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Article

A Framework for Profitability-Focused Land Use Transitions between Agriculture and Forestry

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Abstract

Understanding when and where to shift land from agriculture to forestry is essential for developing sustainable land-use strategies that balance climate, biodiversity, and rural development goals. Traditional profitability comparisons rely on long-term discounting, which is sensitive to assumptions and misaligned with the decision-making horizons of landowners and policymakers. This study introduces a deposit-based framework that treats annual timber biomass growth as accumulating economic value, enabling direct comparison with yearly agricultural profits on a per-hectare basis. By integrating parcel-level spatial data, land quality indicators, national statistics, and expert input, the framework generates high-resolution maps of annual profitability for both land uses. Applied in Latvia, the analysis reveals significant regional variation in agricultural returns, with many low-quality areas showing marginal or negative profits, while forestry offers stable, modest gains across diverse biophysical conditions. The results highlight where afforestation becomes a financially rational alternative and suggest transition pathways that enhance overall land-use profitability while supporting climate and biodiversity objectives. The framework is transferable to other contexts by substituting context-specific data on land quality, prices and growth, and can complement policy instruments such as performance-based CAP payments and afforestation support. The approach supports future-oriented differentiated land-use planning using annually updated spatial economic signals.

Keywords: afforestation; land use profitability; parcel-level assessment; sustainable land management; land quality; crop groups; regional differentiation

1. Introduction

Land is a limited resource that must serve multiple, often competing demands, including food production, timber supply, biodiversity conservation, and climate change mitigation. In recent decades, global population growth and rising incomes have increased demand for food, particularly animal-based products [1]. This trend has contributed to the large-scale conversion of forests into agricultural land [2,3], while urban expansion has further intensified pressure on natural land resources [4]. Even well-intentioned policies to reduce agricultural intensity can lead to unintended environmental impacts, such as indirect land use change and deforestation elsewhere [5].

In response, afforestation is gaining political momentum as a key element of climate and biodiversity strategies. The European Union (EU) has committed to ambitious afforestation targets in support of its climate neutrality and biodiversity restoration goals [6,7,8]. Countries such as Ireland and Spain have introduced national afforestation plans to expand forest cover, increase carbon

sequestration, and improve ecosystem services [9,10]. Similar initiatives are also underway in Brazil and India [11,12].

Despite these efforts, afforestation policies are often met with hesitation from landowners, particularly in the agricultural sector. Concerns include the risk of higher land prices and food insecurity [19], potential restrictions on converting land back to farming [6], the long time periods before financial returns are received, and changes in soil properties that may reduce agricultural productivity [14,15,16].

Nevertheless, some researchers, such as Rämö et al. (2023), argue that transforming not only unused but also low-yield agricultural land into forests is essential for meeting ambitious climate targets [17]. Similarly, West et al. (2020) found that afforesting low-productivity grasslands can also be financially beneficial [18]. These findings support the broader view that land with limited agricultural potential, due to poor soil quality, low fertility, or other biophysical constraints, offers greater opportunity for land use change without significantly affecting food production.

At the same time, several experts suggest that innovations in agriculture, particularly precision farming, may help optimise land use efficiency [19,20,21]. By ensuring that high-yield crops are cultivated on the most suitable land, marginal or less productive areas could be freed up for afforestation [22]. Financial incentives and support for sustainable farming practices, combined with education and awareness programmes, can further encourage farmers to adopt such integrated approaches [23,24].

Financial considerations are central to land use decisions, especially where land is treated as an economic asset. Landowners generally seek to maximise returns, making the relative profitability of agriculture and forestry a key factor in decisions about land use change [25]. Yet, comparing the two systems is methodologically difficult. Agriculture typically generates annual profits, whereas forestry provides returns only a few times over a rotation cycle that may span several decades. Discounting methods are commonly used to make these comparisons [26,27,28], but they depend heavily on long-term assumptions about future prices, costs, and interest rates. Even small changes in these assumptions can significantly affect the outcome, potentially reversing the conclusion from afforestation being more profitable than agriculture to the opposite.

In this study, we present a parcel-level framework for comparing the annual profitability of agricultural and forestry land uses. This approach is designed to reduce reliance on long-term discounting methods, which can be difficult to interpret and highly sensitive to assumptions. Instead, we treat the annual growth of timber biomass as an accumulating economic value, enabling a more transparent and consistent comparison with agricultural profits. The framework integrates spatial data, land quality assessments, official statistics, and expert knowledge to calculate land profitability at a high resolution. We apply the method to a case study from Latvia, where afforestation is increasingly relevant in light of climate policy targets and structural challenges in agriculture. This framework supports regionally differentiated land use strategies by identifying where afforestation presents a financially viable alternative to agriculture. By enabling transparent, spatially explicit assessments of profitability, it contributes to the design of adaptive and multi-objective land management policies that align with economic viability, climate mitigation, biodiversity conservation, and rural development.

2. Materials and Methods

2.1. Case Region

The case region for this study is Latvia, a Northern European country located in the temperate cool moist climate zone. Approximately 50% of Latvia's territory is forested, while about one-third is designated as agricultural land. Latvia is sparsely populated, with a population density of 30 persons per square kilometre as a country average, and 10 persons per square kilometre for rural areas [29].

Agricultural land in Latvia is almost entirely privately owned and managed by individual farmers or enterprises. As of the end of 2023, Latvia had 62 thousand agricultural holdings, with large

holdings managing half of the total agricultural land. In contrast, 46% of forest land is owned and managed by the state, while the remaining 54% is under the ownership of private individuals, municipalities, or other entities.

The agricultural sector in Latvia is primarily oriented towards cereal and milk production, positioning the country as a net exporter of these commodities. In total, the agricultural area covers approximately 1.97 million hectares, of which 1.36 million hectares is arable land. The average land area per agricultural holding is 45 hectares, with 31 hectares being agricultural land. Despite strong performance in certain sectors, domestic production of vegetables, fruits, and berries remains insufficient to meet national consumption needs. In 2023, the total agricultural output at current prices amounted to 1.85 billion euros [29]. As a member of the European Union, Latvia operates under the Common Agricultural Policy (CAP), benefiting from financial support mechanisms similar to those available in other EU member states.

In Latvia, forests are a significant national resource, both economically and ecologically. Forest stands are predominantly composed of pine (25.6%), birch (27.2%), and spruce (19.6%), together accounting for 72.4% of the total forest area. Other notable species include grey alder (10.1%), aspen (8.2%), black alder (6.3%), ash and oak (1.0%), and a variety of other species (2.1%). In 2022, a total of 13.1 million cubic meters of wood were harvested in Latvia, with 6.4 million cubic meters sourced from state forests and 6.7 million cubic meters from forests owned by private entities. Forest restoration efforts covered an area of 41 thousand hectares [30].

2.2. Methodology Description

The methodology is structured as a comprehensive framework for calculating and comparing the annual profitability of agricultural and forest land uses at the parcel level. All calculations are conducted on a per-hectare basis to ensure consistency and comparability across land-use types and regions. The analysis integrates spatial data with economic and biophysical indicators relevant to each sector.

For agriculture, average annual profitability (XA) is calculated for different crop groups and livestock specialisations using farm accountancy data, complemented by expert evaluations and calibrated against official statistics.

For forestry, a deposit-based approach is applied: potential profit (XF) associated with the average annual accumulation of timber biomass in forests eligible for harvesting is treated as a financial deposit. This value is calculated based on the net income potential of standing volume growth, incorporating current prices and species-specific yield assumptions. Total timber accumulation, accumulation of harvestable timber and financial parameters are calibrated against official statistics.

The methodology begins with the development of equations required to calculate annual profitability for both agricultural and forest land uses. These equations incorporate key variables such as yields, prices, production costs, and land characteristics. Once the equations are established, relevant input data are collected and processed, including spatial land parcel data, statistical records, and species-specific growth parameters. Parameter values are derived from national statistics, official registers, published research, and expert assessments. A schematic representation of the full methodology is provided in Figure 1, and each methodological component is explained in detail in the following subsections.

Detailed descriptive statistics on the Latvian agricultural and forestry sectors, as well as extended tables of parameter values, are provided in the Appendices. The main text reports only the information necessary to apply and interpret the framework, while all supporting details remain available for replication and adaptation in other regions.

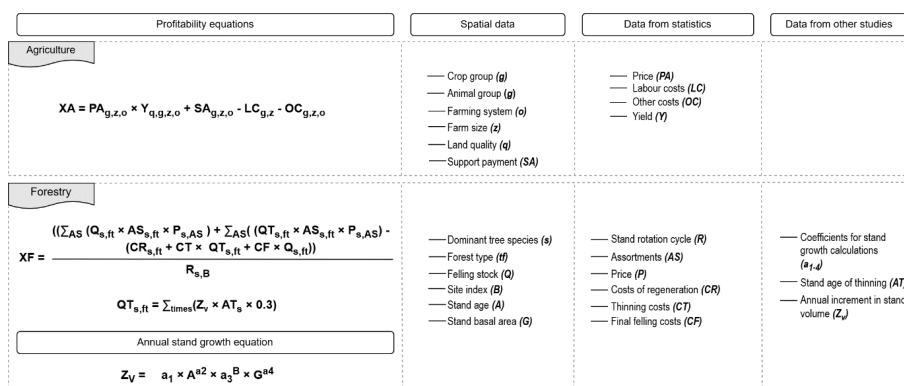


Figure 1. Schematic representation of key steps.

2.2.1. Profitability in Agriculture

In this study, agricultural land profitability is defined as the net profit before taxes per hectare of land or per grazing animal. Profitability is calculated for the major crop groups (cereals; rapeseeds; pulses; potatoes; vegetables, strawberries, flowers; perennial crops; other crops (e.g. nectar plants, herbs, flaxseed, lavender, chamomile, caraway); fallow land; grassland in arable land; meadows and pastures) and major grazing animal groups (dairy cows; suckler cows; sheep). The poultry and pig sectors are excluded from the analysis as these animals are typically not directly linked to nearby land use.

To calculate agricultural profitability (*XA*), data from the Latvian Farm Accountancy Data Network (FADN) [31], Latvian Rural Advisory and Training Centre (LLKC) Gross Margin data [32], and expert evaluations are used. Anonymised FADN data at the individual farm level was used. The calculations are based on data from 2019, 2020, and 2021. The years 2022, 2023, and 2024 are excluded from the analysis due to atypically high profitability in major agricultural sub-sectors. Farms are classified into four groups based on the size of the managed area, as summarised in Annex A1, taking into account differences in productivity, costs, and revenues associated with farm size.

Prices (*PA*) for agricultural products were obtained from national statistics on the purchase prices of agricultural products for the period 2019 to 2021 [33]. Yields are calculated for each crop and farm size group from national statistics, with annual yields varying by crop type and farm size group [32,34]. In certain cases, yields are also influenced by land quality and the farming system employed (conventional or organic). Calculated profitability parameters per farm size and farming system are detailed in Annex A2.

