

Irrigation gaps and subsidy readiness in Hungarian forest nurseries

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Abstract: Climate change is intensifying pressures on European forest-nursery production, particularly during drought periods, yet no comprehensive national-level assessment of irrigation infrastructure and development needs has existed for the Hungarian sector. This study characterised irrigation infrastructure, willingness to participate in subsidy schemes, and development priorities among responding Hungarian forest tree nurseries, and assessed regional differences and associations among these characteristics. An anonymous online questionnaire was distributed to all 426 registered Hungarian forest nurseries. Over 20 days, 150 valid responses were received (35% response rate). Potential non-response bias was assessed using three complementary methods. Data were analysed with Fisher's exact tests, Cramér's V effect sizes, and binomial logistic regression with multimodel inference ('glmulti') in R. National statistics indicated a heterogeneous nursery production structure: the smallest nurseries (≤ 1 ha) accounted for only 2.5% of the total nursery area but produced 25% of all seedlings. Against this sectoral background, the survey revealed a substantial irrigation gap among respondents, with 40% of responding nurseries reporting no irrigation infrastructure. Overall, 62% of respondents indicated willingness to participate in irrigation-development programmes. Existing infrastructure did not show a strong correlation with subsidy-participation intentions; there was only a minor correlation among some parameters of existing infrastructures and preferred development goals, whereas the multivariable logistic model explained only modest variance (McFadden $R^2 = 0.14$; $AICc = 119.5$). The most frequently requested development components were pump purchases (66%) and water-source improvements, including new wells and water permits (52%). The survey findings indicate substantial unmet irrigation infrastructure needs alongside considerable subsidy interest among respondents, suggesting that targeted public investment could effectively modernise the sector and enhance its climate resilience.

Keywords: climate adaptation; forest nursery sector; Hungary; precision irrigation; subsidy programmes; water management

Climate change and associated drought have elevated irrigation to a strategic priority for maintaining forest nursery productivity and agriculture (Vaulin 2022; McCauley et al. 2024). In Hungary, observation-based analyses using the Forest Aridity Index indicate a shift towards drier forest-climate

conditions between the 1961–1990 and 1981–2010 reference periods (Führer 2018). Climate-envelope projections further suggest that conditions suitable for heat- and drought-tolerant tree species are likely to expand in Central Europe (Illés, Móricz 2022). Shifting precipitation patterns and intensifying heat-

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waves can compromise seedling production and increase the need for supplemental irrigation during dry periods (Iglesias, Garrote 2015), while modern precision systems rationalise quality nursery output by enhancing water-use efficiency and supporting germination, root development, and late-frost protection (South, Nadel 2020; Durló et al. 2025; Găitan et al. 2025). Conventional methods entail water waste and uneven distribution; data-driven precision approaches are therefore required. Recent systems integrate sensor monitoring (Florea et al. 2023), automation, and machine-learning algorithms to deliver water precisely when and where needed, reducing consumption and environmental load while improving seedling resilience under adverse conditions (Oğuztürk 2025; Jobbágy et al. 2021; Lakhiar et al. 2024). These systems can also support fertigation and the application of plant-protection products, thereby improving the efficiency and precision of input use. In container-grown forest seedlings, fertigation refers to the application of nutrients through micro-sprinkler irrigation water. This approach allows nutrient supply to be more closely matched to plant demand than when nutrients are incorporated directly into peat, and may therefore improve nutrient uptake and overall nutrient-use efficiency.

Among forest nurseries, irrigation solutions include drip, micro-sprinkler, hose-reel, and sprinkler systems, the choice of which is governed by production purpose and conditions (Aldhous, Mason 1994; South, Nadel 2020; Klimek et al. 2009; Spinelli et al. 2024). Drip irrigation is water-efficient but, in forestry contexts, its higher labour and material demands render it less effective than overhead systems. Sprinkler systems are simpler to operate, and micro-droplet or pressure-regulated technologies reduce evaporative losses and improve uniformity. Information technologies are also applicable in container production for precise environmental control.

In Europe, irrigation systems have become fundamental infrastructure for forest nurseries. The sector has prioritised sustainability and resource efficiency, consistent with EU directives and national water and digitalisation policies (Hoyk et al. 2022; Andreassen et al. 2023). In Hungary, the adoption of precision irrigation, including in afforestation, faces economic barriers, necessitating a reassessment of nursery-sector support policy for climate adaptation.

A recent development in Hungary was the introduction of the KAP-RD40-RD12-1-26 funding scheme, Support for Investments Promoting Competitive Forest Management, published in February 2026 under the Hungarian Common Agricultural Policy Strategic Plan. The call explicitly included the establishment and modernisation of on-site irrigation systems in forest tree nurseries, as well as investments in machinery and equipment used for forest reproductive material production. Applications could be submitted between May and September 2026.

Before February 2026, however, there had been no irrigation-related funding scheme specifically targeting forest tree nurseries. Under earlier calls, Hungarian nurseries were often excluded in practice because of administrative eligibility criteria, such as minimum shares of agricultural revenue, the main target area of the support scheme, or requirements related to the composition of the applicant's turnover.

