

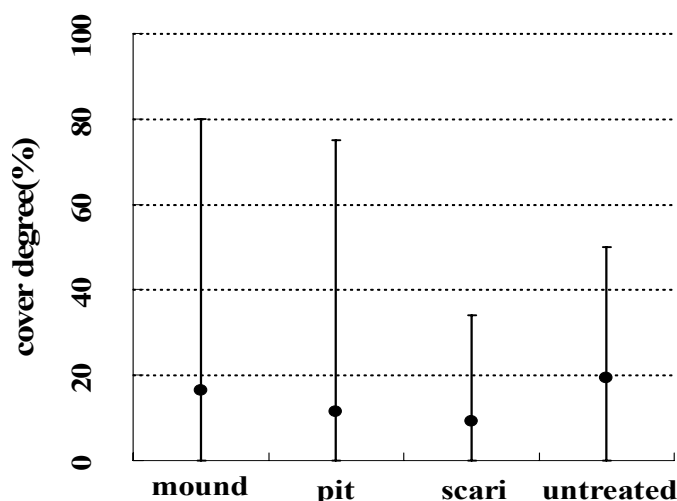


Figure 7. Cover degree of vegetation

6. Conclusion

In this study, the result shows the order of survival rate among planted seedlings from high to low was pit > scarification = untreated > mound. This result would be caused by soil moisture content because of quite dry condition on this test site. Though this result can be referred to silviculture in dry condition, it is expected that different result will be found in humid or mesic condition. Thus it is necessary to do similar study on the hillside or the bottom of slope, or using different species.

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THE INFLUENCE OF FOREST STAND SIZE AND LOCALITY ON THE OPERATIONAL EFFICIENCY OF MECHANISED FOREST OPERATIONS

The sizes of stands on which forest operations are carried out upon, and the distances between pairs of stands, were analysed for four regions comprising all Danish state forests.

Methods of assessing network density included single-linkage cluster analysis, a shortest path density estimate, as well as a simulation of relocation for a harvester and forwarder. Only marginal differences in machine utilisation were found.

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Вплив таксаційних параметрів та розміщення лісового масиву на ефективність машинної заготівлі лісу

Таксаційні характеристики лісоексплуатаційних масивів та відстані між ними проаналізовано в чотирьох регіонах, що охоплюють всі Датські державні ліси. Методи оцінювання густини лісотransпортної мережі включали кластерний аналіз, визначення найкоротшої відстані, а також моделювання руху лісозаготівельної і лісотransпортної машин. Було знайдено тільки граничні відмінності у використанні лісових машин.

Introduction

The level of spatial dispersion of raw materials distinguishes the production environment in forest operations from most industrial production settings. The necessity of having to frequently relocate production units between forest stands incurs a direct transport cost, a set-up cost, an efficiency reduction during the familiarisation phase in a new stand, as well as a subsequent indirect cost of reduced machine utilisation levels.

To some degree, forest operations managers have varying potential for obtaining high utilisation levels on their machines, owing simply to the differences in the underlying structure, or topology, of the forest. Distances between stands, and the size of destination stands play an important role in determining how much time is spent in relocating machinery, as against producing timber (Talbot et al. (2003).

Spatial constraints on forest harvesting have been addressed from a number of perspectives in the References. Both aesthetic and biodiversity issues have been solved for by clustering harvesting through periodic blocks, using algorithms which minimise 'interior edges' (Gustafson (1996) Gustafson (1998)). Economically optimal harvest scheduling can also handle spatial data, for example in the form of an internalised numerical adjacency measure (Tarp and Helles (1997)). However, the majority of procurement studies utilising GIS and explicit spatial analysis deal with biomass supply e.g. Björheden (1997); Borjesson and Gustavsson (1996a); Borjesson and Gustavsson (1996b); Downing and Graham (1996); Forsberg (2000); Gustavsson and Borjesson (1996); Noon and Daly (1996).

