes in carbon sequestration for converted mixed conifer/broadleaved stands under two models that diverge significantly (+29.4 tC ha^{-1} and –10.6 tC ha^{-1} in PICUS and 4C models respectively) (Seidl et al., 2008). Thus, an exhaustive sensitivity analysis should be conducted to reveal merits of a conversion project taking into account a specific forestry, social and economic context of a project.

Special care in CBA appraisal has discounting. Nijnik and Pajot (2014), Schiberna et al. (2012) showed that choice of a discounting rate has a significant influence on a forest decision-making, inquiring the CBA framework. A standard exercise in the financial analysis aimed in a reassessment of future values from today's perspective becomes challenging in the economic analysis: a loss of ecosystem capability and a strong reduction of ecosystem services flows suggest us a completely opposite approach and raises a question of a zero or even negative value of a social discount rate (Layard and Glaister, 1996). But such arguments have rather moral character than a practical application. Even though a relatively low interest rate of 2% cannot compete with other investment alternatives, it allows real and low-risk long-time investment attractiveness for certain types of investors and justifies forest projects with multidimensional long-term changes in human well-being. In addition, the sensitivity and risk analysis give us analytical tools for testing these assumptions and profitability indicators' sensitivity to changes in underlying hypotheses and shadow values.

Summarising these reflections, we should say that for a holistic, comprehensive evaluation of the conversion projects across different scenarios and contexts a universal framework should be developed to ensure that a whole range of impacts is considered (including positive and negative externalities), none of the stakeholders is forgotten, nothing important is omitted (TEEB, 2015). The four-capital frame of ecological economics (Daly and Farley, 2010) could serve as a reliable background for these purposes. The framework should be robust for business purposes and policy development and should be reliable for comparisons and resource allocation.

3. Results

3.1. DPSIR conceptual model of the conversion process

DPSIR conceptual model of the conversion process was developed to analyse existing interactions between social and ecological systems, namely mountain forest ecosystems in the Ukrainian Carpathians socio-economic context. Based on the literature review and dialogues with stakeholders, we identified three groups of driving forces: natural, socio-economic and institutional (Fig. 2).

Among natural drivers we stress global climate change and a complex nature of both social and ecological systems. According to Sitko and Troll (2008), in 2001 an average timberline elevation in the Carpathian Mountains was 1376 m asl, that is 47m higher than in 1933. Authors state that spruce forests reached, on average, 80 m higher than beech forests. Recent investigations of climate change in the Carpathians, conducted by Hlásny et al. (2016), predict a strong exposure of the region to climate change. One of two hot-spots, identified by these scientists for the Ukrainian Carpathians, is located in Lviv region near the border with Poland and reaches 60% of the maximum permissible change. According to the research, this change will be followed by the highest change for the whole Carpathians in a number of cumulative dry days by 42% and a decrease of precipitation during the growing season by 12%. For another hot-spot, predicted in the south-west region of the Ukrainian Carpathians, the projected changes are severe as well: 58% of the maximum permissible change, growing season length will increase by 33%, total number of days with maximum daily air temperature exceeding 30°C will increase by 26% and total precipitation decrease will reach 19%. In this water-limited and temperature-increased environment the secondary Norway spruce monocultures will lose significantly their resilience. They will be much more sensitive to destructive biotic and abiotic impacts compared to forests consisting of species better adapted to the ambient conditions (Stoyko, 1998; Klimo et al., 2000; Spiecker et al., 2004).