In this study, land quality is indexed from 5 to 85 points, with a weighted average of 36 points. Although the methodology for land quality indexing was developed over 40 years ago, it is based on a detailed and comprehensive evaluation framework that remains relevant for comparative analysis today. The index was originally designed to estimate the potential rye yield in kilograms per hectare, with one land quality point corresponding to 70 kilograms of rye per hectare [35]. Particular emphasis in the assessment methodology was given to soil related characteristics, including soil type, granulometric composition, and agrochemical properties. These were considered alongside a broader set of biophysical and site-specific variables, such as natural environmental conditions, moisture regime, drainage infrastructure, topography, parcel size and configuration, stoniness, microdepression occurrence, and the degree of land cultivation. Historical parcel level land quality data, based on this methodology, cover a significant portion of agricultural land in Latvia [36], enabling spatially detailed assessments despite the historical origin of index. For parcels lacking historical data, land quality is estimated using the average of the nearest neighbouring parcels. While the index corresponds with rye yields, its linear structure allows it to remain useful for other crops as well, when combined with appropriate correction coefficients. These coefficients are calculated by dividing the average annual productivity of crop groups (cereals, rapeseeds, and pulses) from statistical data by the average land quality points and are refined or adjusted as necessary [37]. It is important to note that land quality is not a determining factor in all agricultural sectors. In this study,

it is considered only in cases where its influence is clearly observable, most notably in crop production.

Almost every market-oriented farmer in Latvia submits spatial information about all fields and crops used for production to the Rural Support Service in order to apply for support payments. Using this data (prepared by the Rural Support Service upon request) and overlaying it with the land quality index data layer, it is possible to calculate the indicative profitability of each field using the formula in Figure 1.

Additionally, all animal holdings are registered with the Agricultural Data Center, which provides information on the number of animals. By using this data along with the location coordinates of the holdings (prepared by the Agricultural Data Center upon request), it is possible to calculate the indicative profitability of each grazing animal holding.

Although the FADN dataset offers detailed information for approximately one thousand individual farms, there are notable limitations that complicate the accurate assessment of profitability indicators. A key issue is that many farm operators do not allocate themselves a formal wage. Instead, the value of their labour is covered by the remaining profit after expenses, which is often done to reduce taxable income. This practice can lead to an overstatement of reported profits, particularly on smaller farms with minimal or no hired labour. As a result, land use profitability may appear higher than it actually is, since the cost of the farmer's own labour is not included. Additionally, the majority of farms in the dataset use mixed production systems, involving several outputs such as different crops or types of livestock. However, cost data are usually reported for the entire farm as a whole, without breaking them down by specific activity. This lack of detail makes it difficult to assess how profitable each type of production really is.

To address the first challenge, labour costs are adjusted by recalculating them using labour salary data from national statistics [38], rather than relying solely on bookkeeping records. This recalculation involves multiplying the sum of paid and unpaid labour inputs [39] by the agricultural labour salary. Since larger and technologically advanced farms typically employ more qualified labour, salary rates are adjusted based on farm size. In many instances, particularly for smaller farms, this recalculation of labour costs results in increased expenses and consequently reduces the profits indicated in the FADN data.

To address the second challenge, calculations are performed by selecting individual FADN farms with potentially narrow specialisations. However, notable differences in results between farms often persist. Therefore, corrections are made using LLKC Gross margin calculations. These calculations provide standard incomes and costs for different crop groups (cereals, rapeseeds, and pulses, potatoes, vegetables, strawberries, flowers, perennial crops, other crops, fallow land, grasslands in arable land, meadows and pastures), animals (dairy cows, suckler cows, sheep), farming systems (conventional and organic), and farm sizes (large, medium, small, micro).

The category of **other costs** encompasses various farm expenses that are essential for agricultural production and farm maintenance, such as fertilisers and plant protection products, animal feed, fuel, machinery and equipment maintenance, and services and equipment rental. One significant component of this category is **depreciation**, which increases with the capital intensity of a farm. Higher capital investment in machinery, equipment, and infrastructure leads to greater depreciation expenses. This trend reflects the economic burden associated with maintaining and replacing capital assets over time [31].

The results of our calculations are cross-validated against statistical data from the Eurostat [40]. This ensures that our aggregated parcel-level estimates are consistent with national statistics.

2.2.2. Profitability in Forestry

Unlike agriculture, profit in forestry is typically generated only 2 to 3 times during a stand rotation cycle, which ranges from 30 to 100 years depending on the dominant tree species. This results in a situation where yearly profits in forestry are largely negative or close to zero, but significantly

high during felling years. Consequently, direct comparisons of forestry profitability with agricultural production, which generates profit annually, are challenging.

To calculate forestry investment profitability, discounting methods are commonly used [41]. However, this approach relies on long-term assumptions about prices, inflation, and interest rates. Even minor changes, for instance, in interest rate assumptions over a 70-year period can substantially impact discounted values, making projection results highly sensitive to long-term assumptions. This results in a wide range of scenarios with significant differences between minimum and maximum outcomes [42]. Moreover, if forestry profitability results are to be compared with agricultural profitability, agricultural profits must also be calculated and discounted over the same long-term period, facing similar challenges of assumptions over an extended timeframe.

To address these challenges, in this study, forestry is instead conceptualised as an economic deposit, where annual increments in standing timber volume are treated as additions to a latent profit balance that materialises when the land or standing stock is sold. This perspective reframes forestry as generating an implicit yearly income stream, comparable in temporal resolution to agricultural profits, while avoiding long-term discounting of uncertain future flows.

For each forest stand, the annual deposited profit XF (EUR per hectare per year) is defined as the product of species- and site-specific net income per hectare of forest stand (EUR per hectare per year) and the annual increment in standing volume Zv (m^3 per hectare per year). Net income per hectare of forest stand is obtained as the difference between expected revenues from assortments (EUR per m^3) and the full set of logging and regeneration costs at current prices. The cumulative deposit (EUR per hectare) at time is then the sum of annual deposited profits since stand establishment, representing the unrealised yet quantifiable economic value stored in the standing stock.

Due to the structure of the available data, we have initially calculated the cumulative deposit (EUR per hectare) of each dominant tree species and forest type at the end of the rotation cycle. Then, by dividing the cumulative deposit into years corresponding to the length of the rotation cycle of each dominant tree species, we have calculated the annual deposited profit (EUR per hectare per year). The length of the rotation cycle for different dominant species is determined in Section 9 of the Law on Forests of the Republic of Latvia [43].

The expected revenues from assortments have been calculated based on the assumption that the proportion of assortments depends on the dominant species and the forest type [44]. The proportion of assortments is multiplied by the price for the respective assortment and the felling stock at the end of rotation cycle, obtaining revenues of final felling (EUR per ha). Revenues of thinning have been calculated by multiplying the proportion of assortments with the price for respective assortments and the thinning stock. The price of assortments depends on the dominant tree species, and the assortment type [45]. The thinning stock has been calculated by multiplying the annual increment in standing volume with the times and age of thinning (3 times at age 30, 46 and 60 for conifers and 2 times at age 20 and 40 for deciduous trees, for grey alder and aspen – 1 thinning at age 20) and the coefficient 0.3 (assuming that 30% of the total stock is removed with thinning (for spruce the coefficient is 0.2)) [46]. Data for assortment proportion and prices used in the calculations can be found in the Annex A3.

The regeneration costs consist of the forestry measures after the final felling: soil preparation, purchase of planting material, planting, forest protection, agrotechnical maintenance, felling for maintenance of the composition and underbrush tending. The costs associated with soil preparation, planting material, planting, agro-technical practices, and young forest stand maintenance are derived from statistical data on forest regeneration and maintenance expenses for 2024 [47]. The costs of young stand protection include labour compensation for this activity, set at 100 euro in 2024 [48], and 36 euro for repellents [49]. Supplementation costs consist of seedling and planting expenses, adjusted by coefficients of 0.3 (assuming that, on average, 30% of the stand requires supplementation) and 0.5 (assuming that labour costs are by 50% lower). Underwood clearing costs are estimated based on industry practitioners' evaluations [50]. The annual maintenance cost of land amelioration systems is

estimated at EUR 23 per hectare, based on expert assessment. It is assumed that these systems require maintenance every five years. Accordingly, the total maintenance cost over a given rotation cycle is calculated as EUR 23 multiplied by the ratio of the rotation cycle (in years) to five. This provides a simplified estimate of cumulative maintenance expenditure per hectare over the rotation cycle. The regeneration costs used in this study can be found in Annex A4.

The logging costs of rotation cycle consist of the expenses arising from the preparation and transportation of the assortments in thinning and final felling. The logging costs per unit of harvested wood (EUR per m³) are derived from statistical data on average expenses of forest exploitation for 2024 [51]. The costs of thinning (EUR per hectare) have been calculated by multiplying the costs of thinning per unit of harvested wood (EUR per m³) with the thinning stock per hectare (m³ per hectare) for each dominant tree species. The costs of logging (EUR per hectare) have been calculated by multiplying the costs of logging per unit of harvested wood (EUR per m³) with the total felling stock (m³ per hectare) at the end of rotation cycle for each dominant tree species. Logging costs are attached in the Annex A5.

Calculations for the annual increment in stand volume per hectare are based on equations that incorporate data about the main dominant species, site index, stand basal area, and age of the stand. Parcel level data for the dominant species, site index, stand basal area, and age of the stand are from State Register of Forests [52]. The coefficients used in the calculation of the stand growth are specified in Annex A6. Furthermore, to avoid extreme values, the calculated stand growth is aligned with the maximum standing volume per hectare from Donis (2019) which depends on the dominant species and the site index [53] (Annex A7).

To ensure the accuracy and reliability of our findings, our calculations are validated against statistical data from the Eurostat [40]. Similarly to agriculture, this ensures that our aggregated parcel-level estimates align with statistical aggregates.

2.3. Mapping at Parcel Level

In this study, profitability calculations were conducted at the individual field level to account for the specific characteristics and management practices of each parcel. However, for spatial visualisation and data privacy purposes, the field-level results were aggregated into a uniform grid with cells of 100 hectares each. By standardising the data into regular 100-hectare grid cells, we enabled a more consistent and comparable spatial representation of profitability across the case region, while preserving high spatial resolution. This method aligns with established practices in spatial land use analysis, where various aggregation techniques, such as the use of regular square grids, are used to harmonise heterogeneous data and support cross-regional comparisons [54]. Additionally, grid-based aggregation simplifies complex field geometries, improving the clarity and usability of spatial data for analysis and interpretation.

2.4. Technical Implementation

Profitability modelling and spatial data processing were performed in R version 4.4.1. Initial data preparation and spatial operations were implemented in R through the RStudio interface, using `dplyr` for data processing and `sf` for the management and transformation of spatial objects. The `tidyverse` and `janitor` packages were employed to streamline data manipulation, cleaning, and the standardisation of tabular datasets, ensuring consistent and analysis-ready inputs. Map creation, visualisation, and exploratory spatial analysis were carried out using the `tmap`, `tmaptools`, and `leaflet` packages, which enabled the production of both static and interactive cartographic outputs suitable for detailed spatial interpretation.

During the preparation of this work the author used ChatGPT-4 by OpenAI in order to enhance the phrasing of certain sentences and to correct potential grammatical errors, as none of the authors are native English speakers. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

3. Results

3.1. Per-Hectare Profitability Patterns for Agricultural and Forest Land

Profitability in agricultural land use varies considerably across different crop groups and land quality points. As shown in Figure 2, profitability is strongly influenced by land quality: land with a quality score above 45 is classified as high-quality agricultural land. In such areas, local municipalities often impose restrictions on land use changes to preserve the productive potential of land.

Cereals and pulses show consistently positive profitability across all land quality classes, reflecting their relatively low input requirements and stable market demand. In contrast, the profitability of vegetables, potatoes, and perennial plantations tends to decline sharply on lower quality land. In many cases, particularly in marginal areas, these crops show negative returns, despite having positive average profitability values overall. These crop groups are more input and labour intensive, making them less economically viable on soils of lower quality.

Meadows and pastures generally show lower profitability compared to cultivated crops. This reflects their primary function in supporting the livestock sector through feed provision, sustainable grazing, and ecosystem services, rather than generating direct market revenue. As illustrated in Figure 2, the profitability of meadows and pastures is several times lower than that of cereals, rapeseeds, and pulses. However, when these grasslands are used as feed sources within livestock sector, they contribute significantly to overall farm profitability.