The required level of own contribution is also an important consideration. Forest tree nurseries are currently not necessarily in a liquidity position that would allow them to undertake investments even under a 65% support intensity, as required under the 2026 call. In addition, the often lengthy processing and reimbursement periods associated with such schemes may require sufficient liquidity to bridge one to two years. Many Hungarian nursery enterprises have limited capital reserves, which may further constrain their ability to participate in investment-support programmes.

Against this background of limited access to dedicated support and potentially substantial financial constraints on investment, up-to-date information on irrigation infrastructure and development needs is particularly important for designing effective support measures. No comprehensive recent survey has examined the irrigation status and development needs of the Hungarian forest tree nursery sector, while the scope and detail of nursery data collection vary considerably across European countries. The specific objectives of this study were to (i) characterise the distribution of nursery area and seedling production using national statistics for 2023–2024; (ii) describe irrigation availability, irrigation system types, water sources, and system age among responding nurseries, together with their willingness to participate in subsidy schemes and their preferred development options; (iii) assess

regional differences in irrigation characteristics, subsidy willingness, and development preferences; and (iv) examine associations among existing irrigation infrastructure, subsidy willingness, and preferred development options. The findings may inform future support programmes and improve water use, productivity, and climate resilience.

MATERIAL AND METHODS

Data collection

The study was based on an anonymous online questionnaire distributed by the Forestry and Energy Propagation-Material Product Council to managers of Hungarian forest nurseries. Anonymity enhanced response reliability on sensitive questions. The questionnaire remained accessible for 20 days; 150 responses were received (35% response rate), with two e-mail reminders sent during that period.

With a response rate of 35%, the representativeness of the sample cannot be assumed. Voluntary participation may have resulted in an overrepresentation of nursery operators with a particular interest in irrigation development. As the questionnaire was anonymous, individual responses could not be linked to nursery-level administrative characteristics, and irrigation availability and subsidy willingness among non-respondents remained unknown. Although the available data did not allow formal statistical testing of non-response bias, three complementary approaches were applied to gauge its likely magnitude.

Survey structure

The questionnaire comprised ten closed-ended items as follows: Q_1 : presence of irrigation (T/F); Q_2 : irrigation type (five types or mixed); Q_3 : water source (well, pond or mixed); Q_4 : water source registered (T/F); Q_5 : water source operational permit (T/F); Q_6 : irrigation-system age (0–5, 5–10, 10–20, 20+ years); Q_7 : subsidy participation willingness (T, F, three reasoned F options); Q_8 : minimal subsidy intensity (30%/50%/60%/70%); Q_9 : intended developments (multiple choice, 11 options covering water source, irrigation hardware and control systems) and Q_{10} : nursery region.

Data processing

After closure, responses were exported, screened for inconsistencies, and restructured for analysis. Corrections and transformations applied are summarised in Table 1. Microsoft Excel (Version 365)

was used for processing; statistical analysis was conducted in R (Version 4.5.2., 2025).

Hereafter, Q_7 is referred to as 'subsidy willingness', whereas Q_{7a} is referred to as 'subsidy willingness binomial'. Q_9 was completed by respondents irrespective of their response to Q_7 and therefore reflects preferred development options across all responding nurseries, including those unwilling to participate in a subsidy programme. Accordingly, all Q_9 responses were included in the subsequent analyses.

For a context-setting reference of the sector, 2023–2024 area and production statistics for all Hungarian forest nurseries were used, supplied by the Forestry Propagation-Material Supervision Department. Inequality of area and output between nurseries was compared visually and quantified using the Gini coefficient (Gini 1912). As the statistics of Central and Western Transdanubian nurseries were similar and both contained limited observations, they were merged into a 'Northern Transdanubia' region for subsequent analyses.

Non-response bias check

As the survey targeted the entire small population (426 forest nurseries) and achieved a 35% response rate, three complementary checks were applied.

First – answer rate vs irrigation rate by region. No clear association was observed between regional survey response rates and the proportion of respondents reporting irrigation infrastructure (Figure 1). Irrigation prevalence varied approximately twice as widely among regions as response rates, and regions with higher response rates did not consistently show greater irrigation prevalence, indicating that well-irrigated nurseries were not markedly more likely to respond.

Second – irrigation indicators vs day of response. Wave analysis is the accepted approach for non-response bias assessment in postal surveys (Armstrong, Overton 1977). Here, two weeks elapsed between first and last response. Although the window did not permit a full wave analysis, response-day patterns in irrigation availability and subsidy willingness were examined (Table 2; Figure 2).

Irrigation availability and mean irrigation system points were consistently higher among late respondents, which argues against the assumption that non-respondents had lower irrigation potential.