The synergetic nature of social and natural systems and processes within them is another decisive driving force in the systems co-evolution (Fig. 2). Synergetic systems are featured by a relatively simple behaviour of their elements compared to emergent/adaptive behaviour of the whole system they constitute (Camazine et al., 2003; Epstein and Axtell, 1996; Holling, 2001). Under constant operating conditions some relationships between the systems' elements may remain latent for a long time. Only in the case of threshold crossing these relations give rise to unexpected system behaviour that may occur as a system adaptation or self-organization, non-predicted shift to a new state, or a new way of functioning (Scheffer et al., 2015). Emergent behaviour of a synergetic system can be explained by its hierarchical organization, a positive and negative feedback, its capacity for processing information about the environment and ability to adapt to new conditions. The phenomenon of dynamic complexity of ecosystem processes (Costanza, 2008; Fisher et al., 2009) reflects our ignorance on the systems and, consequently, our limited understanding of co-evolution of social and ecological systems (Daly and Farley, 2010). Risk of approaching a deleterious tipping point should keep us in a safe operating space to avoid unwanted shifts in regimes of socio-ecological systems functioning (Rockström and Karlberg, 2010).

Considering social-economic drivers in the case of the Ukrainian Carpathians, we should first of all mention a globally-relevant misperception and underestimation of the vital role that (forest) ecosystems play in human well-being and lack of understanding of a complex nature of both systems (Fig. 2). Thus changes in a forest resource use become increasingly destructive and non-reversible. Additionally, a high unemployment rate and a low level of income per capita, especially in the mountain regions of Ukraine, force local stakeholders to non-sustainable forest practices (Soloviy and Melnykovych, 2014).

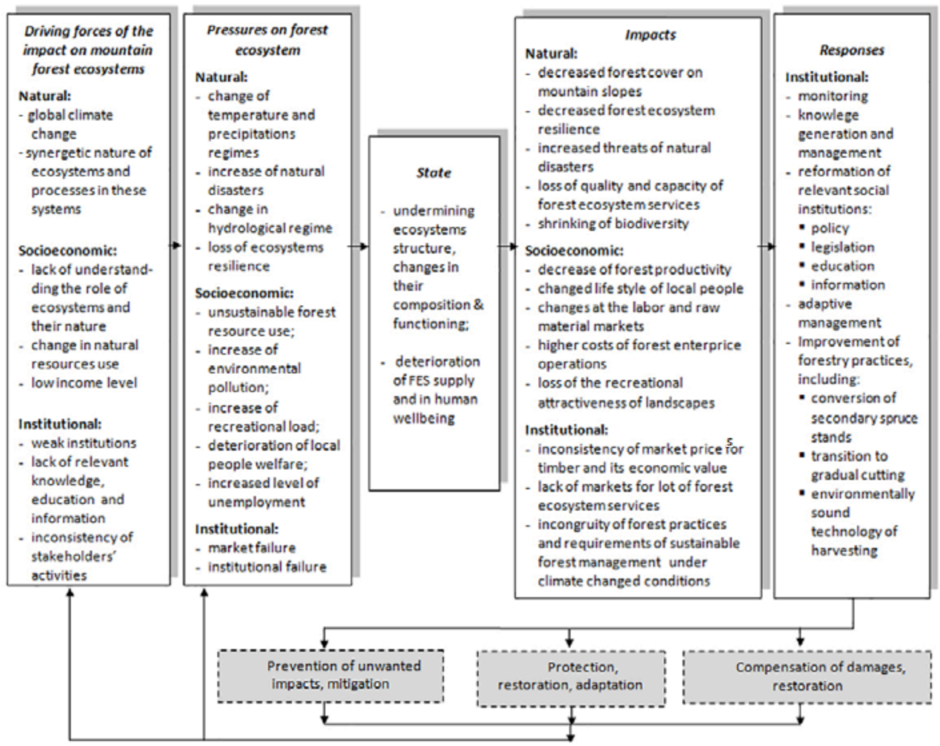

Figure 2: Conceptual DPSIR-model of interactions between society and forest ecosystems in the Ukrainian Carpathians: a conversion project perspective

Abbildung 2: Konzeptionelles DPSIR-Modell der Wechselwirkungen zwischen Gesellschaft und Bergwaldökosystemen in den ukrainischen Karpaten: eine Waldumwandlungsprojekt-Perspektive

As regards the analysis of institutional driving forces we should begin with a weakness of public society institutions, lack of transparency and a strong corruption, which push Ukraine into a low-efficiency trap. One more important, globally-relevant driver is a lack of education for sustainable development. Traditional practices are to be questioned in face of changing climatic conditions, (forest) ecosystems decline and resource scarcity. But the content of education (Farley et al., 2009) and vocational training both formal and non-formal does not tackle these challenges in a comprehensive way yet. This is especially acute to forestry education and vocational training: climate change and anthropogenic pressure demands adaptive decisions to embrace uncertainty of coming events and to disseminate a successful experience including for the conversion projects.

