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Ju-Kwang Yoon*, Walter Dirksmeyer

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Johann Heinrich von Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries, Institute of Farm Economics,
Bundesallee 63, 38116 Braunschweig, Germany;
ju-kwang.yoon@thuenen.de, walter.dirksmeyer@thuenen.de

* Correspondence: ju-kwang.yoon@thuenen.de

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Ju-Kwang Yoon, Walter Dirksmeyer

Thünen Institute of Farm Economics, Germany

Abstract

Over the past decades, the demand for blueberries in Germany has drastically increased but the expansion of cultivation areas has been constrained by limited availability of suitable natural growing conditions. For this reason, various peat and substrate-based production systems evolved in the past. However, increasing pressure to reduce peat use in agricultural production poses a major challenge. In this context, a financial analysis of the impact of reducing peat use in the blueberry production systems can inform blueberry farmers about the profitability of different options. For this purpose, a typical production system approach was adopted, involving interviews with farms and focus groups with experts to define the typical status quo blueberry production systems and to identify the potential impacts of peat reduction under both peat-reduced and peat-free scenarios. A dynamic investment analysis was carried out to analyze the profitability effects of peat reduction and peat elimination as compared to the typical status quo production systems. The findings reveal two typical production systems for blueberry cultivation, namely cultivation in 'artificial soil' and in 'container'. The results show that a complete replacement of peat is not profitable in both systems. Although it is possible to reduce the peat used in 'artificial soil' and 'container' production systems to 50% and 25% respectively, this would entail considerable financial losses.

1. Introduction

Blueberries are the third most popular berry after strawberries and raspberries in Germany based on the per capita consumption (AMI 2023). Demand for blueberries in Germany has increased more than tenfold in the last two decades (Kopp 2022). Although the area under cultivation has steadily increased, production has not kept pace with demand. There are two reasons for this disparity. On the one hand off-season demand increased heavily. On the other hand, there is a lack of suitable blueberry production regions (Harb and Streif 2006). Consequently, various substrate-based production systems have been developed in Germany to overcome the limitation.

Traditionally substrate-based blueberry production systems relied on the use of large quantities of pure peat to imitate the natural growing conditions (Heiberg and Lunde 2006; Tasa et al. 2012; Kingston et al. 2020). Additionally, since the peat used for cultivation degrades over time, it is necessary to replenish the peat regularly (Winter et al. 2002). However, the use of peat in agricultural production has been challenged in recent years, primarily due to its negative climate impacts, i.e. the carbon emission due to its use and the loss of carbon sequestration potential in depleted peatlands (Dirksmeyer et al. 2020). These concerns have been addressed in the 'German Climate Action Plan 2050 (German: Klimaschutzplan 2050)' and 'Climate Action Program 2030 (German: Klimaschutzprogramm 2030)' launched by the German government. These initiatives include plans to reduce peat use and to promote the use of sustainable alternatives to peat-based substrates (BMEL 2019).

However, when the effect of reducing peat use on the physiology of blueberry plants and harvest levels are well documented (Iancu et al. 2008; Ortiz-Delvasto et al. 2023; Pinto et al. 2017; Ochmian et al. 2010; Krewer et al. 2002; Xie and Wu 2009; Fang et al. 2022; Yang et al. 2022; Kingston et al. 2020), there is limited research on the financial implications of the reduction in peat use at the farm level. This paper aims to address this gap by analyzing the financial effects of changes in substrate composition (peat-reduced and peat-free) in two different blueberry production systems in Germany using a dynamic investment analysis.

2. Data, Methods and Approach

The dataset utilized in this paper originates from the ToPGa project, a collaborative research project. The data was collected, following the typical production system approach. A typical production system reflects a predominant cultivation practice of a specific crop in a defined region (Chibanda et al. 2020). This approach ignores farm-specific variances and facilitates a generalized assessment of the impact of changes in the production system such as reductions in peat use.