Third – correlation between response rate and irrigation possibility. Shapiro–Wilk testing

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Table 1. Corrections and restructuring of survey data

Q_i^1	Condition	Change	Frequency ²
Q_1	$Q_1 = 'F'$ and Q_2-Q_5 is given	Q_1 to 'T'	2
Q_2	Q_2 is given and Q_1 ; Q_3 ; $Q_4 = 'F'$	Q_2 to 'no irrigation'	2
Q_2	multiple values given	Q_2 to 'combined'	26
Q_2	$Q_2 = 'micro\ sprayer'$ then Q_{2a} as frost protection availability	Q_{2a} to 'T'	47
Q_3	Q_3 given and Q_1 ; $Q_2 = 'F'$	Q_3 to 'F'	1
Q_3	$Q_3 = 'well'$ and 'pond'	Q_3 to 'pond' (as it is the better, more relevant option)	16
Q_4-Q_6	–	unchanged	–
Q_1 ; Q_2 ; Q_3 ; Q_6	calculation with weighing ³	Q_{6a} to value from 1 to 5 rounded to 0.5	all
Q_7	$Q_7 = 'T'$ then Q_{7a} (willingness to participate for subsidy, binomial) to 'T' otherwise 'F'	Q_{7a} to 'T' or 'F'	all
Q_8	–	unchanged	–
Q_9	new columns based on the 11 categories in 3 groups (water source, irrigation, controllers)	Q_{9a-k} : 'T'/'F' for each separate category Q_{9j} : upgrade type based on 3 groups ⁴ Q_{9m-o} : cumulated value for each group ⁵	all
Q_{10}	Q_{10} is an invalid value in 4 cases	Q_{10} to 'none'	4

¹Questionnaire item(s) i (1–10) on which the correction or restructuring was based; ²frequency: the amount of records edited; ³the evaluation of the irrigation system: the product of 4 parameters (Q_1 ; Q_2 ; Q_3 ; Q_6) rated from 1 to 5 under fourth root (Q_1 : 'T' – 5, 'F' – 1; Q_2 : 'none' – 1, 'hose reel irrigator/sector water canon' – 2, 'irrigation boom/drip irrigation' – 3, 'micro sprayer/combined' – 4, 'combined with micro sprayer' – 5; Q_3 : 'none' – 1, 'well' – 3, 'pond' – 5; Q_6 : 'none' – 1, '20+' – 2, '10–20' – 3, '5–10' – 4, '0–5' – 5); micro sprayer got a higher value for additional late frost protection; ⁴the 11 development options in Q_9 were aggregated into three domains: water-source development (first three options), irrigation-system development (next six options), and control-system development (last two options); selection of at least one option within a domain indicated membership in that domain, resulting in seven possible non-empty combinations plus a category for no selected development; ⁵number of affirmative ('T') responses within each group; T – true; F – false

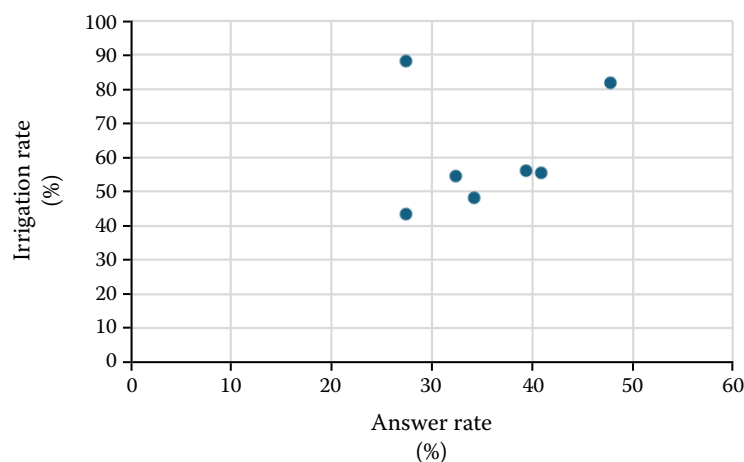


Figure 1. Relationship between regional survey response rates and the prevalence of irrigation among responding forest nurseries

Each point represents one of the seven Hungarian regions

Table 2. Irrigation systems by day of survey response

Day of answer	Irrigation	No irrigation	Irrigation rate (%)	Mean irrigation system points	Subsidy willingness (%)
1	22	14	61	2.71	72
2	14	14	50	2.34	57
3	29	21	58	2.52	54
4	16	9	64	2.74	72
5	3	0	100	4.33	67
7	4	2	67	2.92	50
8	1	0	100	4.50	100
13	0	1	0	1.00	0
Days 1–2	36	28	56	2.55	65
Days 3–4	45	30	60	2.59	60
Days 5+	8	3	73	3.27	55
Summary	89	61	59	2.62	62

indicated a normal distribution of response rates by region ($P > 0.05$), so Pearson correlation test was applied ($R = 0.13$, $P = 0.77$), indicating no statistically significant relationship between regional survey response rates and irrigation availability.

Together, the three checks provided no evidence that non-respondents had lower irrigation rates or development willingness; the applied methods did not indicate regional or response wave differences, but non-responder bias cannot be fully excluded.

Statistical analysis

The analyses pursued two aims: identifying regional variation and identifying factors most strongly predictive of subsidy willingness.

For regional variability, Fisher's exact tests were run, first without P -value adjustment, then Holm adjusted P -values were calculated for region and 10 different variables (simulated P -values, 500 000 iterations; R Core Team 2025). Cramér's V was also calculated, bias correction was applied, and confidence intervals were calculated with the non-central chi-square method (Signorell 2025). Four records with missing regions were excluded. Water-source analyses excluded non-irrigated nurseries.