A strong focus on short-term financial interests of business and local stakeholders conflicts with a long-term perspective of the secondary Norway spruce conversion benefits, making them unattractive from a macroeconomic perspective of resource allocation. Gaps in communication of conversion project goals and benefits to local stakeholders fail to initiate adaptive governance in the region (Zahvoyska et al., 2015). Discrepancy and lack of coherence in stakeholders' activity, as well as financial shortage, make conversion projects (even those already initiated) difficult to complete.

In the proposed DPSIR conceptual model we pay a lot of attention to the analysis of drivers in interactions between a society and mountain forest ecosystems because understanding of the roots facilitates solving the problem in a sustainable way. As we see, global and local drivers make a complicated nexus of destructive factors which pressures forest ecosystems. These pressures, well described in the literature on secondary Norway spruce decline (Stoyko, 1998; Klimo et al, 2000; Spiecker et al., 2004; Keeton and Crow, 2009; Soloviy et al., 2011; Parpan et al., 2014), cause a worsening state of both systems: ecological – because of loss of a forest vitality and social system – because of deterioration of FES supply and related changes in human well-being.

Deeper insight into the roots provides us with a better preparedness to a response activity. We stress on proactive institutional changes in knowledge generation, education and information to change human behaviour, land and resource use. Preventive and reactive responses should complement each other to put a forest resource use, management and governance on the sustainability track.

To conclude with the DPSIR approach application we can say that the proposed DPSIR conceptual model of interactions between society and forest ecosystems in the Ukrainian Carpathians, developed from a conversion project perspective, allows us to examine how changes in institutions, forest management paradigm and practices, including the conversion processes, will weaken the destructive drivers, mitigate their pressures and affect the state of ecosystems and of the ecosystem services flows they generate. In condensed form this conceptual model reveals casual links between driving forces, pressures and impacts and facilitates stakeholders' communication and collaborative decision-making. The proposed model synthesizes forestry, socio-economic and institutional perspectives and provides a common point of reference for a further transdisciplinary research.

3.2. Evaluation of benefits from the conversion process using the ecosystem services approach

To investigate an interdependence between social and ecological systems from the FES perspective we propose to complement the ecosystem service cascade model (Potschin and Haines-Young, 2011; Potschin et al., 2016) with a backward link in order to explain how ecosystem services, their prices and stakeholders' knowledge, perceptions and values underpin forest decision-making and shape institutions, which, in turn, foreshadow the ecosystems' structure and quality (Fig. 3).

Such extended cascade ecosystem service model reveals synergies and conflicts which arise at all levels of ecosystem services provision, use, and governance from FES perspective. Institutional structures are considered to be shaped by human perceptions and values associated with FES and generate relevant policy and instruments to mitigate anthropogenic impacts on FES and biophysical structures, generating these FES. Integration of a societal perspective into the cascade ecosystem service model makes the model more realistic and operational for adaptive forest management and governance.

To understand stakeholders' perceptions of FES role, their values and preferences concerning pure or mixed forest stands, central for the proposed extended cascade ecosystem service model, we run a survey, based on the CICES classification. Our respondents – Scientists of the forest research institutions and Employees of the forest enterprises – were asked to evaluate the importance of FES, using a 5-point Likert scale. The main part of the questionnaire contained a CICES list of ecosystem services and respondents were asked to express their perceptions of these services' importance and to compare the quality of FES, provided by pure vs. mixed forest stands. We conducted twenty face to face interviews that lasted from 15 to 25 minutes each and approached two groups of stakeholders: Scientists (ten respondents) and Forestry enterprise employees (ten respondents).