Other crop groups may yield high returns depending on the interaction between crop-specific characteristics and land quality. Notably, high profitability tends to occur where favourable yield and price conditions align with relatively low input requirements and depreciation costs.



Figure 2. Average profitability in agricultural land use (EUR/ha).

While land quality is a key determinant of agricultural profitability, farm size is also a critical factor influencing economic outcomes. As the Figure 3 show, larger farms tend to achieve higher profitability, benefiting from economies of scale, more efficient use of inputs, and better access to modern technologies and markets. In contrast, smaller farms, particularly micro farms, often face structural disadvantages that limit profitability. This is especially evident in capital- and labour-intensive sectors such as vegetable, potato, and perennial plantations production. For instance, micro farms operating in perennial plantations show average losses exceeding 2 500 EUR/ha. These losses would be even more pronounced without income support, highlighting the structural dependence of small and micro farms on subsidy payments to maintain continued production.

Grassland systems used for dairy production also show negative profitability for smaller farms, while meadows and pastures used for suckler cow systems tend to be modestly profitable. Cereals, rapeseeds, and pulses maintain stable positive returns across all farm sizes, likely due to lower input intensity and higher compatibility with mechanised farming. The other crops category also shows high profitability, particularly for larger farms, possibly reflecting specialisation in high value or niche production, such as like mustard, flaxseed, nectar plants, and herbs (e.g. lavender, chamomile, and caraway).

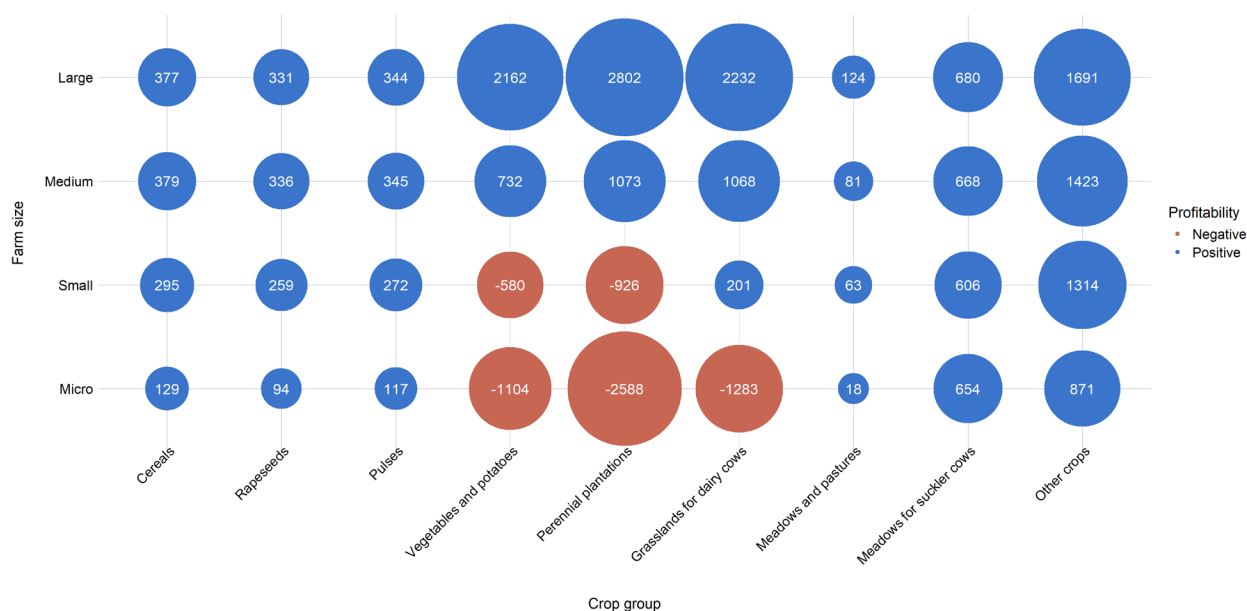


Figure 3. Average profitability in agriculture across different crop groups and farm size categories (EUR/ha).

Yearly profitability in forest land use ranges from 4 to 266 EUR per hectare, depending on the dominant tree species and forest growth conditions. While revenue primarily depends on the main tree species, costs vary based on forest growth conditions. Coniferous species, such as pine and spruce, are highly profitable across all forest growth conditions due to their high assortment prices and the larger proportion of high value assortments, particularly saw logs.

Although birch saw logs are not produced in Latvia, a significant share of birch is sold as veneer logs, which represent the most valuable tree assortment. This makes birch one of the most profitable tree species. In contrast, the profitability of deciduous species such as black alder, grey alder, and aspen is lower, as these trees mainly yield packing case timber, pulpwood, and firewood, lower-quality assortments that fetch lower prices.

Other tree species, including oak, ash, and linden, exhibit the highest profitability due to their superior assortment quality, high market prices, and relative rarity in Latvia. When comparing profitability across different forest growth conditions, the highest returns are achieved on dry mineral soils, while the lowest are observed on wet organic soils. This is because, despite higher forestry costs, dry soils tend to produce significantly higher yields per hectare (Figure 4).

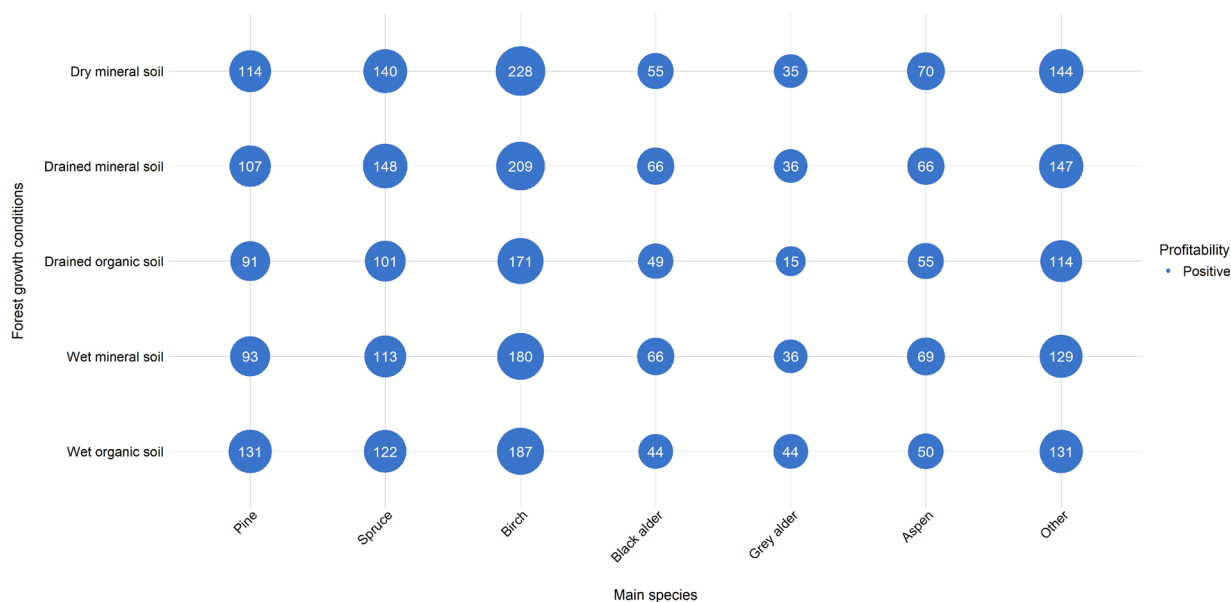


Figure 4. Average profitability in forest land use (EUR/ha).

3.2. Mapping Agricultural and Forest Land Profitability

Figure 5 illustrates substantial spatial variation in agricultural profitability across Latvia. The highest profitability levels (in dark blue) are concentrated in limited areas, primarily in the southern part of the country. However, these high-profit zones are relatively sparse. The majority of agricultural land falls within the moderate profitability range (in medium blue), with widespread distribution across central, western, and parts of eastern Latvia. Areas with low profitability (in light blue) or financial losses (in red) are more prevalent in the eastern, southeastern, and some north-central regions.

This spatial distribution reflects the influence of both natural and structural factors. Soils with lower fertility, smaller and fragmented land parcels, and limited market access contribute to the lower profitability observed in certain regions. In contrast, areas with better soil conditions, more consolidated farms, and improved infrastructure tend to perform better economically.

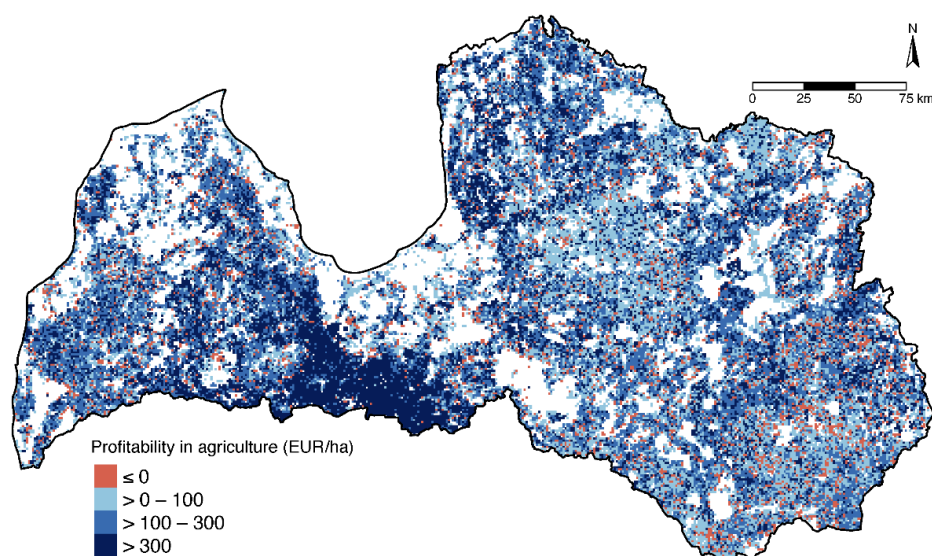


Figure 5. Spatial distribution of agricultural profitability in Latvia (EUR/ha).

In contrast, forestry profitability (Figure 6) shows a more spatially consistent distribution, with the majority of grid cells falling within the low to moderate profitability range (in light and medium blue). High-profit areas (in dark blue) are relatively limited and scattered, while zones with negative returns (in red) are rare and highly localised. This overall pattern indicates that forestry offers relatively stable, though modest, economic returns across a wide range of biophysical conditions. As such, forestry may represent a more resilient land use option in areas where agricultural profitability is low or highly variable.

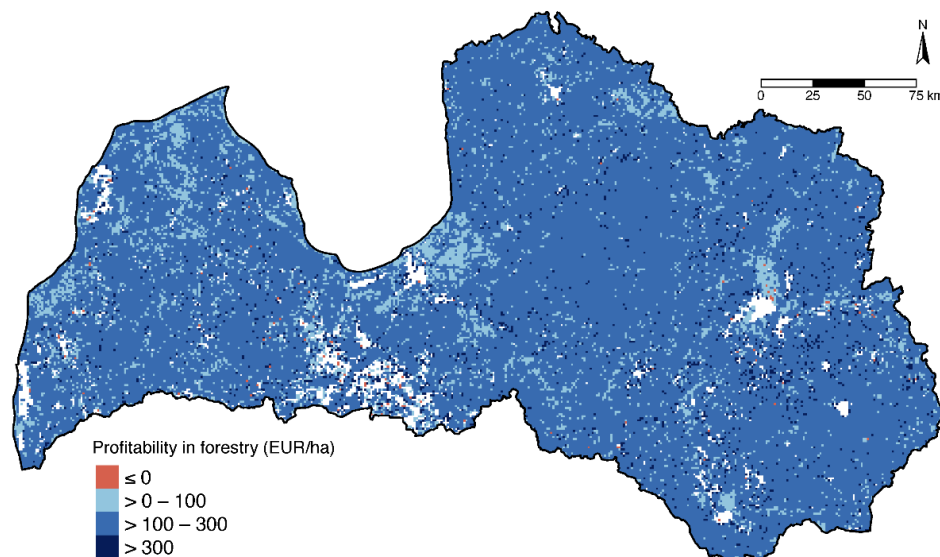


Figure 6. Spatial distribution of forestry profitability in Latvia (EUR/ha).