To identify drivers of subsidy willingness, Fisher tests first highlighted significant relationships, after which a binomial logistic regression was fitted using 'glmulti' (Calcagno, de Mazancourt 2010), testing 32 768 candidate models with the variables age, irri-

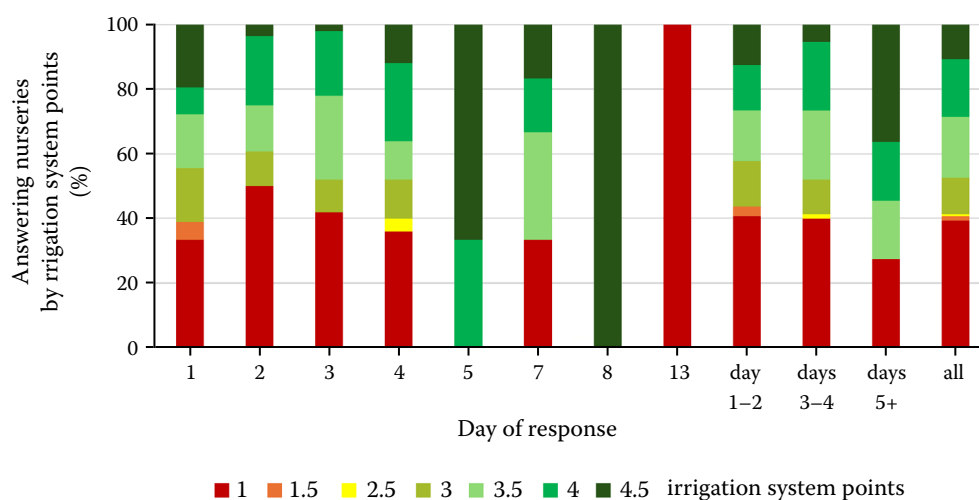


Figure 2. Irrigation system points by day of survey response

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gation availability, irrigation type, water source, and system points. Model performance was assessed using McFadden pseudo- R^2 . Predictors of each specific development option were then examined with unadjusted Fisher tests, then P -values were adjusted using Holm adjustment and Cramér's V values were also calculated for each test. In cases where the adjusted P still showed a significant connection, cells were marked. Analyses involving characteristics defined only for irrigated nurseries were restricted to respondents with an irrigation system, whereas analyses involving region excluded the four respondents with missing regional information. All respondents were retained in analyses of development options.

RESULTS AND DISCUSSION

Survey participation. Of the 426 registered forest nurseries, 150 completed the questionnaire, corresponding to an overall response rate of 35% (Table 3). Regional information was available for 146 respondents, whereas four respondents did not report their location. Regional response rates ranged from 27% in the Southern Great Plain and Northern Great Plain to 48% in Northern Hungary.

Structural characteristics of the forest nursery sector. Table 4 indicates a markedly unequal regional distribution of nursery area and production. The relationship between output and area is weak, and ten-fold differences are common. The largest nurseries are in the Southern Great Plain, while production is regionally more balanced. Area shares vary by a factor of more than 10 000 between the smallest micro-nurseries and the largest state-forest enterprise holdings.

The average share in the area of nurseries by region differs by a factor of 30, with the lowest

in Southern and Central Transdanubia and the highest in the Southern Great Plain, but the average share in production differs by a factor of only 3.3. After excluding nurseries that had no production for one or two years ($n = 148$), mean annual production is approximately 630 000 seedlings per nursery (0.35% of total output). An area of 10 ha corresponds to approximately 0.35% of the total national nursery area. Nevertheless, 42 nurseries (10% of all nurseries) had areas not more than 10 ha but produced at least 630 000 seedlings annually; 17 of these high-output nurseries occupied less than 1 ha (Figure 3). This demonstrates that high output is feasible even on below-average areas.

As Figure 4 shows, nurseries with an area of less than 1 ha (2.5% of the total area) account for 25% of all production. The Gini index for areas is 72, and 80 for output (Table 5). Within regions, area inequalities vary substantially (Gini: 3–51), while production is even more unequally distributed (Gini: 69–82).

Although it is not known from the survey how many nurseries could cover the full market assortment with their current output, one possible interpretation of the observed production patterns is that the number, potential output and total area of nurseries may exceed what is needed to meet forestry sector seedling demand. This potential imbalance may partly explain why many nurseries that remain operational do not produce seedlings at full capacity or are temporarily inactive in seedling production.

Principal survey findings. The survey revealed that 40% of responding nurseries have no irrigation technology, indicating a basic production-security deficit in a substantial part of the sector and a competitive disadvantage, as several EU competitors already apply IT- and AI-based systems for certain production solutions (Andreasen et al. 2023).