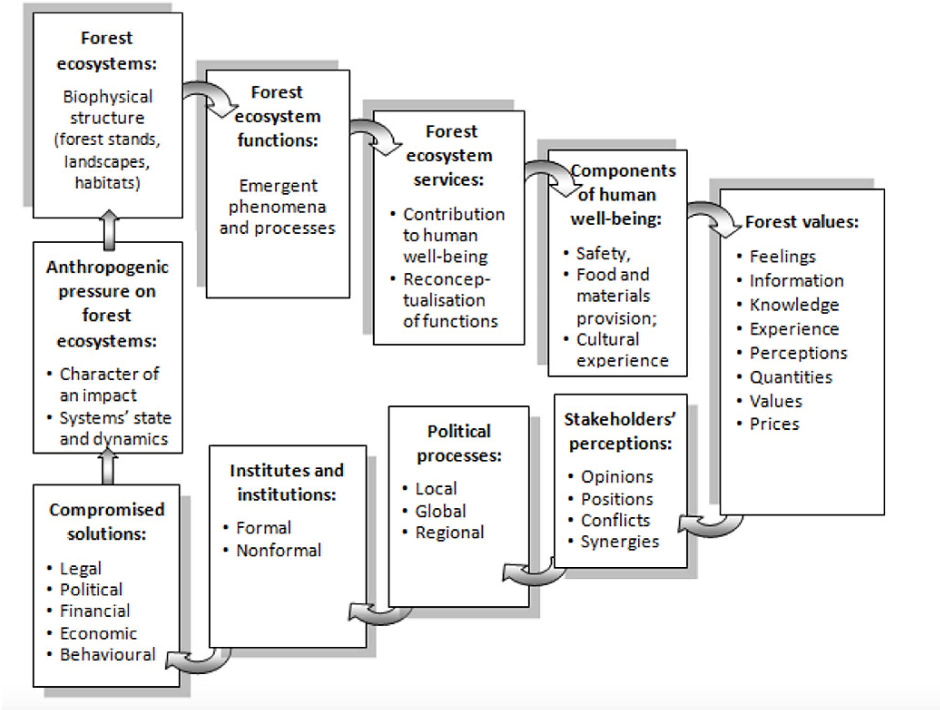

Figure 3: Extended ecosystem service cascade model: perspective of forest decision-making (proposed by Potschin and Haines-Young, 2011; modified in Zahvoyska, 2014)

Abbildung 3: Erweitertes Kaskadenmodell für die Ökosystemleistungen: Perspektive der Entscheidungsfindung im Wald (entwickelt von Potschin and Haines-Young, 2011; erweitert von Zahvoyska, 2014)

The collected data shows that respondents assess the role of FES quite high: an average range of values varies from 3.2 (Provisioning section, Energy in terms of CICES; provided by Scientists; the higher the better) to 4.5 (Regulation & Maintenance, Mediation of waste, toxics and other nuisances; Employees). Both groups of respondents give the highest values to the section Regulation & Maintenance ecosystem services with a mean value of 4.2 whereas the Provisioning section got the lowest estimation (mean 3.6). Note, that the only marketable section – Provisioning services – got the lowest rank in the stakeholders' evaluations while financial efficiency conclusions usually are based on the market values.

Generally, estimations of both groups of stakeholders are quite similar, but Scientists evaluate all divisions except Maintenance of conditions and Physical and intellectual interactions a bit lower as compared to Employees. Among provisioning section both groups of respondents stress Materials (mean value 4.0 for Employees and 3.6 for Scientists) whereas Energy division got the lowest points for both groups of stakeholders (3.5 and 3.2 respectively). Some difference in priorities is expressed in the Cultural section: Scientists consider division Physical and intellectual interactions more important (3.9) while Employees focus on Spiritual, symbolic and other interactions (with the same value 3.9).