4. Discussion

4.1. Profitability Trade-Offs Between Agriculture And Forestry

The profitability analysis across agricultural and forest land use systems reveals that not all agricultural activities are economically viable, particularly on small and micro farms cultivating vegetables and potatoes, perennial crops or managing grasslands. In cases where agricultural land consistently operates at a loss, there is a growing rationale to consider alternative land-use production systems. One such option is afforestation, which, in certain conditions, offers not only competitive profitability but also additional ecosystem benefits. Targeted afforestation, particularly with species like spruce or birch, which have shown strong profitability on dry and drained mineral soils, and drained organic soils, may serve as a productive alternative, especially when aligned with climate, biodiversity, and rural development goals. This perspective does not advocate afforestation across all low-performing farmland, but it does support strategic integration of forestry into land use planning, where economic performance, soil characteristics, and farm structure indicate limited agricultural viability.

This aligns with findings by Lubowski, Plantinga, and Stavins (2006), who showed that land quality is a key determinant of the opportunity cost of afforestation and the potential supply of carbon sequestration from land use change [55]. Their analysis demonstrated that higher quality agricultural land is less likely to be converted to forest, as its productivity in crop production increases the economic trade-offs of afforestation. These findings highlight the importance of incorporating regional land use characteristics and local economic conditions into assessments of afforestation potential and policy design.

Returning to methodological challenges, Rämö et al. (2023) demonstrate that higher interest rates necessitate increased subsidies to make forestry as profitable as agriculture [17]. West et al. (2020) determined the net present value of forests over a 30-year rotation cycle by considering the anticipated felling volumes, prices, and management costs for various assortments [18]. They then

converted the net present value into equivalent annual payments using a discount rate of 8%. Consequently, discounting leads to a lower net present value of forestry at higher interest rates. In contrast, the forest profitability methodology we propose accounts for the specific year of calculation, price fluctuations, and biomass growth. This approach enables relatively precise annual calculations of the required support payments to achieve income equivalence with agriculture.

The deposit-based measure differs conceptually from standard net present value (NVP) in three ways: 1) it uses current prices and costs without projecting future trajectories; 2) it expresses forestry returns as an annual flow comparable to agricultural profit; and 3) it captures the option value of selling land or standing timber before the end of a full rotation [56]. In practice, this means that the ranking of land-use options may diverge from NPV-based assessments, especially under high interest rates or volatile price expectations.

4.2. Institutional Constraints and Policy Implications

Both agriculture and forestry provide benefits that extend beyond individual owners and managers, offering societal value by ensuring food production, raw materials, water and nutrient cycling, climate change mitigation, and the preservation of the rural environment. Our proposed approach can be complemented with evaluations of these additional benefits.

The previous Rural Development Program (2014-2020) of Latvia included support for the forest industry in restoring, preserving, and improving forest ecosystems. The measures were actively used for improving drainage systems in forests, afforestation, enhancing ecological value, and protecting Natura 2000 forest areas, thereby reducing costs, and generating additional income for owners [57]. However, these support measures are insufficient to motivate a significant number of landowners to afforest their land. Many small and micro farmers, as indicated by Nipers and Pilvere (2020), are often seniors and lack spare financial resources [58]. They rely on current cash flows and lack economic mobility, making it challenging for them to find the financial resources needed to invest in afforestation, even with the available support measures. Additionally, West et al. (2020) indicate that incentives for ecosystem services payments are restricted to the first forest rotation, and enrolment in afforestation programmes on various factors other than profitability [18].

While this study focuses primarily on profitability, which is a significant factor for landowners who view their land as a financial asset, it is important to acknowledge other factors, which may influence land use change decisions. Environmental benefits, such as carbon sequestration, biodiversity conservation, and water purification, which align with the aims of the EU Green Deal to achieve climate neutrality, the Paris Agreement's goal to limit global warming to well below 2 degrees Celsius, the EU Biodiversity Strategy's objective to protect and restore ecosystems, and the EU Water Framework Directive's aim to achieve good qualitative and quantitative status of all water bodies, play a crucial role in the broader assessment of land use options.

Switching from agricultural production to forestry will impact net GHG emissions reduction. For instance, in Lithuania, maintaining a stable land use change pattern, where small areas are deforested but large areas are afforested, reaching 32 thousand hectares annually, alongside increased conversion from cropland to grassland, could ensure compliance with the EU target for 2030 [59]. Thus, afforestation could have a beneficial impact at the national or regional level, helping to achieve climate ambitions. Additionally, converting part of agricultural land to forest can partially offset agricultural emissions, thereby reducing the farm's GHG footprint. However, it is crucial to recognise that afforestation alone will not suffice to achieve climate targets.

Afforestation of agricultural land can also significantly affect biodiversity and water quality. By transforming open agricultural fields into forested areas, habitat diversity increases, supporting a broader range of species and enhancing biodiversity [60,61]. However, this may not apply in forest-rich countries. Regarding water quality, afforestation can reduce soil erosion and surface runoff, common in agricultural landscapes [62]. Tree roots stabilise the soil, reducing sediment and agricultural chemicals entering water bodies, thereby improving water quality by decreasing levels of pollutants such as nitrates, phosphates, and pesticides [63].

Additionally, social impacts, such as rural development and community well-being, should be considered to provide a comprehensive assessment of land use options [64]. Transitioning from agricultural production to forestry affects social dynamics due to differing labour input intensities between these sectors [65,66]. Widespread afforestation may influence job opportunities, particularly in rural areas, potentially reducing employment in agriculture while creating new roles in forestry.

By integrating the aforementioned factors into the proposed methodology, policymakers can make more informed decisions that balance economic, environmental, and social objectives. This is particularly important in considering afforestation as a key strategy for achieving carbon neutrality by 2050. Consequently, it is essential to recognise that preserving all agricultural land at any cost is not always justifiable. Financially unsustainable production practices that fail to generate sufficient profit and rely heavily on social support mechanisms do not foster the continuation of farming by future generations and should therefore be reconsidered.

Over the past two to three decades, the structure of agriculture in the EU has changed significantly. Between 2005 and 2020, the number of farms in the EU declined by approximately 37%, representing a reduction of 5.3 million farms, of which around 87% were small farms under 5 hectares [67]. This structural shift raises important questions for policymakers regarding the justification of continued support for such farms, particularly as maintaining this segment of the agricultural sector requires substantial financial resources, primarily through the CAP. Allocating funds to financially unsustainable farms may reduce the availability of resources for other political objectives. From a long-term perspective, it is more appropriate to direct support towards farms that can continue operating while contributing to the sustainability goals of the EU Green Deal. To ensure the effective and efficient use of public funds, support should be linked to measurable outcomes.

Evidence from China's nature reserves, as shown by Cheng, Sims, and Yi (2023), demonstrates that conservation policies prioritising measurable environmental outcomes can deliver clear ecological benefits [68]. However, the study also highlights that the distribution of economic gains may be uneven and influenced by local development conditions. To ensure the effective and efficient use of public resources, support distribution should be based on measurable outcomes, such as environmental performance indicators. Within this context, the CAP plays a critical role by offering subsidies and incentives for sustainable land management practices that aim to balance ecological responsibility with economic viability [69]. By promoting a collaborative, results-oriented approach involving all relevant stakeholders, it is possible to advance ambitious climate goals while maintaining food security and protecting the livelihoods of farmers [70].

4.3. Transferability and Generalisation of the Framework

This study applies the land-use profitability framework to Latvia, but the underlying logic is designed to be transferable to other regions and policy contexts. The framework has three core components: 1) a consistent methodology for calculation annual agricultural profit and forestry deposit flows at the parcel level; 2) integration of spatial, biophysical and economic data to derive these indicators; and 3) spatial mapping of profitability patterns to support informed evaluation of where afforestation could be considered as a viable economic alternative to agriculture. Only the empirical parameterisation of these components is country-specific, while the structure of the approach is generalisable.

Transferring the framework to new contexts mainly requires the replacement of input data with region-specific information on land quality, farming systems, and economic conditions. Land quality indices, for example, can be replaced with national measures such as soil classification, climatic zones, or productivity indices used in national land evaluation systems [71]. Agricultural profitability can be estimated using data from farm accountancy networks, surveys, or standard gross-margin budgets where harmonised farm-level data (e.g. FADN) are not available [72]. Forestry parameters can likewise be adjusted to reflect region-specific species composition, assortment structures, and market prices.

Because the framework relies on transparent, annually based indicators, it can be easily recalibrated using updated or region-specific input data. Changes in prices, costs, or support levels can be readily incorporated, enabling the framework to remain relevant under evolving economic conditions and data availability. This adaptability supports its integration into existing data systems and allows for consistent comparison across different regions or time periods.

4.4. Multi-Objective Land-Use Planning And Future Research Directions

While this study primarily focuses on economic profitability, the proposed framework holds considerable potential for advancing multi-objective land-use planning. By enabling parcel-level comparisons of agricultural returns and forestry deposit values, it establishes a strong foundation for integrated assessments that align economic, environmental, and social policy goals. When combined with spatial indicators such as labour demand, net GHG emissions, or habitat quality, the framework can support the strategic identification of land-use transitions that deliver co-benefits for climate mitigation, biodiversity conservation, and rural development.

This direction aligns with growing recognition in land-system science that land-use decisions must account for overlapping and sometimes competing objectives [73,74,75]. Parcel-level profitability maps can serve as a critical layer in spatial planning tools, guiding where afforestation, extensification, or landscape restoration could deliver both ecological and economic gains. Such tools are increasingly necessary to operationalise national climate strategies, biodiversity targets, and the EU Green Deal commitments in spatially explicit and cost-effective ways.

Importantly, the framework also provides a basis for addressing social equity and territorial cohesion. In many marginal areas, continued agricultural activity is sustained through undercompensated labour or dependence on subsidies [76], raising concerns about the long-term viability and fairness. Identifying where these patterns persist can inform just transition policies that combine environmental objectives with measures to support rural livelihoods, sustain services, and mitigate social risks.

Looking forward, further research should focus on expanding the framework to incorporate additional performance indicators beyond profitability. Existing spatial methodologies for evaluating employment outcomes [39] and biodiversity [77] demonstrate the feasibility of a multi-criteria assessment approach. Developing an integrated decision-support system that includes these dimensions would allow policymakers to better assess trade-offs and synergies across multiple objectives, including climate resilience, food security, ecosystem integrity, and social well-being.