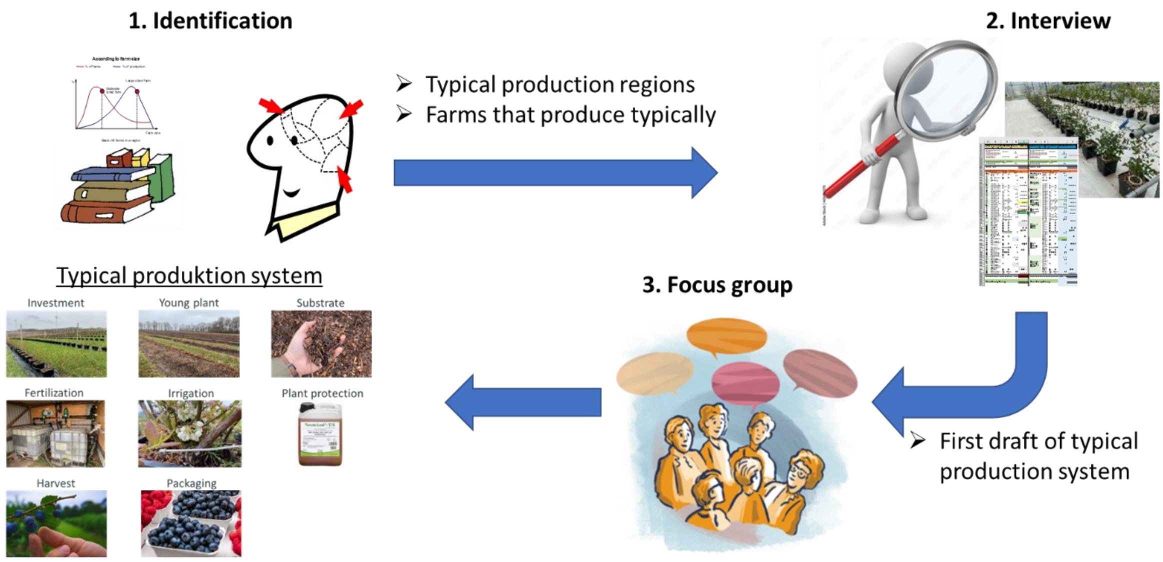

Figure 1: Steps of typical production system approach (Hirschler and Kretzschmann 2022)

Figure 1 illustrates the methodological framework to establish the typical production systems for blueberries. The process consists of three interconnected stages: (1) Identification: Literature review and blueberry experts from Chamber of Agriculture in Lower Saxony and in NRW were consulted to identify the existing knowledge on typical production regions and identify representative farms. Based on the information from the preliminary research, farm survey questionnaires were developed and used to capture the necessary farm-level information for developing typical production systems. This included essential farm details, materials, machinery, and labor employed in each production step. Following the case study approach, 14 farms were selected for the survey based on expert recommendations representing typical farm size, technology use, and farm management practices. The farms had on average one hectare of blueberry cultivation area and are located in Lower Saxony. (2) Interview: Among the chosen farms, 12 surveys were conducted in person during farm visits in February 2023, with two exceptions conducted online due to COVID-19 contact restrictions. Subsequently, the collected survey data was analyzed to develop a preliminary model of the typical blueberry production systems. (3) Focus group: This preliminary model was then validated through a focus group discussion on 12th October 2023 comprising 15 experts including researchers, consultants, and farm managers. In this focus group, the assumptions about the relevant details of the typical production systems were discussed and adapted if necessary. Also, the focus group session was employed to establish hypothetical peat-reduced production systems.

The data was analyzed using the dynamic investment analysis approach, a method to analyze investments incorporating discount rate and utilization period in the calculation, to evaluate the expert-validated typical status quo production systems, as well as peat-reduced and peat-free production systems. This approach was selected due to the long utilization period of the production systems, which spans between 10 to 20 years, and recurring maintenance costs, which include the regular refilling of containers or rows with the substrate. Key figures employed in the analysis include net present value (NPV), internal rate of return (IRR), amortization period, and equivalent annual annuity (EAA) (Brent 1996; Brandes and Odening 1992). The EAA approach, which converts NPV into an average annual cash flow, was specifically adopted to facilitate a direct comparison of peat-reduced scenarios with different utilization periods.