In our poll the group Scientists was represented by researchers from the Ukrainian Research Institute of Mountain Forestry (Ivano-Frankivsk) and the Ukrainian National Forestry University (UNFU). Scientists of both institutions provide quite similar evaluations and it was not surprising: both institutions are closely related, have a common professional background from the UNFU, share a long experience of collaboration and thus no differences in the FES evaluation is to be found.

There are many similarities in the estimations provided by both forestry enterprises as well. The first of all, both rankings are similar, differences come from estimations of some items' importance. Thus, employees of both enterprises give the highest value to the second CISES section Regulation and Maintenance, in particular to the division Mediation of waste and other nuisances with the highest estimate, but employees from the Municipal Forestry Enterprise "Halsillis" estimate it a bit higher (4.7 vs. 4.4) possibly because of a higher sensitivity to the environmental pollution in the more industrialised region. Interesting, that employees from the State Enterprise "Skole Forestry", which operates in a mountain area, evaluate the division Maintenance of physical, chemical, biological conditions a bit higher as compared to employees from the Municipal Forestry Enterprise "Halsillis", that operates in a plain area: 4.2 vs. 4.0. This difference could be explained by a higher focus on a pest and disease control as well as on a climate regulation, relatively sharply revealed in mountain regions. Mediation of flows got the same estimations for both enterprises (4.1).

In the first section (Provisioning services) both enterprises give the highest value to the item 1.2 Materials, however employees of the Municipal Forestry Enterprise "Halsillis", that operates in a better economic conditions, assess this item as 0.2 point higher, then their peers (4.1 vs. 3.9). The remaining estimates are very similar.

Employees from both enterprises estimate the importance of Spiritual and other interactions as 3.9, but employees from the Municipal Forestry Enterprise "Halsillis" estimate the division Physical and intellectual interactions a bit higher than their peers (3.7 vs. 3.5). That can be explained by more intensive physical interactions with wooded landscapes from tourism and recreation.

We note that respondents from both groups with 20-25 years of professional experience evaluate the importance of FES a bit higher (0.3-0.6 points). Surprisingly, both groups of respondents prioritise the second CICES-section – Regulation & Maintenance – because a recent discourse of forest resource use is heavily focused on timber production whereas local population is considered to be more sensitive to the provision of non-timber products (ENPI EAST FLEG II, Bakkegaard, 2014; ENPI EAST FLEG II, Zhyla et al., 2014). A reasonable explanation for the observed set of values could be found in the decline of forest ecosystems and several recent floods in the Carpathian Mountains with severe consequences, which revealed a real set of priorities for the respondents. The results communicate a certain level of willingness and preparedness to a long-term wealth-creation partnership and cooperation for sustainability.

The second research question we examined using the questionnaire, dealt with a comparative assessment of FES quality provided by mixed vs. pure forest stands. According to the results a respective difference is perceived in regard to CICES divisions Materials (Provisioning section), Mediation of waste, toxics and other nuisances, Mediation of flows and Maintenance of physical, chemical and biological conditions (the whole Regulation & Maintenance section). For the rest of FES respondents estimate a bit higher or the same value for services provided by mixed forests as compared to pure stands.

While scientists come up with a more uniform evaluation of mixed FES in a range of 4.0 for Energy to 4.6 for Mediation of flows, employees' evaluations vary in an interval from 3.4 for Energy to 4.5 for Maintenance of conditions. This difference should be examined in a further research because the applied questionnaire does not allow us to collect information about respondents' reflections on the question under consideration but as we see now, this option should be provided. Also it is not clear why employees did not distinguish such FES as Spiritual, symbolic and other interactions with biota, ecosystems, and landscapes, provided by mixed vs. pure forest stands (Fig. 4), while stressed their importance whereas scientists discerned these flows but did not evaluate their importance so high as employees did.