Finally, the framework establishes a basis for more adaptive and evidence-based land-use policy in the future. Its structure is well-suited for integration into tools that can incorporate regularly updated data, allowing policymakers to respond to changing economic and environmental conditions as they emerge. This capacity for gradual refinement is particularly important in regions where land-use dynamics are influenced by both global pressures and local constraints. In this way, the proposed approach offers a scalable and transferable foundation for supporting sustainable land-use transitions

5. Conclusions

This study highlights the importance of incorporating spatially explicit profitability assessments into land use planning and policy development. Profitability varies significantly across land quality, farm size, crop types, and dominant tree species showing that uniform land management strategies are insufficient. Integrating profitability data into decision making can help identify areas where afforestation, agricultural support, or diversification efforts would be most effective. This study contributes a scalable and transferable approach to land-use assessment that goes beyond profitability. It lays the groundwork for an integrated, evidence-based land management system, capable of informing targeted, just, and climate-smart policies across diverse territorial contexts. As future research expands its multi-objective capabilities, the framework can serve as a central tool in the transition toward sustainable and resilient land-use systems.

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Appendix A1

Table 1. Farm size groups in different agricultural sectors

Agricultural sector	Farm size, ha			
	Large farms	Medium farms	Small farms	Micro farms
Cereals, rapeseeds, pulses	>300	>100, ≤300	>20, ≤100	≤20
Vegetables (with potatoes)	>30	>10, ≤30	>2, ≤10	≤2
Perennial plantations	>30	>10, ≤30	>2, ≤10	≤2
Other crops (e.g. mustard, flaxseed, nectar plants, herbs, lavender, chamomile, caraway)	>150	>50, ≤150	>10, ≤50	≤10
Fallow land	>300	>100, ≤300	>20, ≤100	≤20
Grasslands	>300	>100, ≤300	>20, ≤100	≤20
Meadows and pastures	>300	>100, ≤300	>20, ≤100	≤20
Dairy cows (with calves)	>200	>30, ≤200	>4, ≤30	≤4
Suckling cows (with calves)	>200	>30, ≤200	>4, ≤30	≤4

Appendix A2

Table 1. Estimated data for cereal production equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Conventional farms				
Price (EUR/t)	196.84	196.84	177.16	157.47
Average yield (t/ha)	land quality points * 0.1076574			
Support (EUR/ha)	149.85	149.85	149.85	149.85
Labor costs (EUR/ha)	140.25	154.00	197.12	291.06
Other costs and depreciation (EUR/ha)	512.59	497.21	451.08	435.70

Organic farms				
Price (EUR/t)	272.07	272.07	244.87	217.66
Average yield (t/ha)	land quality points * 0.1280373			
Support (EUR/ha)	266.85	266.85	266.85	266.85
Labor costs (EUR/ha)	140.25	154.00	197.12	291.06
Other costs and depreciation (EUR/ha)	486.96	472.35	428.52	413.91

Table 2. Estimated data for rapeseeds production equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Conventional farms				
Price (EUR/t)	477.62	477.62	429.86	382.10
Average yield (t/ha)	land quality points * 0.0426049			
Support (EUR/ha)	187.85	187.85	187.85	187.85
Labor costs (EUR/ha)	140.25	154.00	197.12	291.06
Other costs and depreciation (EUR/ha)	627.10	608.29	551.85	533.03
Organic farms				
Price (EUR/t)	744.06	744.06	669.65	595.25
Average yield (t/ha)	land quality points * 0.0525616			
Support (EUR/ha)	266.85	266.85	266.85	266.85
Labor costs (EUR/ha)	140.25	154.00	197.12	291.06
Other costs and depreciation (EUR/ha)	595.74	577.87	524.26	506.38

Table 3. Estimated data for pulses equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Conventional farms				
Price (EUR/t)	251.81	251.81	226.63	201.45
Average yield (t/ha)	land quality points * 0.0706193			
Support (EUR/ha)	221.94	221.94	221.94	221.94
Labor costs (EUR/ha)	140.25	154.00	197.12	291.06
Other costs and depreciation (EUR/ha)	503.86	488.74	443.40	428.28
Organic farms				
Price (EUR/t)	413.44	413.44	372.10	330.75
Average yield (t/ha)	land quality points * 0.0784871			
Support (EUR/ha)	318.94	318.94	318.94	318.94
Labor costs (EUR/ha)	140.25	154.00	197.12	291.06

Other costs and depreciation (EUR/ha)	478.67	464.31	421.23	406.87
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Table 4. Estimated data for vegetable and potato production equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Conventional farms				
Price (EUR/t)	273.07	273.07	273.07	273.07
Average yield (t/ha)	22.41	21.06	17.32	12.84
Support (EUR/ha)	376.78	376.78	376.78	376.78
Labor costs (EUR/ha)	2 010.25	3 118.50	3 665.20	3 081.54
Other costs and depreciation (EUR/ha)	2 200.43	2 134.41	1 936.38	1 870.36
Organic farms				
Price (EUR/t)	427.65	427.65	427.65	427.65
Average yield (t/ha)	9.30	7.86	7.18	5.68
Support (EUR/ha)	939.90	939.90	939.90	939.90
Labor costs (EUR/ha)	2 010.25	3 118.50	3 665.20	3 081.54
Other costs and depreciation (EUR/ha)	2 090.41	2 027.69	1 839.56	1 776.84

Table 5. Estimated data for production of perennial plantations equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Price (EUR/t)	1 737.43	1 737.43	1 737.43	1 737.43
Average yield (t/ha)	7.30	6.86	5.64	4.18
Support (EUR/ha)	285.64	285.64	285.64	285.64
Labor costs (EUR/ha)	2 187.90	3 395.70	3 985.52	3 354.12
Other costs and depreciation (EUR/ha)	7 978.81	7 739.45	7 021.35	6 781.99

Table 6. Estimated data for fallow land equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Conventional farms				
Revenue (EUR/ha)	0	0	0	0
Support (EUR/ha)	149.85	149.85	149.85	149.85
Labor costs (EUR/ha)	65.45	61.60	98.56	129.36
Other costs and depreciation (EUR/ha)	201.01	194.98	176.89	170.86
Organic farms				
Revenue (EUR/ha)	0	0	0	0

Support (EUR/ha)	246.85	246.85	246.85	246.85
Labor costs (EUR/ha)	65.45	61.60	98.56	129.36
Other costs and depreciation (EUR/ha)	190.96	185.23	168.04	162.32

Table 7. Estimated data for grasslands equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Price (dry matter) (EUR/t)	59.31	59.31	59.31	59.31
Average yield (dry matter) (t/ha)	4.68	4.68	4.68	4.68
Support (EUR/ha)	149.85	149.85	149.85	149.85
Labor costs (EUR/ha)	149.60	231.00	271.04	406.56
Other costs and depreciation (EUR/ha)	102.02	98.96	89.78	86.72

Table 8. Estimated data for meadows and pastures equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Price (EUR/t)	36.90	36.90	36.90	36.90
Average yield (t/ha)	3.81	3.02	2.46	1.87
Support (EUR/ha)	149.85	149.85	149.85	149.85
Labor costs (EUR/ha)	28.05	46.20	55.44	83.16
Other costs and depreciation (EUR/ha)	138.42	134.27	121.81	117.66

Table 9. Estimated data for other crops (e.g. mustard, flaxseed, nectar plants, herbs, lavender, chamomile, caraway) equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Price (EUR/t)	2 700.00	2 700.00	2 700.00	2 700.00
Average yield (t/ha)	0.90	0.90	0.90	0.90
Support (EUR/ha)	149.85	149.85	149.85	149.85
Labor costs (EUR/ha)	514.25	793.10	936.32	1 390.62
Other costs and depreciation (EUR/ha)	374.65	363.41	329.69	318.45

Table 10. Estimated data for milk production equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Price (EUR/t)	318.01	308.37	279.46	240.92
Average yield (t/ha)	8.81	6.20	5.70	4.32
Support (EUR/ha)	235.87	235.87	235.87	235.87
Labor costs (EUR/ha)	813.45	816.20	1 207.36	1 787.94
Other costs and depreciation (EUR/ha)	662.58	642.71	583.07	563.20

Table 11. Estimated data for suckler cow sector equations (calve for sales)

Factor	Large farms	Medium farms	Small farms	Micro farms
Price (EUR/t)	3 180.10	3 180.10	3 180.10	3 180.10
Average yield (t/ha)	0.30	0.30	0.30	0.30
Support (EUR/ha)	132.01	132.01	132.01	132.01
Labor costs (EUR/ha)	224.40	246.40	338.80	300.30
Other costs and depreciation (EUR/ha)	331.07	321.14	291.34	281.41

Table 12. Estimated data for sheep farming sector equations

Factor	Large farms	Medium farms	Small farms	Micro farms
Price (EUR/t)	2 750.00	2 750.00	2 750.00	2 750.00
Average yield (t/ha)	0.05	0.05	0.05	0.05
Support (EUR/ha)	34.09	34.09	34.09	34.09
Labor costs (EUR/ha)	84.15	69.30	110.88	207.90
Other costs and depreciation (EUR/ha)	28.38	27.53	24.97	24.12

Appendix A3

Table 1. Proportion of wood assortments from wood to be obtained in final felling, depending on the dominant tree species

Dominant tree species	Type of assortments (proportion)				
	Packing case timber	Veneer logs	Saw logs	Paper wood	Firewood
Pine	0.05	-	0.60	0.30	0.05
Spruce	0.05	-	0.60	0.30	0.05
Birch	0.15	0.35	0.05	0.40	0.05
Aspen	0.25	-	0.20	0.30	0.25
Black alder	0.05	-	0.40	0.45	0.10

Dominant tree species	Type of assortments (proportion)				
	Packing case timber	Veneer logs	Saw logs	Paper wood	Firewood
Grey alder	0.50	-	-	-	0.50
Other species	0.15	-	0.45	0.30	0.10

Table 2. Proportion of wood assortments from wood to be obtained in thinning, depending on the dominant tree species

Dominant tree species	Type of assortments (proportion)				
	Packing case timber	Veneer logs	Saw logs	Paper wood	Firewood
Pine	0.05	-	0.55	0.35	0.05
Spruce	0.20	-	0.35	0.30	0.15
Birch	0.10	0.25	-	0.60	0.05
Aspen	0.35	-	0.05	0.20	0.40
Black alder	0.05	-	0.30	0.50	0.15
Grey alder	0.60	-	-	-	0.40
Other species	0.15	-	0.45	0.30	0.10

Table 3. Prices of different wood assortments depending on the dominant tree species

Dominant tree species	Price (EUR/m ³)				
	Packing case timber	Veneer logs	Saw logs	Paper wood	Firewood
Pine	73	-	95	85	42
Spruce	73	-	90	76	42
Birch	61	127	115	90	42
Aspen	61	-	85	68	42
Black alder	61	-	78	62	42
Grey alder	61	-	-	-	42
Other species	61	-	140	62	42

Appendix A4

Table 1. The costs of silvicultural measures depending on the dominant tree species and forest type in rotation cycle