Table 3. Main survey statistics by region

Region	Nurseries answering	Answer rate (%)	Irrigation rate (%)	Mean system points (Q_{6a})	Mean subsidy willingness (%)
Southern Great Plain	17	27	88	3.62	71
Southern Transdanubia	48	39	56	2.54	52
Northern Great Plain	23	27	43	2.13	74
Northern Hungary	11	48	82	3.18	91
Central Transdanubia	11	32	55	2.68	55
Western Transdanubia	27	34	48	2.31	56
Pest County	9	41	56	2.33	78
Missing	4	–	100	3.29	25
Summary	150	35	59	2.62	62

Table 4. Overall statistics of the Hungarian forest tree nursery sector, 2023–2024

Region	Area of nurseries (ha)	Share by area (%)	2023/2024 average output (1 000 seedlings)	Number of nurseries	Mean area (ha)	Median area (ha)	Mean output (1 000 seedlings/nursery)	Share by production (%)
Southern Great Plain	1 797	63	30 548	62	29.0	20.6	493	17
Southern Transdanubia	476	17	65 573	122	3.9	2.4	537	37
Northern Great Plain	183	6	24 534	84	2.2	1.0	292	14
Northern Hungary	206	7	18 685	23	9.0	11.8	812	10
Central Transdanubia	49	2	8 392	34	1.4	1.5	247	5
Western Transdanubia	85	3	24 909	79	1.1	1.3	315	14
Pest County	69	2	5 662	22	3.1	3.2	257	3
Summary	2 865	100	178 303	426	6.7	1.9	419	100

Among irrigated nurseries, micro-sprinklers were the most common systems (32%). Hose-reel and drip systems were reported by 19% and 15%, respectively. Overall, 42% of responding nurseries (70% of irrigated nurseries) used water-efficient multipurpose equipment. 63% of systems were more than 10 years old, with drip systems generally newer than other types. Most irrigated nurseries used wells directly, and only 40% had a storage pond.

Overall, 62% of respondents would participate in an irrigation-development programme. Two-thirds of irrigated nurseries would upgrade their systems, while market uncertainty and water-permit difficulties were the principal barriers among those unwilling to participate. Among non-irrigated nurseries, 57% would participate, 27% did not plan irrigation, and 10% cited market conditions.

Pumps (66%) and well drilling and water permitting (52%) were the most requested investments, followed by control systems (45%); reservoirs, hose reels, and micro-sprinklers (40% each); and fertigation (30%). Drip and sprinkler systems were selected less frequently. Respondents selected a mean of 4.5 options (mode: 4). Combined water-source, irrigation-equipment, and control investments were selected by 38%, compared with water source and equipment only (28%) or equipment only (13%). Overall, 90% selected irrigation-system establishment or upgrading, whereas approximately half selected precision components.

Regional differences. For regional analysis, Central and Western Transdanubia were merged into Northern Transdanubia. Fisher's exact test results are summarised in Table 6 (Cramér's V ranges: weak 0–0.3, moderate 0.3–0.7, strong > 0.7).

Raw Fisher tests P -values show some differences among regions for 4 parameters, of which only the connection between region and irrigation type is significant after Holm adjustment ($P = 0.003$). Cramér's V values, however, did not indicate strong associations for any of these variables. Region does not appear critical for investment willingness, and no large regional differences exist in irrigation-system characteristics. Only irrigation type showed moderate association, which is partly caused by mixed irrigation types and the differing ratio of less precise irrigation systems in two Great Plain regions. Among the development options, only hose-reel popularity differed significantly across regions (less popular in Transdanubia, more popular in the Northern Great Plain). Based on these

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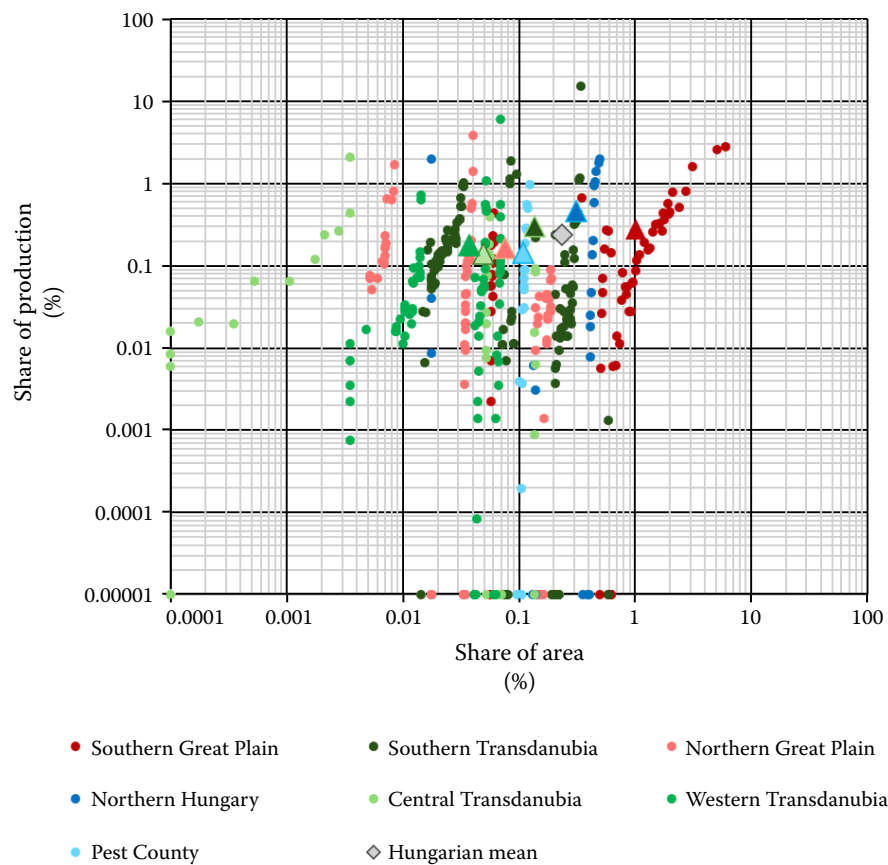