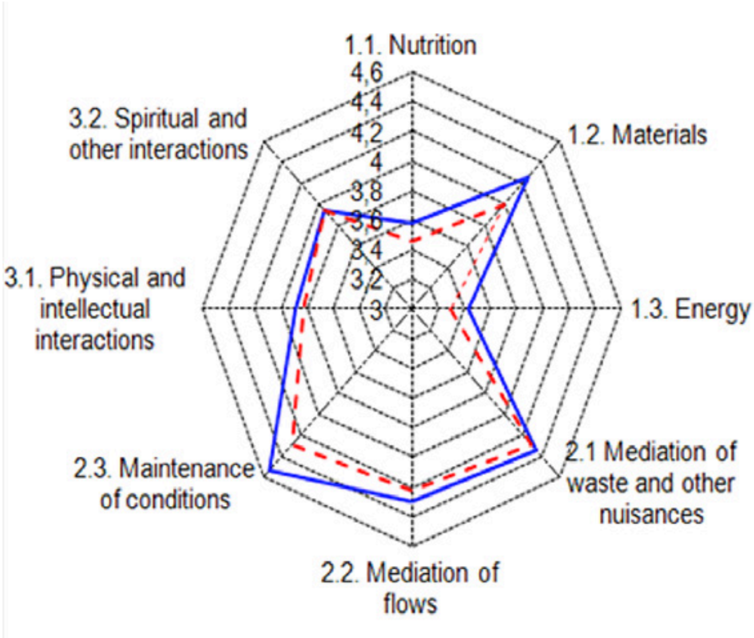

Figure 4: Comparative evaluation of forest ecosystem services provided by secondary spruce vs. mixed stands: Vision of forestry enterprises employees. CICES classification (2013) and 5-point Likert scale were used (the higher value is better).

Abbildung 4: Vergleichende Beurteilung der Wald-Ökosystemleistungen von sekundären Fichten- vs. Mischbeständen: Vision von Angestellten der Forstbetriebe. CICES-Klassifikation (2013) und 5-teilige-Likert-Skala wurden verwendet (höhere Werte sind besser).

We analysed the collected data using non-parametric statistics methods. With a probability of 99.9%, according to the Wilcoxon signed-rank test (Lowry, 2014), results of our survey demonstrate that both groups of respondents value FES of mixed stands a bit higher than FES, generated by pure secondary Norway spruce stands (Table 1). Therefore, this statistically significant difference should be considered in the economic assessment of benefits from conversion projects.

We can conclude that respondents, based on their knowledge and experience, express higher preferences to mixed forests comparing to pure secondary Norway spruce stands because they believe that FES flows, provided by mixed forests, are better and richer. Generated quantitative estimates of stakeholders' perceptions of FES should be integrated into forest decision-making aimed at sustainability. Obtained results will provide forest decision-makers and society with important information on the attractiveness and necessity of the conversion process. Hence forest conversion gains a support from stakeholders. In this context arises a question: "Do conversion projects pay?" To answer this question, we propose to apply the economic approach.

Table 1: Comparative stakeholders' evaluation of a quality of forest ecosystems services provided by mixed vs. pure forest stands. CICES classification (2013)

Tabelle 1: Vergleichende Bewertung der von den Rein- und Mischbeständen zur Verfügung gestellten Ökosystemleistungen durch die Interessengruppen. CICES –Klassifikation (2013)

Stakeholders	Number of comparisons (out of 48 services listed in CICES v. 4.3)		
	Ecosystem services, provided by mixed forest, are better	No difference in quality of ecosystem flows, generated by both forest stands	Z-ratio for the Wilcoxon signed-rank test
Scientists	31	17	4.856
Employees of forest enterprises	20	28	3.911

Critical value $z_{0.001;\ \text{two-tailed}} = 3.291$.