Dominant tree species	Forest type	Costs (EUR/ha)									
		Maintenance of	Soil preparation	Seedlings	Planting	Forest protection	Forest replenishment	Tending	Young stand tending	Underbrush tending	TOTAL
Pine	<i>Cladinoso – callunosa</i>	-	288	404	232	136	104	217	224	250	1855
Pine	<i>Vacciniosa</i>	-	239	447	188	136	103	260	292	250	1915
Pine	<i>Myrtillosa</i>	-	239	447	188	136	103	260	292	250	1915
Pine	<i>Hylocommiosa</i>	-	282	479	261	136	114	268	296	250	2086
Pine	<i>Oxalidosa</i>	-	282	479	261	136	114	268	296	250	2086
Pine	<i>Aegopodiosa</i>	-	282	479	261	136	114	268	296	250	2086
Pine	<i>Callunoso – sphagnosa</i>	-	242	236	297	136	72	184	184	250	1601
Pine	<i>Vaccinioso – sphagnosa</i>	-	288	404	232	136	104	217	224	250	1855
Pine	<i>Myrtilloso – sphagnosa</i>	-	288	404	232	136	104	217	224	250	1855
Pine	<i>Myrtilloso – polytrichosa</i>	-	288	404	232	136	104	217	224	250	1855
Pine	<i>Dryopteriosa</i>	-	288	404	232	136	104	217	224	250	1855
Pine	<i>Sphagnosa</i>	-	242	236	297	136	72	184	184	250	1601
Pine	<i>Caricoso – phragmitosa</i>	-	288	404	232	136	104	217	224	250	1855
Pine	<i>Dryopterioso – caricosa</i>	-	288	404	232	136	104	217	224	250	1855
Pine	<i>Filipendulosa</i>	-	288	404	232	136	104	217	224	250	1855
Pine	<i>Callunosa mel.</i>	506	288	404	232	136	104	217	224	250	2361
Pine	<i>Vacciniosa mel.</i>	506	239	447	188	136	103	260	292	250	2421
Pine	<i>Myrtillosa mel.</i>	506	282	479	261	136	114	268	296	250	2592
Pine	<i>Mercurialiosa mel.</i>	506	282	479	261	136	114	268	296	250	2592
Pine	<i>Callunosa turf. mel.</i>	506	288	404	232	136	104	217	224	250	2361
Pine	<i>Vacciniosa turf. mel.</i>	506	239	447	188	136	103	260	292	250	2421
Pine	<i>Myrtillosa turf. mel.</i>	506	282	479	261	136	114	268	296	250	2592
Pine	<i>Oxalidosa turf. mel.</i>	506	282	479	261	136	114	268	296	250	2592
Spruce	<i>Cladinoso - callunosa</i>	-	288	404	232	136	104	217	224	250	1855
Spruce	<i>Vacciniosa</i>	-	239	447	188	136	103	260	292	250	1915
Spruce	<i>Myrtillosa</i>	-	239	447	188	136	103	260	292	250	1915
Spruce	<i>Hylocommiosa</i>	-	282	479	261	136	114	268	296	250	2086
Spruce	<i>Oxalidosa</i>	-	282	479	261	136	114	268	296	250	2086
Spruce	<i>Aegopodiosa</i>	-	282	479	261	136	114	268	296	250	2086
Spruce	<i>Callunoso – sphagnosa</i>	-	242	236	297	136	72	184	184	250	1601
Spruce	<i>Vaccinioso – sphagnosa</i>	-	288	404	232	136	104	217	224	250	1855
Spruce	<i>Myrtilloso – sphagnosa</i>	-	288	404	232	136	104	217	224	250	1855
Spruce	<i>Myrtilloso – polytrichosa</i>	-	288	404	232	136	104	217	224	250	1855
Spruce	<i>Dryopteriosa</i>	-	288	404	232	136	104	217	224	250	1855

Dominant tree species	Forest type	Costs (EUR/ha)									
		Maintenance of	Soil preparation	Seedlings	Planting	Forest protection	Forest replenishment	Tending	Young stand tending	Underbrush tending	TOTAL
Spruce	<i>Sphagnosa</i>	-	242	236	297	136	72	184	184	250	1601
Spruce	<i>Caricoso – phragmitosa</i>	-	288	404	232	136	104	217	224	250	1855
Spruce	<i>Dryopterioso – caricoso</i>	-	288	404	232	136	104	217	224	250	1855
Spruce	<i>Filipendulosa</i>	-	288	404	232	136	104	217	224	250	1855
Spruce	<i>Callunosa mel.</i>	368	288	404	232	136	104	217	224	250	2223
Spruce	<i>Vacciniosa mel.</i>	368	239	447	188	136	103	260	292	250	2283
Spruce	<i>Myrtillosa mel.</i>	368	282	479	261	136	114	268	296	250	2454
Spruce	<i>Mercurialiosa mel.</i>	368	282	479	261	136	114	268	296	250	2454
Spruce	<i>Callunosa turf. mel.</i>	368	288	404	232	136	104	217	224	250	2223
Spruce	<i>Vacciniosa turf. mel.</i>	368	239	447	188	136	103	260	292	250	2283
Spruce	<i>Myrtillosa turf. mel.</i>	368	282	479	261	136	114	268	296	250	2454
Spruce	<i>Oxalidosa turf. mel.</i>	368	282	479	261	136	114	268	296	250	2454
Birch	<i>Cladinoso - callunosa</i>	-	288	404	232	136	104	217	224	250	1855
Birch	<i>Vacciniosa</i>	-	239	447	188	136	103	260	292	250	1915
Birch	<i>Myrtillosa</i>	-	239	447	188	136	103	260	292	250	1915
Birch	<i>Hylocommiosa</i>	-	282	479	261	136	114	268	296	250	2086
Birch	<i>Oxalidosa</i>	-	282	479	261	136	114	268	296	250	2086
Birch	<i>Aegopodiosa</i>	-	282	479	261	136	114	268	296	250	2086
Birch	<i>Callunoso – sphagnosa</i>	-	242	236	297	136	72	184	184	250	1601
Birch	<i>Vaccinioso – sphagnosa</i>	-	288	404	232	136	104	217	224	250	1855
Birch	<i>Myrtilloso – sphagnosa</i>	-	288	404	232	136	104	217	224	250	1855
Birch	<i>Myrtilloso – polytrichosa</i>	-	288	404	232	136	104	217	224	250	1855
Birch	<i>Dryopteriosa</i>	-	288	404	232	136	104	217	224	250	1855
Birch	<i>Sphagnosa</i>	-	242	236	297	136	72	184	184	250	1601
Birch	<i>Caricoso – phragmitosa</i>	-	288	404	232	136	104	217	224	250	1855
Birch	<i>Dryopterioso – caricoso</i>	-	288	404	232	136	104	217	224	250	1855
Birch	<i>Filipendulosa</i>	-	288	404	232	136	104	217	224	250	1855
Birch	<i>Callunosa mel.</i>	276	288	404	232	136	104	217	224	250	2131
Birch	<i>Vacciniosa mel.</i>	276	239	447	188	136	103	260	292	250	2191
Birch	<i>Myrtillosa mel.</i>	276	282	479	261	136	114	268	296	250	2362
Birch	<i>Mercurialiosa mel.</i>	276	282	479	261	136	114	268	296	250	2362
Birch	<i>Callunosa turf. mel.</i>	276	288	404	232	136	104	217	224	250	2131
Birch	<i>Vacciniosa turf. mel.</i>	276	239	447	188	136	103	260	292	250	2191
Birch	<i>Myrtillosa turf. mel.</i>	276	282	479	261	136	114	268	296	250	2362

Dominant tree species	Forest type	Costs (EUR/ha)									
		Maintenance of	Soil preparation	Seedlings	Planting	Forest protection	Forest replenishment	Tending	Young stand tending	Underbrush tending	TOTAL
Birch	<i>Oxalidosa turf. mel.</i>	276	282	479	261	136	114	268	296	250	2362
Aspen	<i>Cladinoso - callunosa</i>	-	-	-	-	-	-	217	224	250	691
Aspen	<i>Vacciniosa</i>	-	-	-	-	-	-	260	292	250	802
Aspen	<i>Myrtillosa</i>	-	-	-	-	-	-	260	292	250	802
Aspen	<i>Hylocommiosa</i>	-	-	-	-	-	-	268	296	250	814
Aspen	<i>Oxalidosa</i>	-	-	-	-	-	-	268	296	250	814
Aspen	<i>Aegopodiosa</i>	-	-	-	-	-	-	268	296	250	814
Aspen	<i>Callunoso – sphagnosa</i>	-	-	-	-	-	-	184	184	250	618
Aspen	<i>Vaccinioso – sphagnosa</i>	-	-	-	-	-	-	217	224	250	691
Aspen	<i>Myrtilloso – sphagnosa</i>	-	-	-	-	-	-	217	224	250	691
Aspen	<i>Myrtilloso – polytrichosa</i>	-	-	-	-	-	-	217	224	250	691
Aspen	<i>Dryopteriosa</i>	-	-	-	-	-	-	217	224	250	691
Aspen	<i>Sphagnosa</i>	-	-	-	-	-	-	184	184	250	618
Aspen	<i>Caricoso – phragmitosa</i>	-	-	-	-	-	-	217	224	250	691
Aspen	<i>Dryopterioso – caricosa</i>	-	-	-	-	-	-	217	224	250	691
Aspen	<i>Filipendulosa</i>	-	-	-	-	-	-	217	224	250	691
Aspen	<i>Callunosa mel.</i>	184	-	-	-	-	-	217	224	250	875
Aspen	<i>Vacciniosa mel.</i>	184	-	-	-	-	-	260	292	250	986
Aspen	<i>Myrtillosa mel.</i>	184	-	-	-	-	-	268	296	250	998
Aspen	<i>Mercurialiosa mel.</i>	184	-	-	-	-	-	268	296	250	998
Aspen	<i>Callunosa turf. mel.</i>	184	-	-	-	-	-	217	224	250	875
Aspen	<i>Vacciniosa turf. mel.</i>	184	-	-	-	-	-	260	292	250	986
Aspen	<i>Myrtillosa turf. mel.</i>	184	-	-	-	-	-	268	296	250	998
Aspen	<i>Oxalidosa turf. mel.</i>	184	-	-	-	-	-	268	296	250	998
Black alder	<i>Cladinoso - callunosa</i>	-	288	404	232	-	104	217	224	250	1719
Black alder	<i>Vacciniosa</i>	-	239	447	188	-	103	260	292	250	1779
Black alder	<i>Myrtillosa</i>	-	239	447	188	-	103	260	292	250	1779
Black alder	<i>Hylocommiosa</i>	-	282	479	261	-	114	268	296	250	1950
Black alder	<i>Oxalidosa</i>	-	282	479	261	-	114	268	296	250	1950
Black alder	<i>Aegopodiosa</i>	-	282	479	261	-	114	268	296	250	1950
Black alder	<i>Callunoso – sphagnosa</i>	-	242	236	297	-	72	184	184	250	1465
Black alder	<i>Vaccinioso – sphagnosa</i>	-	288	404	232	-	104	217	224	250	1719
Black alder	<i>Myrtilloso – sphagnosa</i>	-	288	404	232	-	104	217	224	250	1719
Black alder	<i>Myrtilloso – polytrichosa</i>	-	288	404	232	-	104	217	224	250	1719