3. Results and Discussion

Based on the typical production system approach, two typical production systems, namely cultivation in artificial soil and in containers, were identified as the most prominent substrate-based blueberry production systems in Germany. The 'artificial soil' production system is applied for open field production where the soils are unsuitable for blueberry plants. Large quantities of peat are applied to improve the soil conditions and to bring the soil closer to the natural soil for blueberry cultivation.[1] Porous soils such as sandy loams, loamy sands, and coarse sands with a high organic matter content are suitable for such a soil improvement (Foulk et al. 2014). In the 'container' production system blueberries are produced independently from natural soil in containers traditionally filled with peat-based substrates.

Table 1 provides a summary and comparison of important characteristics of the two typical substrate-based blueberry production systems mentioned. Both systems share similarities in terms of the age of the young plants, plant distance, yield per hectare, and product price. Each system utilizes 3,000 three-year-old young plants per hectare, planted 1 meter apart with 3.3 meters between rows, resulting in a typical yield of 7,000 kg per hectare under similar environmental conditions and plant varieties. The main differences between the production systems lie in the substrate quantity and utilization period of the plantation. In the 'artificial soil' production system, the quantity of substrate is 900 m³/ha, which is 5,5 times more than in the 'container' production system with only 165 m³/ha. The average

[1] According to Winter et al. (2002), the natural soil for blueberry plants, such as peatland or pine forest, has a humus-rich, moist, but not waterlogged, well-aerated topsoil with a pH ($CaCl_2$) value between 3.5 and 5.0.

utilization period for blueberry plants is 20 years in the 'artificial soil' and 15 years in the 'container' production system.

Table 1: Comparison of the typical substrate-based production systems 'artificial soil' and 'container'

Variable	Unit	Artificial soil	Container
Age of young plant	Year	3	3
Plant density	Plants/ha	3,000	3,000
Substrate quantity	m^3/ha	900	165
Utilization period	Year	20	15
Yield per ha	kg/ha	7,000	7,000
Price per kg	€/kg	5.0	5.0

The substrate composition varies significantly between the two types of blueberry production systems, as depicted in Figure 2. In the current 'artificial soil' production system, blueberry plants are typically cultivated using 100% peat, whereas in current 'container' production system, the typical substrate contains only 33% peat, with the remainder being coconut coir and sawdust in equal shares. During the focus group discussions, participants identified two different peat reduction strategies. One of them is characterized by maximizing peat reduction while constraining profitability reduction to financially sustainable level. Hence, this strategy was intended to have only a moderate financial effect from peat reduction. On the other hand, a strategy with more ambitious peat free varieties was also discussed. As a result of these discussions, a 50% peat content in the 'artificial soil' production system and a 25% peat content in the 'container' production system were suggested as moderate peat-reduced scenarios (Figure 2). The extreme case for both production systems was defined with full substitution of peat, however, the composition of peat-free substrates in the production systems differ from each other.