3.3. Evaluation of benefits from the conversion process using the economic approach

Identification of changes in social welfare and their further valuation (Fig. 1, step 3) is a crucial stage of CBA. It is especially complicated for forestry projects because a significant part of the benefits are public goods, that means that they are vital for human well-being but there are no markets for them and consequently no incentives to supply them.

To identify benefits of a conversion project we applied the ecosystem service framework and CICES classification that allow us to reveal benefits in a systemic and comprehensive way, to avoid ambiguity in identification and double counting in valuation. Analysis of existing literature on Norway spruce conversion projects, their options and consequences (Stoyko, 1998; Klimo et al., 2000; Spiecker et al., 2004; Seidl et al., 2008; Parpan et al., 2014) and stakeholders' preferences stated in abovementioned survey let us identify relevant ecosystem services to be considered in CBA of a conversion project.

To capture existing dichotomies among beneficiaries and in valuation approaches we present these benefits as matrix of a conversion project's impacts (Table 2) and position them by two axes: one axis is valuation approaches (whether or not (non-distorted) market prices exist). The other axis refers to beneficiaries (winners of a project). Dixon et al. (1997) propose to identify such relations discovering location and valuation dichotomies but this is not correct in the case of conversion projects. For instance, nonwood forest products (NWFP) appear on-site but in Ukrainian socio-economic and institutional context an investor does not care about making profit by selling them. Income from the sale of permissions for NWFP harvesting goes directly to local authorities.

Quadrant 1 of Table 2 includes conversion project outputs that the investor can sell on a market. In Quadrant 2 we present market-priced outputs that society gains from the project. The benefits in the last two quadrants are usually ignored in CBA because there are no markets for them. Quadrant 3 includes social value of business, image of the investor and other benefits that arise due to a successful run of a secondary Norway spruce conversion. Quadrant 4 contains benefits that do not have a market price, but have influence on society welfare.

Among all CICES-divisions only one division was not mentioned in the impact matrix, namely Spiritual, symbolic and other interactions with biota, ecosystems, and landscapes (Cultural section). This feature should be examined deeply because Employees stressed an importance of this division (Fig. 4), but were indifferent to type of forest whereas symbolic, sacred and/or religious, bequest and existence outputs could be strongly linked to stands with natural origin.

The proposed matrix could serve as a checklist for an appraiser and be further developed to value the benefits. Valuation techniques, such as revealed preference approaches for market outputs and stated preference approaches for nonmarket ones, developed and vetted by environmental economists during several decades of research, should be carefully used taking into account such criteria as geography, social-economic context and the applicability of certain techniques. However, the fundamental difference between values and prices, as well as between values and costs, should be articulated carefully, with a reliable evidence of relevance and correctness, keeping in mind the limited scope of CBA and relevance of financial indicators in general when it comes to multidimensional human well-being.

*Table 2: Matrix of conversion project impacts**

Tabelle 2: Matrix der Auswirkungen von Waldumwandlungsprojekten

		Beneficiary	
		Investor	**Society**
Valuation of Benefits	**Marketed**	**1** Project outcomes: - Revenue from sale of the increased timber volume *Provisioning / Materials / Biomass* - Additional revenue from sale of firewood *Provisioning / Energy / Biomass-based energy sources* - Decreased financial risks due to forest species diversification	**2** Marketed social benefits of the conversion projects that local communities obtain: - Changes in productivity of non-wood forest products *Provisioning / Nutrition / Biomass* - Taxes on revenues from sale of timber and firewood which go to local budgets (in case of clear cuttings these taxes go to the state budget) - Increased productivity of cultivated crops on sites which border sites under conversion *Provisioning / Nutrition / Biomass* - Increased supply of water for drinking *Provisioning / Nutrition / Water*
	Non-marketed	**3** Non marketed benefits of a conversion project that investor obtain: - Know-how gained by project performers - Social value of business - Image and reputation of investor - Other non-marketed benefits, that an investor gains due to successful implementation of a conversion project	**4** Non marketed benefits of a conversion project that stakeholders obtain: - Better quality of the environment *Regulation & Maintenance (R&M) / Mediation of waste, toxics and other nuisances* - Flood and storm protection *R&M / Mediation of flows / Liquid and Air flows* - Improved habitats for biodiversity *R&M / Maintenance of Conditions (M&C) / Lifecycle maintenance* - Benefits from avoided costs for biological protection of drying sites from pests *R&M / M&C / Pest and disease control* - Benefits from prevention of soil erosion *R&M / M&C / Soil formation & composition* - Benefits from climate regulation by reduction of greenhouse gas concentrations *R&M / M&C / Atmospheric composition and climate regulation* - Higher recreational / aesthetic value of forests *Cultural / Physical and intellectual interactions / Representative & intellectual interactions* - Enhanced biodiversity - Benefits from nonmarketed changes of human and natural capital derived due to a conversion project implementation