Dominant tree species	Forest type	Costs (EUR/ha)									
		Maintenance of	Soil preparation	Seedlings	Planting	Forest protection	Forest replenishment	Tending	Young stand tending	Underbrush tending	TOTAL
Black alder	<i>Dryopteriosa</i>	-	288	404	232	-	104	217	224	250	1719
Black alder	<i>Sphagnosa</i>	-	242	236	297	-	72	184	184	250	1465
Black alder	<i>Caricoso – phragmitosa</i>	-	288	404	232	-	104	217	224	250	1719
Black alder	<i>Dryopterioso – caricosa</i>	-	288	404	232	-	104	217	224	250	1719
Black alder	<i>Filipendulosa</i>	-	288	404	232	-	104	217	224	250	1719
Black alder	<i>Callunosa mel.</i>	322	288	404	232	-	104	217	224	250	2041
Black alder	<i>Vacciniosa mel.</i>	322	239	447	188	-	103	260	292	250	2101
Black alder	<i>Myrtillosa mel.</i>	322	282	479	261	-	114	268	296	250	2272
Black alder	<i>Mercurialiosa mel.</i>	322	282	479	261	-	114	268	296	250	2272
Black alder	<i>Callunosa turf. mel.</i>	322	288	404	232	-	104	217	224	250	2041
Black alder	<i>Vacciniosa turf. mel.</i>	322	239	447	188	-	103	260	292	250	2101
Black alder	<i>Myrtillosa turf. mel.</i>	322	282	479	261	-	114	268	296	250	2272
Black alder	<i>Oxalidosa turf. mel.</i>	322	282	479	261	-	114	268	296	250	2272
Grey alder	<i>Cladinoso - callunosa</i>	-	-	-	-	-	-	217	224	250	691
Grey alder	<i>Vacciniosa</i>	-	-	-	-	-	-	260	292	250	802
Grey alder	<i>Myrtillosa</i>	-	-	-	-	-	-	260	292	250	802
Grey alder	<i>Hylocomniosa</i>	-	-	-	-	-	-	268	296	250	814
Grey alder	<i>Oxalidosa</i>	-	-	-	-	-	-	268	296	250	814
Grey alder	<i>Aegopodiosa</i>	-	-	-	-	-	-	268	296	250	814
Grey alder	<i>Callunoso – sphagnosa</i>	-	-	-	-	-	-	184	184	250	618
Grey alder	<i>Vaccinioso – sphagnosa</i>	-	-	-	-	-	-	217	224	250	691
Grey alder	<i>Myrtilloso – sphagnosa</i>	-	-	-	-	-	-	217	224	250	691
Grey alder	<i>Myrtilloso – polytrichosa</i>	-	-	-	-	-	-	217	224	250	691
Grey alder	<i>Dryopteriosa</i>	-	-	-	-	-	-	217	224	250	691
Grey alder	<i>Sphagnosa</i>	-	-	-	-	-	-	184	184	250	618
Grey alder	<i>Caricoso – phragmitosa</i>	-	-	-	-	-	-	217	224	250	691
Grey alder	<i>Dryopterioso – caricosa</i>	-	-	-	-	-	-	217	224	250	691
Grey alder	<i>Filipendulosa</i>	-	-	-	-	-	-	217	224	250	691
Grey alder	<i>Callunosa mel.</i>	138	-	-	-	-	-	217	224	250	829
Grey alder	<i>Vacciniosa mel.</i>	138	-	-	-	-	-	260	292	250	940
Grey alder	<i>Myrtillosa mel.</i>	138	-	-	-	-	-	268	296	250	952
Grey alder	<i>Mercurialiosa mel.</i>	138	-	-	-	-	-	268	296	250	952
Grey alder	<i>Callunosa turf. mel.</i>	138	-	-	-	-	-	217	224	250	829
Grey alder	<i>Vacciniosa turf. mel.</i>	138	-	-	-	-	-	260	292	250	940

Dominant tree species	Forest type	Costs (EUR/ha)									
		Maintenance of	Soil preparation	Seedlings	Planting	Forest protection	Forest replenishment	Tending	Young stand tending	Underbrush tending	TOTAL
Grey alder	<i>Myrtillosa turf. mel.</i>	138	-	-	-	-	-	268	296	250	952
Grey alder	<i>Oxalidoso turf. mel.</i>	138	-	-	-	-	-	268	296	250	952
Other species	<i>Cladinoso - callunosa</i>	-	288	404	232	136	104	217	224	250	1855
Other species	<i>Vacciniosa</i>	-	239	447	188	136	103	260	292	250	1915
Other species	<i>Myrtillosa</i>	-	239	447	188	136	103	260	292	250	1915
Other species	<i>Hylocomniosa</i>	-	282	479	261	136	114	268	296	250	2086
Other species	<i>Oxalidoso</i>	-	282	479	261	136	114	268	296	250	2086
Other species	<i>Aegopodiosa</i>	-	282	479	261	136	114	268	296	250	2086
Other species	<i>Callunoso – sphagnosa</i>	-	242	236	297	136	72	184	184	250	1601
Other species	<i>Vaccinioso – sphagnosa</i>	-	288	404	232	136	104	217	224	250	1855
Other species	<i>Myrtilloso – sphagnosa</i>	-	288	404	232	136	104	217	224	250	1855
Other species	<i>Myrtilloso – polytrichosa</i>	-	288	404	232	136	104	217	224	250	1855
Other species	<i>Dryopteriosa</i>	-	288	404	232	136	104	217	224	250	1855
Other species	<i>Sphagnosa</i>	-	242	236	297	136	72	184	184	250	1601
Other species	<i>Caricoso – phragmitosa</i>	-	288	404	232	136	104	217	224	250	1855
Other species	<i>Dryopterioso – caricosa</i>	-	288	404	232	136	104	217	224	250	1855
Other species	<i>Filipendulosa</i>	-	288	404	232	136	104	217	224	250	1855
Other species	<i>Callunosa mel.</i>	368	288	404	232	136	104	217	224	250	2223
Other species	<i>Vacciniosa mel.</i>	368	239	447	188	136	103	260	292	250	2283
Other species	<i>Myrtillosa mel.</i>	368	282	479	261	136	114	268	296	250	2454
Other species	<i>Mercurialiosa mel.</i>	368	282	479	261	136	114	268	296	250	2454
Other species	<i>Callunosa turf. mel.</i>	368	288	404	232	136	104	217	224	250	2223
Other species	<i>Vacciniosa turf. mel.</i>	368	239	447	188	136	103	260	292	250	2283
Other species	<i>Myrtillosa turf. mel.</i>	368	282	479	261	136	114	268	296	250	2454
Other species	<i>Oxalidoso turf. mel.</i>	368	282	479	261	136	114	268	296	250	2454

Appendix A5

Table 1. The costs of harvesting and transportation

Harvesting and transportation	Costs (EUR/m3)
Thinning	14.06
Final felling	9.39
Transportation in thinning	18.86

Transportation in final felling	16.27
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To enable spatially explicit profitability modelling, harvesting and transportation costs (EUR/m³) were recalculated to a per-hectare basis, using estimated standing volume growth rates (Annex A6 and A7).

Table 2. The average costs of harvesting and transportation in rotation cycle

Dominant tree species	Forest type	Costs (EUR/ha)			
		Thinning	Final felling	Transportation	Total
Pine	<i>Cladinoso callunosa</i> –	1 219	2 211	5 465	8 895
Pine	<i>Vacciniosa</i>	1 537	2 787	6 891	11 215
Pine	<i>Myrtillosa</i>	1 934	3 508	8 673	14 116
Pine	<i>Hylocomniosa</i>	2 384	4 325	10 693	17 403
Pine	<i>Oxalidosa</i>	2 212	4 013	9 921	16 146
Pine	<i>Aegopodiosa</i>	775	1 406	3 475	5 656
Pine	<i>Callunoso sphagnosa</i> –	1 172	2 127	5 257	8 556
Pine	<i>Vaccinioso sphagnosa</i> –	1 676	3 040	7 515	12 230
Pine	<i>Myrtilloso sphagnosa</i> –	2 067	3 749	9 267	15 082
Pine	<i>Myrtilloso polytrichosa</i> –	2 086	3 785	9 356	15 227
Pine	<i>Dryopteriosa</i>	1 782	3 232	7 990	13 004
Pine	<i>Sphagnosa</i>	987	1 790	4 426	7 203
Pine	<i>Caricoso phragmitosa</i> –	1 331	2 415	5 970	9 717
Pine	<i>Dryopterioso caricosa</i> –	1 696	3 076	7 604	12 375
Pine	<i>Filipendulosa</i>	1 729	3 136	7 752	12 617
Pine	<i>Callunosa mel.</i>	1 729	3 136	7 752	13 123
Pine	<i>Vacciniosa mel.</i>	2 080	3 773	9 327	15 685
Pine	<i>Myrtillosa mel.</i>	2 252	4 085	10 099	16 942
Pine	<i>Mercurialiosa mel.</i>	2 186	3 965	9 802	16 459
Pine	<i>Callunosa turf. mel.</i>	1 219	2 211	5 465	9 401
Pine	<i>Vacciniosa turf. mel.</i>	1 530	2 775	6 861	11 673
Pine	<i>Myrtillosa turf. mel.</i>	1 682	3 052	7 544	12 785
Pine	<i>Oxalidosa turf. mel.</i>	1 788	3 244	8 020	13 558

Dominant tree species	Forest type	Costs (EUR/ha)			
		Thinning	Final felling	Transportation	Total
Spruce	<i>Cladinoso callunosa</i> -	4 171	5 503	15 130	24 804
Spruce	<i>Vacciniosa</i>	3 133	4 133	11 364	18 630
Spruce	<i>Myrtillosa</i>	3 388	4 469	12 289	20 146
Spruce	<i>Hylocomniosa</i>	3 015	3 977	10 934	17 926
Spruce	<i>Oxalidosa</i>	3 452	4 554	12 520	20 525
Spruce	<i>Aegopodiosa</i>	3 461	4 566	12 553	20 580
Spruce	<i>Callunoso sphagnosa</i> -	2 778	3 664	10 076	16 518
Spruce	<i>Vaccinioso sphagnosa</i> -	3 106	4 097	11 265	18 467
Spruce	<i>Myrtilloso sphagnosa</i> -	3 015	3 977	10 934	17 926
Spruce	<i>Myrtilloso polytrichosa</i> -	3 142	4 145	11 397	18 684
Spruce	<i>Dryopteriosa</i>	3 270	4 313	11 859	19 442
Spruce	<i>Sphagnosa</i>	1 949	2 571	7 069	11 590
Spruce	<i>Caricoso phragmitosa</i> -	2 477	3 268	8 985	14 731
Spruce	<i>Dryopterioso caricosa</i> -	2 687	3 544	9 745	15 976
Spruce	<i>Filipendulosa</i>	2 942	3 881	10 670	17 493
Spruce	<i>Callunosa mel.</i>	3 743	4 938	13 577	22 626
Spruce	<i>Vacciniosa mel.</i>	3 379	4 457	12 256	20 460
Spruce	<i>Myrtillosa mel.</i>	3 315	4 373	12 025	20 081
Spruce	<i>Mercurialiosa mel.</i>	3 342	4 409	12 124	20 243
Spruce	<i>Callunosa turf. mel.</i>	2 960	3 905	10 736	17 969
Spruce	<i>Vacciniosa turf. mel.</i>	2 823	3 725	10 241	17 157
Spruce	<i>Myrtillosa turf. mel.</i>	2 996	3 953	10 868	18 186
Spruce	<i>Oxalidosa turf. mel.</i>	3 097	4 085	11 232	18 781
Birch	<i>Cladinoso callunosa</i> -	988	2 199	5 134	8 321
Birch	<i>Vacciniosa</i>	1 258	2 799	6 537	10 594
Birch	<i>Myrtillosa</i>	1 646	3 664	8 557	13 868
Birch	<i>Hylocomniosa</i>	1 884	4 193	9 792	15 869
Birch	<i>Oxalidosa</i>	1 916	4 265	9 960	16 141