Figure 3. Nursery-level shares of total nursery area and mean annual seedling production in Hungary, by region

Each circle represents an individual nursery, coloured triangles represent regional means, and the grey diamond represents the overall mean; area share was calculated relative to the total nursery area of 2 865 ha, whereas production share was calculated relative to the total mean annual production of 178.303 million seedlings; both axes show dimensionless proportions on base-10 logarithmic scales; 0 values for area were set to 1.0×10^{-5} ($n = 4$) and to 1.0×10^{-6} for production ($n = 71$) so these nurseries also can be shown on the logarithmic graph

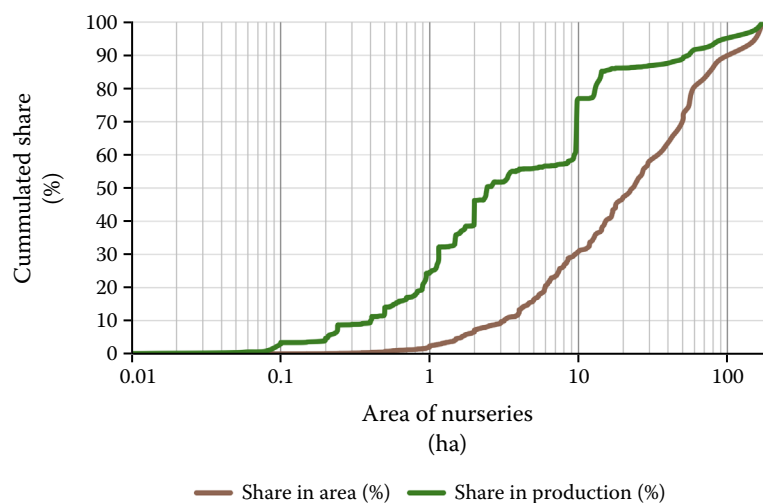


Figure 4. Cumulative shares of total nursery area and mean annual seedling production according to individual nursery area
Nursery area is displayed on a logarithmic scale

Table 5. Inequality of area and production among nurseries by region

Region	Area (ha)			Output (1 000 seedlings)		
	mean	median	Gini	mean	median	Gini
Southern Great Plain	29.0	20.6	51	493	173	69
Southern Transdanubia	3.9	2.4	48	537	104	82
Northern Great Plain	2.2	1.0	47	292	58	81
Northern Hungary	9.0	11.8	28	812	71	72
Central Transdanubia	1.4	1.5	51	247	42	77
Western Transdanubia	1.1	1.3	35	315	58	82
Pest County	3.1	3.2	3	257	73	73
All	6.7	1.9	72	419	90	80

results, region doesn't seem to be a critical parameter in subsequent analyses; thus, the four region-missing records were retained.

Factors affecting subsidy willingness. Among the 32 768 candidate multivariable logistic regression models tested via 'glmulti', the best $AICc$ (Corrected Akaike Information Criterion) was 119.5. However, 31 additional models fell within $\Delta AICc < 2$ (weights 0.018), indicating that no single model was decisively superior. McFadden pseudo- R^2 was uniformly 0.14 across the top 30 models, indicating weak predictive power. Collectively, these results suggest that the measured questionnaire variables provided limited explanatory information and that additional, unmeasured factors may influence will-

ingness to participate in an irrigation-development subsidy programme.

Crude responses indicated that 62% of respondents would participate in irrigation-development programmes; the leading reason for refusal was uncertain market conditions (14%), followed by water-permit difficulties (9%). A more accurate willingness forecast, ideally following a focus-group consultation, would require additional data on the financial and market situation of the nurseries.

Characteristics predicting infrastructure development. Relationships between nursery characteristics and development options are summarised in Table 7. Most characteristic–development pairs showed no significant relationship; where inde-

Table 6. Fisher's exact test parameters across regions

Variables	Conditions	<i>P</i> -value	Holm adj.	Cramér's V (95% CI)
Region (Q_{10}) ~ irrigation possibility (Q_1)	Q_{10} is known	0.028*	0.193	0.219 (0.000–0.409)
Region (Q_{10}) ~ irrigation type (Q_2)	Q_{10} is known, $Q_2 = \text{true}$	0.001***	0.003**	0.268 (0.142–0.374)
Region (Q_{10}) ~ water source (Q_3)	Q_{10} is known, $Q_2 = \text{true}$	0.134	0.446	0.108 (0.000–0.326)
Region (Q_{10}) ~ water source registered (Q_4)	Q_{10} is known, $Q_2 = \text{true}$	0.013*	0.108	0.208 (0.000–0.395)
Region (Q_{10}) ~ water source permit (Q_5)	Q_{10} is known, $Q_2 = \text{true}$	0.08	0.446	0.126 (0.000–0.336)
Region (Q_{10}) ~ irrigation system age (Q_6)	Q_{10} is known, $Q_2 = \text{true}$	0.271	0.542	0.089 (0.000–0.280)
Region (Q_{10}) ~ irrigation system points (Q_{6a})	Q_{10} is known, $Q_2 = \text{true}$	0.074	0.446	0.155 (0.000–0.297)
Region (Q_{10}) ~ subsidy willingness (Q_7)	Q_{10} is known	0.718	0.718	0.000 (0.000–0.1486)
Region (Q_{10}) ~ subsidy willingness binomial (Q_{7a})	Q_{10} is known	0.095	0.446	0.176 (0.000–0.373)
Region (Q_{10}) ~ minimal intensity (Q_8)	Q_{10} is known, $Q_{7a} = \text{true}$	0.012*	0.108	0.180 (0.044–0.293)