* CICES (2013) classification of ecosystem services is applied. CICES v. 4.3 categories are listed in italic.

4. Discussion and Conclusion

Such close attention to benefits of the conversion projects is explained by a high importance, uncertainty and some disadvantages, related to this activity, that are well presented in the scientific literature. From the economic point of view, we should mention first of all a higher cost of thinning and harvesting of non-mature trees (less than financial optimum maturity), as well as a significant decrease in increment and standing volume across the conversion period (Hanewinkel and Pretzsch, 2000; Roessiger et al., 2013). Higher profitability of even-aged pure spruce stands, well established markets for coniferous sawnwood and simple forest operations ensure preference of monoculture spruce sites for investments. Additional losses could come from a timber market: trees in uneven-aged stands have a longer crown compared to even-aged ones that means a worse quality of timber.

From a silvicultural perspective, conversion projects are exposed to a higher risk because of strong dependence on the success of a reforestation: in case of a lack of seed trees / years a necessity of planting could arise, that considerably increases the direct cost of reforestation. Besides, an intensive gradual cutting could pose a high risk, especially for mature even-aged stands during a time span after the cutting.

All these difficulties multiplied by an uncertainty of climate change require stronger competence, knowledge and relevant skills from forest policy-makers, scientists and forest managers. Further research and evaluations across a social-ecological gradient are needed. Forest managers should be trained to be able to design conversion projects, taking into consideration global changes, a local context and features of each site (Krynytskyy and Chernyavskyy, 2014). Conversion projects necessitate environmentally sound technology and facility for forest operations that is particularly acute for Ukrainian forestry enterprises.

To tackle these complications and obstacles relevant institutional changes are needed. First of all, it should be a holistic and long-term vision of forest management goals and tasks as well as criteria and indicators of successful activity aimed at the long-term wealth-creation partnership of forest agencies, scientific communities, business and civil society. Institutional regulations are essential to initiate and support an activity with numerous positive outcomes, that now are not considered by market transactions. Implementation of the conversion projects can induce a multiplier effect in the whole forestry cluster: development of new technologies, manufacture of equipment for a target harvesting and for beech wood processing, research programmes as well as tourism development that brings a lot of benefits to local stakeholders.

Deeper insight into the multidimensional nexus of Norway spruce monoculture conversion provides a comprehensive background for adaptive ecosystem-based forest management. To bring this perspective into a long-term forest decision-making context the whole complexity of such transformations should be holistically understood and well-presented for the stakeholders to gain their co-learning and collaboration with future generations in mind. We believe that approaches, considered in this paper, are helpful in the evaluation of efficiency of a conversion activity but none of them is universal. They complement each other and are needed to validate results and to overcome the dominance of commercial criteria in the evaluation of forest-related decision-making when implicit values and public goods are a matter of concern. These approaches can create a backbone of the framework to be applied across different policy, economic and cultural landscapes and contribute to development of a transdisciplinary, holistic and universal framework for the evaluation of conversion of even-aged secondary Norway spruce stands. It is expected that this integrated approach will contribute to the development of an evaluation framework and merits further attention of scientists, policy makers and businessmen.

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