Dominant tree species	Forest type	Costs (EUR/ha)			
		Thinning	Final felling	Transportation	Total
Birch	<i>Aegopodiosa</i>	1 695	3 773	8 810	14 277
Birch	<i>Callunoso sphagnosa</i> –	685	1 526	3 563	5 775
Birch	<i>Vaccinioso sphagnosa</i> –	1 171	2 607	6 088	9 867
Birch	<i>Myrtilloso sphagnosa</i> –	1 544	3 436	8 024	13 004
Birch	<i>Myrtilloso polytrichosa</i> –	1 603	3 568	8 333	13 504
Birch	<i>Dryopteriosa</i>	1 409	3 136	7 323	11 867
Birch	<i>Sphagnosa</i>	664	1 478	3 451	5 593
Birch	<i>Caricoso phragmitosa</i> –	939	2 091	4 882	7 912
Birch	<i>Dryopterioso caricosa</i> –	1 106	2 463	5 752	9 321
Birch	<i>Filipendulosa</i>	1 306	2 908	6 790	11 003
Birch	<i>Callunosa mel.</i>	1 128	2 511	5 864	9 779
Birch	<i>Vacciniosa mel.</i>	1 468	3 268	7 632	12 644
Birch	<i>Myrtillosa mel.</i>	1 662	3 701	8 642	14 280
Birch	<i>Mercurialiosa mel.</i>	1 684	3 749	8 754	14 462
Birch	<i>Callunosa turf. mel.</i>	923	2 055	4 798	8 051
Birch	<i>Vacciniosa turf. mel.</i>	1 058	2 355	5 499	9 188
Birch	<i>Myrtillosa turf. mel.</i>	1 506	3 352	7 828	12 962
Birch	<i>Oxalidosa turf. mel.</i>	1 446	3 220	7 519	12 462
Aspen	<i>Cladinoso callunosa</i> –	2 435	4 337	10 782	17 555
Aspen	<i>Vacciniosa</i>	1 815	3 232	8 034	13 081
Aspen	<i>Myrtillosa</i>	1 909	3 400	8 452	13762
Aspen	<i>Hylocomniosa</i>	2 273	4 049	10 065	16 388
Aspen	<i>Oxalidosa</i>	2 220	3 953	9 826	15 999
Aspen	<i>Aegopodiosa</i>	1 788	3 184	7 915	12 886
Aspen	<i>Callunoso sphagnosa</i> –	1 848	3 292	8 184	13 324
Aspen	<i>Vaccinioso sphagnosa</i> –	1 916	3 412	8 482	13 810
Aspen	<i>Myrtilloso</i> –	1 943	3 460	8 602	14 005

Dominant tree species	Forest type	Costs (EUR/ha)			
		Thinning	Final felling	Transportation	Total
	<i>sphagnosa</i>				
Aspen	<i>Myrtilloso polytrichosa</i> –	2 091	3 725	9 259	15 075
Aspen	<i>Dryopteriosa</i>	1 666	2 968	7 377	12 011
Aspen	<i>Sphagnosa</i>	1 504	2 679	6 660	10 844
Aspen	<i>Caricoso phragmitosa</i> –	1 538	2 739	6 810	11 087
Aspen	<i>Dryopterioso caricosa</i> –	1 747	3 112	7 736	12 595
Aspen	<i>Filipendulosa</i>	1 606	2 859	7 108	11 573
Aspen	<i>Callunosa mel.</i>	1 781	3 172	7 885	13 022
Aspen	<i>Vacciniosa mel.</i>	1 815	3 232	8 034	13 265
Aspen	<i>Myrtillosa mel.</i>	2 226	3 965	9 856	16 231
Aspen	<i>Mercurialiosa mel.</i>	2 139	3 809	9 468	15 599
Aspen	<i>Callunosa turf. mel.</i>	1 768	3 148	7 825	12 925
Aspen	<i>Vacciniosa turf. mel.</i>	1 511	2 691	6 690	11 077
Aspen	<i>Myrtillosa turf. mel.</i>	2 341	4 169	10 364	17 058
Aspen	<i>Oxalidosa turf. mel.</i>	2 220	3 953	9 826	16 183
Black alder	<i>Cladinoso callunosa</i> -	1 452	3 232	7 547	12 231
Black alder	<i>Vacciniosa</i>	1 225	2 727	6 369	10 321
Black alder	<i>Myrtillosa</i>	1 641	3 652	8 529	13 823
Black alder	<i>Hylocomniosa</i>	1 635	3 640	8 501	13 777
Black alder	<i>Oxalidosa</i>	2 013	4 481	10 465	16 960
Black alder	<i>Aegopodiosa</i>	1 743	3 881	9 063	14 686
Black alder	<i>Callunoso sphagnosa</i> –	1 554	3 460	8 080	13 095
Black alder	<i>Vaccinioso sphagnosa</i> –	1 452	3 232	7 547	12 231
Black alder	<i>Myrtilloso sphagnosa</i> –	1 614	3 592	8 389	13 595
Black alder	<i>Myrtilloso polytrichosa</i> –	1 722	3 833	8 950	14 505
Black alder	<i>Dryopteriosa</i>	1 592	3 544	8 277	13 413
Black alder	<i>Sphagnosa</i>	1 139	2 535	5 920	9 594
Black alder	<i>Caricoso</i> –	1 279	2 847	6 650	10 776

Dominant tree species	Forest type	Costs (EUR/ha)			
		Thinning	Final felling	Transportation	Total
	<i>phragmitosa</i>				
Black alder	<i>Dryopterioso caricosa</i> –	1 376	3 064	7 155	11 595
Black alder	<i>Filipendulosa</i>	1 446	3 220	7 519	12 186
Black alder	<i>Callunosa mel.</i>	1 365	3 040	7 098	11 826
Black alder	<i>Vacciniosa mel.</i>	1 603	3 568	8 333	13 826
Black alder	<i>Myrtillosa mel.</i>	1 689	3 761	8 782	14 554
Black alder	<i>Mercurialiosa mel.</i>	1 759	3 917	9 147	15 145
Black alder	<i>Callunosa turf. mel.</i>	1 311	2 920	6 818	11 371
Black alder	<i>Vacciniosa turf. mel.</i>	1 349	3 004	7 014	11 689
Black alder	<i>Myrtillosa turf. mel.</i>	1 484	3 304	7 716	12 826
Black alder	<i>Oxalidosa turf. mel.</i>	1 608	3 580	8 361	13 872
Grey alder	<i>Cladinoso callunosa</i> –	727	2 427	5 180	8 334
Grey alder	<i>Vacciniosa</i>	547	1 826	3 898	6 271
Grey alder	<i>Myrtillosa</i>	450	1 502	3 206	5 157
Grey alder	<i>Hylocomniosa</i>	626	2 091	4 462	7 179
Grey alder	<i>Oxalidosa</i>	633	2 115	4 513	7 261
Grey alder	<i>Aegopodiosa</i>	590	1 970	4 206	6 766
Grey alder	<i>Callunoso sphagnosa</i> –	450	1 502	3 206	5 157
Grey alder	<i>Vaccinioso sphagnosa</i> –	612	2 042	4 359	7 014
Grey alder	<i>Myrtilloso sphagnosa</i> –	594	1 982	4 231	6 807
Grey alder	<i>Myrtilloso polytrichosa</i> –	612	2 042	4 359	7 014
Grey alder	<i>Dryopteriosa</i>	576	1 922	4 103	6 601
Grey alder	<i>Sphagnosa</i>	414	1 382	2 949	4 745
Grey alder	<i>Caricoso phragmitosa</i> –	446	1 490	3 180	5 116
Grey alder	<i>Dryopterioso caricosa</i> –	504	1 682	3 590	5 776
Grey alder	<i>Filipendulosa</i>	536	1 790	3 821	6 147
Grey alder	<i>Callunosa mel.</i>	856	2 859	6 103	9 957
Grey alder	<i>Vacciniosa mel.</i>	561	1 874	4 000	6 574

Dominant tree species	Forest type	Costs (EUR/ha)			
		Thinning	Final felling	Transportation	Total
Grey alder	<i>Myrtillosa mel.</i>	622	2 079	4 436	7 275
Grey alder	<i>Mercurialiosa mel.</i>	633	2 115	4 513	7 399
Grey alder	<i>Callunosa turf. mel.</i>	608	2 030	4 334	7 110
Grey alder	<i>Vacciniosa turf. mel.</i>	471	1 574	3 359	5 543
Grey alder	<i>Myrtillosa turf. mel.</i>	673	2 247	4 795	7 853
Grey alder	<i>Oxalidosa turf. mel.</i>	640	2 139	4 565	7 482
Other species	<i>Cladinoso callunosa</i> -	1 028	3 052	6 667	10 747
Other species	<i>Vacciniosa</i>	891	2 643	5 774	9 308
Other species	<i>Myrtillosa</i>	1 028	3 052	6 667	10 747
Other species	<i>Hylocomniosa</i>	1 178	3 496	7 638	12 312
Other species	<i>Oxalidosa</i>	1 247	3 701	8 084	13 031
Other species	<i>Aegopodiosa</i>	1 081	3 208	7 008	11 297
Other species	<i>Callunoso sphagnosa</i> -	822	2 439	5 328	8 589
Other species	<i>Vaccinioso sphagnosa</i> -	951	2 823	6 168	9 943
Other species	<i>Myrtilloso sphagnosa</i> -	1 052	3 124	6 824	11 001
Other species	<i>Myrtilloso polytrichosa</i> -	1 109	3 292	7 192	11 593
Other species	<i>Dryopteriosa</i>	976	2 896	6 326	10 197
Other species	<i>Sphagnosa</i>	680	2 018	4 410	7 108
Other species	<i>Caricoso phragmitosa</i> -	773	2 295	5 013	8 081
Other species	<i>Dryopterioso cariosa</i> -	870	2 583	5 643	9 097
Other species	<i>Filipendulosa</i>	907	2 691	5 879	9 477

Dominant tree species	Forest type	Costs (EUR/ha)			
		Thinning	Final felling	Transportation	Total
Other species	<i>Callunosa mel.</i>	976	2 896	6 326	10 565
Other species	<i>Vacciniosa mel.</i>	1 004	2 980	6 509	10 861
Other species	<i>Myrtillosa mel.</i>	1 137	3 376	7 376	12 257
Other species	<i>Mercurialiosa mel.</i>	1 146	3 400	7 428	12 342
Other species	<i>Callunosa turf. mel.</i>	854	2 535	5 538	9 295
Other species	<i>Vacciniosa turf. mel.</i>	814	2 415	5 276	8 872
Other species	<i>Myrtillosa turf. mel.</i>	1 101	3 268	7 139	11 876
Other species	<i>Oxalidos turf. mel.</i>	1 085	3 220	7 034	11 707

Appendix A6

Table 1. Coefficients for stand growth calculations depending on the dominant tree species

Dominant tree species	a ₁	a ₂	a ₃	a ₄
Pine	3.9049	-0.4473	0.8518	0.8571
Spruce	8.7959	-0.5371	1.0000	0.6810
Birch	9.6997	-0.4776	0.8772	0.6097
Black alder	10.7240	-0.5133	0.8822	0.6234
Aspen	12.4910	-0.3753	1.0000	0.4480
Grey alder	11.5837	-0.4727	1.0000	0.4737
Other species	12.4910	-0.3753	1.0000	0.4480

Appendix A7

Table 1. Maximum stand stock at felling age depending on the dominant tree species and site index (Donis, 2019)

Dominant tree species	Site index	Maximum standing volume at felling age (m ³ /ha)
Pine	5	214
Pine	4	306
Pine	3	381
Pine	2	453

Dominant tree species	Site index	Maximum standing volume at felling age (m ³ /ha)
Pine	1	525
Pine	0	586
Spruce	5	198
Spruce	4	332
Spruce	3	401
Spruce	2	494
Spruce	1	556
Spruce	0	600
Birch	5	200
Birch	4	285
Birch	3	346
Birch	2	392
Birch	1	460
Birch	0	481
Black alder	5	201
Black alder	4	289
Black alder	3	362
Black alder	2	416
Black alder	1	495
Black alder	0	562
Aspen	5	91
Aspen	4	157
Aspen	3	248
Aspen	2	321
Aspen	1	399
Aspen	0	482
Grey alder	5	99
Grey alder	4	138
Grey alder	3	183
Grey alder	2	238
Grey alder	1	284

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