*significant at $P < 0.05$; **significant at $P < 0.01$; ***significant at $P < 0.005$; CI – confidence interval

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Table 7. Links between nursery characteristics and chosen development options

Development type	Irrigation possibility		Irrigation type		Frost protection		Water source		Water source registration		Water source permit		System age		System points		Region	
	P	CV	P	CV	P	CV	P	CV	P	CV	P	CV	P	CV	P	CV	P	CV
Subsidy willingness	<u>0.00</u> *	0.47	0.23	0.00	0.86	0.00	0.51	0.00	0.02	0.16	<u>0.00</u>	0.22	0.03	0.22	0.15	0.15	0.72	0.00
	<u>0.00</u> *	0.43	0.32	0.10	0.18	0.12	0.59	0.00	<u>0.00</u> **	0.37	<u>0.00</u>	0.33	0.17	0.16	0.71	0.00	0.27	0.10
Permit	0.02	0.18	0.12	0.21	1.00	0.00	0.33	0.00	<u>0.00</u>	0.30	<u>0.00</u>	0.34	0.30	0.09	0.28	0.10	0.09	0.18
Pump	0.22	0.07	0.09	0.20	0.27	0.09	0.25	0.08	0.62	0.00	0.42	0.00	0.36	0.05	0.27	0.11	0.31	0.08
Pond	<u>0.01</u>	0.22	0.18	0.20	0.35	0.04	0.01	0.26	0.54	0.00	0.63	0.00	0.52	0.00	0.14	0.17	0.81	0.00
Hydrant	0.84	0.00	0.15	0.18	0.21	0.09	0.06	0.18	0.70	0.00	0.46	0.00	0.21	0.14	0.17	0.16	0.10	0.18
Hose reel	0.40	0.01	<u>0.00</u>	0.36	0.83	0.00	0.05	0.20	0.03	0.22	<u>0.00</u>	0.28	0.08	0.21	0.03	0.26	<u>0.00</u>	0.32
Canon	0.71	0.00	0.27	0.15	0.17	0.12	0.64	0.00	1.00	0.00	0.87	0.00	0.86	0.00	0.13	0.18	0.29	0.11
Micro sprayer	1.00	0.00	0.05	0.26	<u>0.00</u>	0.33	1.00	0.00	0.32	0.06	0.81	0.00	0.43	0.00	0.58	0.00	0.11	0.17
Drip irrigation	0.86	0.00	0.02	0.30	0.17	0.12	0.41	0.06	0.02	0.24	0.03	0.22	0.62	0.00	0.39	0.05	0.08	0.17
Control system	0.87	0.00	0.12	0.20	0.09	0.17	0.33	0.00	0.74	0.00	0.74	0.00	0.15	0.16	0.12	0.18	0.25	0.11
Fertigation unit	<u>0.01</u>	0.22	0.08	0.24	0.09	0.15	0.54	0.00	0.43	0.00	0.62	0.00	0.30	0.09	0.43	0.00	0.07	0.20

CV = Cramér's *V* (italics – a medium strength connection, where *adjusted $P < 0.005$, where **adjusted $P < 0.05$); P = Fisher P -value (italics – $P < 0.05$; underline – $P < 0.01$; both italics and underline – $P < 0.005$); population for 1st condition = 150, 2nd–8th conditions = 89, 9th condition = 146

pendence was rejected, Cramér's V values indicated predominantly weak and only a few moderate associations.

Irrigation availability was moderately associated with subsidy willingness (Q_7). However, this association primarily reflected differences in the reasons given for unwillingness rather than differences in the decision to participate. When willingness was analysed as a binary variable (Q_{7a}), Fisher's exact test was not significant and Cramér's V was 0.05, indicating a negligible association; nurseries with existing irrigation were only slightly more likely to participate. Well drilling was selected by 80% of non-irrigated versus 35% of irrigated nurseries. Non-irrigated nurseries also selected water permitting and pond construction more often, but fertigation less often.

Selection of hose-reel systems was significantly associated with existing system type, with a moderate effect size: nurseries with more developed systems were less interested, whereas micro-sprinkler users were more interested, presumably reflecting positive experience. Direct-well users did not select pond construction, unlike nurseries with storage ponds or no water source.

Participation willingness was approximately 70% among nurseries with 10+ years old systems, compared with 55% for newer systems and 57% for non-irrigated nurseries. Among non-participants, non-irrigated nurseries mainly cited market uncertainty or unspecified reasons, whereas operators with newer systems more often cited permitting and administrative burdens.