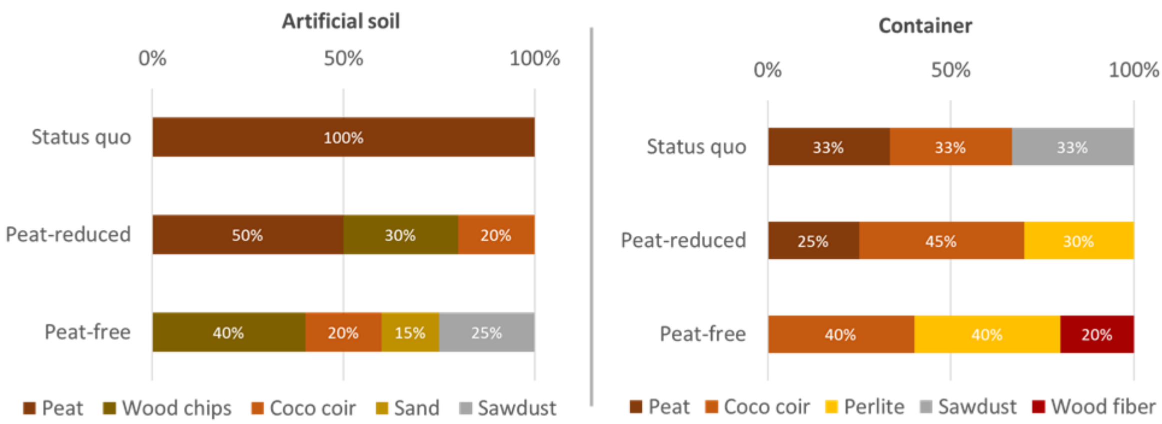

Figure 2: Substrate composition of typical blueberry production systems

The impact of peat reduction on investment costs is relatively low in the 'container' production system compared to the 'artificial soil' production system, which corresponds to the large difference in the amount of substrate used in the two systems. Figure 3 provides the results of an initial investment cost comparison at year 0, outlining the main effects of peat reduction in blueberry production systems under different scenarios: status quo, peat-reduced, and peat-free.

In the current 'artificial soil' production system, substrate costs account for 41% of the total investment cost (Figure 3). Peat substitutes tend to be more expensive, resulting in higher substrate costs with peat reduction. For instance, increasing the substrate cost from 30 €/m³ to 40 €/m³ in the 'artificial soil' production system with 50% peat content raises the total investment cost by 9,000 €/ha, making the substrate cost account for 48% of the investment cost. With the peat-free substrate priced at 60 €/m³, the investment cost rises by 27,000 €/ha in this production system with the substrate portion comprising 58% of the total investment cost.

In contrast, based on farm survey and focus group, substrate costs constitute a smaller part of investment costs in the 'container' production system (Figure 3). Substrate costs at 60 €/m³ in the current production system comprise 15% of the total investment cost. Peat-reduced substrate costs 70 €/m³ in the 'container' production system and it increases the total investment cost by 1,650 €/ha or 2%, while peat-free substrate costing 80 €/m³ in this system contributes to a 3,300 €/ha or 5% higher investment cost.

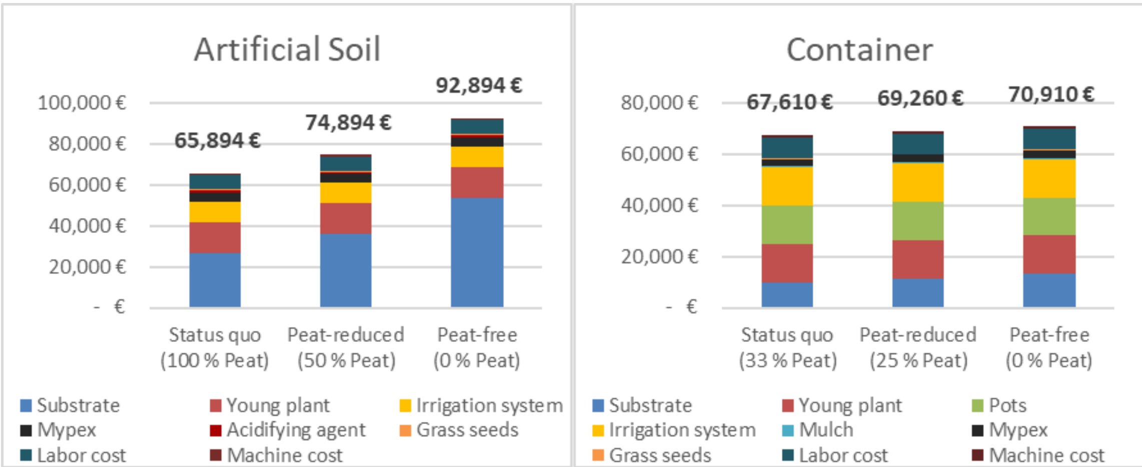

Figure 3: Comparison of initial investment costs for typical blueberry production systems, ‘artificial soil’ and ‘container’ for status quo, peat-reduced, and peat-free scenarios.