CONCLUSION

Hungarian forest nurseries show substantial irrigation deficits despite broad willingness to modernise. Market uncertainty, permitting requirements, and administrative burdens remain the main barriers to investment, indicating that support programmes should combine targeted funding with simplified administration. Production is highly concentrated, suggesting that adequately equipped nurseries could meet demand even if their number declines. However, the generally weak associations and the use of only two years of production data limit the evidence available for programme design. Further research should therefore incorporate nursery-level financial, production, and market information.

REFERENCES

- Aldhous J.R., Mason W.L. (1994): Forest Nursery Practice. 2nd Ed. Forestry Commission Bulletin 111. London, HMSO: 270. Available at: <https://cdn.forestresearch.gov.uk/1994/03/fcbu111.pdf>
- Andreasen C., Rasmussen J., Bitarafan Z. (2023): Site-specific seed yield prediction of red fescue (*Festuca rubra* L.) based on drone imaging and local regression models. *Agronomy*, 13: 316.
- Armstrong J.S., Overton T.S. (1977): Estimating nonresponse bias in mail surveys. *Journal of Marketing Research*, 14: 396–402.
- Calcagno V., de Mazancourt C. (2010): glmulti: An R package for easy automated model selection with (generalized) linear models. *Journal of Statistical Software*, 34: 1–29.
- Durlo G., Szymański N., Małek S. (2025): Mobile sensing system for phenotyping of forest seedlings in container nurseries. *New Forests*, 56: 15.
- Florea A., Popa D., Morariu D., Maniu I., Berntzen L., Fiore U. (2023): Digital farming based on a smart and user-friendly IoT irrigation system: A conifer nursery case study. *IET Cyber-Physical Systems: Theory & Applications*, 9: 150–168.
- Führer E. (2018): A klímaértékelés erdészeti vonatkozásai. *Erdészettudományi Közlemények*, 8: 27–42. (in Hungarian)
- Găitan N.C., Batinas B.I., Ursu C., Crainiciuc F.N. (2025): Integrating artificial intelligence into an automated irrigation system. *Sensors*, 25: 1199.
- Gini C. (1912): Variabilità e Mutabilità: Contributo allo Studio delle Distribuzioni e delle Relazioni Statistiche. Bologna, Tipografia di Paolo Cuppini: 158. (in Spanish)
- Hoyk E., Szalai Á., Palkovics A., Farkas J.Z. (2022): Policy gaps related to sustainability in Hungarian agribusiness development. *Agronomy*, 12: 2084.
- Iglesias A., Garrote L. (2015): Adaptation strategies for agricultural water management under climate change in Europe. *Agricultural Water Management*, 155: 113–124.
- Illés G., Móricz N. (2022): Climate envelope analyses suggests significant rearrangements in the distribution ranges of Central European tree species. *Annals of Forest Science*, 79: 35.
- Jobbágy J., Dančaniň P., Kristóf K., Maga J., Slaný V. (2021): Evaluation of the quality of irrigation machinery by monitoring changes in the coefficients of uniformity and non-uniformity of irrigation. *Agronomy*, 11: 1499.
- Klimek A., Rolbiecki S., Rolbiecki R., Malczyk P. (2009): Impact of chosen bare root nursery practices on white birch seedling quality and soil mites (Acari). *Polish Journal of Environmental Studies*, 18: 1013–1020. Available at: <https://www.pjoes.com/pdf-88322-22180?filename=22180.pdf>

<https://doi.org/10.17221/70/2026-JFS>

- Lakhiar I.A., Yan H., Zhang C., Wang G., He B., Hao B., Han Y., Wang B., Bao R. (2024): A review of precision irrigation water-saving technology under changing climate for enhancing water use efficiency, crop yield, and environmental footprints. *Agriculture*, 14: 1141.
- McCauley D., Keller S.Q., Transue K., Wiman N.G., Nackley L.L. (2024): A crop water stress index for hazelnuts using low-cost infrared thermometers. *Sensors*, 24: 7764.
- Oğuztürk G.E. (2025): AI-driven irrigation systems for sustainable water management: A systematic review and meta-analytical insights. *Smart Agricultural Technology*, 11: 100982.
- R Core Team (2025): R: A Language and Environment for Statistical Computing. Vienna, R Foundation for Statistical Computing. Available at: <https://www.R-project.org/>
- Signorell A. (2025): DescTools: Tools for Descriptive Statistics. R Package. Available at: <https://CRAN.R-project.org/package=DescTools>
- South D.B., Nadel R.L. (2020): Irrigation in pine nurseries. *REFORESTA*, 10: 40–83.
- Spinelli G., Bonarrigo A.C., Cui W., Grobowsky K., Jordan S.H., Ondris K., Prieto García C., Redding K., Waldman K.J.Z., Dahlke H.E. (2024): Evaluating the distribution uniformity of ten overhead sprinkler models used in container nurseries. *Agricultural Water Management*, 303: 109042.
- Vaulin A.Y. (2022): A new innovative irrigation method for wood, shrub crops and grapes. *IOP Conference Series: Earth and Environmental Science*, 949: 012089.

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