Results of the dynamic investment analyses show the significant financial impact of peat reduction and elimination on the typical status quo production systems (Table 2). In the 'artificial soil' production system, reducing peat usage compared to the status quo decreases the utilization period by 3 years and increases substrate costs. This results in a 66% reduction in NPV and a decrease in the equivalent annual annuity (EAA) by 4,724 €/ha. Additionally, the internal rate of return (IRR) is 6.45 percentage points lower, and the amortization period is extended by 3 years. Complete elimination of peat in the 'artificial soil' production system further reduces the utilization period by 5 years and significantly increases substrate costs. This results in a negative NPV and EAA, with the IRR falling 1.8 percentage points below the discount rate, indicating an economically unviable scenario. In the 'container' production system, reducing peat usage compared to the status quo leads to a 61% decrease in NPV and a reduction of 3,826 €/ha in EAA. The IRR is 5.62 percentage points lower, and the amortization period is extended by 2 years. Additionally, peat-free production results in a negative NPV of -6,414 €/ha and an IRR below the discount rate, making full amortization impossible within the utilization period.

Table 2: Results of the dynamic investment analysis across the two typical production systems, 'artificial soil' and 'container', with status quo, peat-reduced, and peat-free scenarios

Variable	Unit	Artificial soil			Container		
		Status quo (100% Peat)	Peat-reduced (50% Peat)	Peat-free (0% Peat)	Status quo (33% Peat)	Peat-reduced (25% Peat)	Peat-free (0% Peat)
Utilization period	Years	20	17	15	15	13	10
NPV*	€	102,927	34,666	- 13,866	74,732	28,917	- 6,414
IRR	%	14.69	8.24	2.22	14.52	8.90	2.47
Amortization period	Year	9	12	-	8	10	-
EAA*	€/year	7,574	2,850	- 1,247	6,722	2,896	- 791

* Discount Rate = 4%

4. Conclusions

On the one hand, the dynamic investment analysis shows that peat-free blueberry production is currently not financially viable with existing technology for both 'artificial soil' and 'container' systems. Reducing peat use to 50% in 'artificial soil' and 25% in 'container' systems remains profitable but extends the amortization period by two to three years and reduces net present value returns by over 60%. Therefore, reducing peat use significantly lowers the financial appeal of blueberry cultivation in these production systems.

On the other hand, it is noticeable that transitioning from the 'artificial soil' production system to the 'container' production system can also significantly reduce peat usage while minimizing financial drawbacks. The 'container' system requires only one-sixth of the substrate needed by the 'artificial soil' system, and its substrate contains just one-third of peat. As a result, this structural change alone can reduce peat use by more than 90%. The transition to 'container' production system will incur an addition cost equivalent to 27% of NPV or 852 €/ha in equivalent annual annuity (EAA) from the current 'artificial soil' production system, which is significantly lower than the cost from peat reduction within the existing system.

The main risks of reducing peat include higher substrate costs, shorter utilization periods, and reduced harvest levels. To address these, advances in substrate technology and better sourcing of alternatives are needed. Furthermore, future innovations like sensor-based irrigation and fertigation, as well as efficient production systems like raised substrate beds, could help adapt to new substrates. Additionally, effective knowledge sharing and model and demonstration projects will also likely catalyse the transition. Therefore, further research into technological innovations for substrates, production systems, precision farming, and knowledge transfer is recommended.

Finally, questions remain about how different compositions of peat-reduced and peat-free substrates might impact current blueberry production systems, including substrate price and berry yield. This paper analyses only one variant of substrate mixtures, highlighting the need for further research into the financial and agronomic effects of alternative substrate compositions.

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