The aim of this study is to quantify the effect that the underlying forest stand topology has on the potential to achieve reasonable levels of machine utilisation. Four machine-rings, owned by the Danish Forest and Nature Agency, were chosen as the administrative units of analysis. These machine-rings service all state forests in the country, and are located in geographic regions referred to here as North, Mid, South (all on the Jutlandic peninsula) and East, which covers the island of Zealand (**Figure 1**). It is therefore, a strictly comparative study.

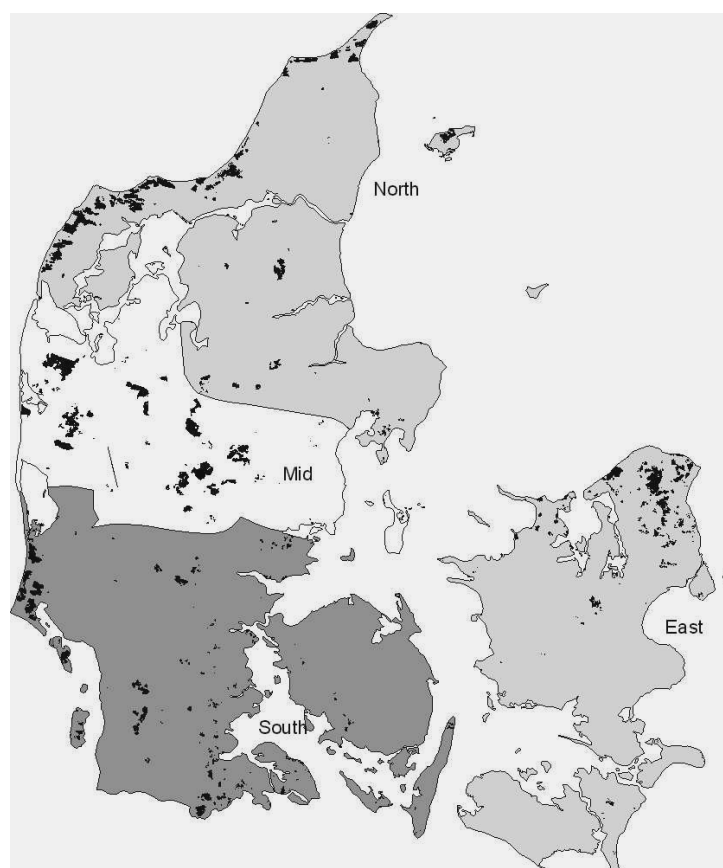


Figure 1. The four operational areas covered by state-owned machine rings in Denmark. The blackened polygons represent coniferous stands included in the study



Figure 2. A map of region 'East' (1:1 200 000), the black quadrants represent the 1 km² grid cells that include at least one coniferous stand

Materials and methods

Universal Transverse Mercator (UTM zone 32 ED 50) co-ordinates of the centroids of all coniferous stands within each of the four operational areas, (**Figure 2**) were determined. Coniferous stands were considered to represent the forest area of interest, as fully mechanised cut-to-length (CTL) operations, are not yet commonplace in hardwood stands. In the forest management database used, individual stands were not directly linked to the forest road network, or to the national road database. Therefore, to overcome the problem of calculating distances between stands, a grid of 1 km² cells was draped over the entire country, using a GIS. All coniferous stands were then accrued to the mid-point of a grid cell. The mid-point of each cell was linked through a line coverage to the national road database. Because of the very high public road density in the country (1-1.5 km km⁻²), misrepresentation associated with this approach, on a regional level, was considered minimal.

The active grid cells were read into the network analyst programme in ArcView[®]. Using the national road database, a script was written to generate matrices of road distances between each pair of active grid cells. Together with data on forest densities, table 1 shows the number (n), of active grid cells in each region. The number of unique shortest routes between all pairs of grid cells is equal to half the matrix of $n^2 - n$.

Table 1. Overview of the extent of the operational areas, forest densities, and grid statistics within each of the four regions

Region	Area (km ²)	Total forest (ha)	Coniferous forest (ha)	Density (ha.km ⁻²)	No. of grid cells
North	11 559	50 290	23 897	2.07	722
Mid	8 491	40 395	23 488	2.77	639
South	13 093	41 635	13 731	1.05	663
East	9 251	37 606	8 611	0.93	576

Owing to the high road density mentioned above, and the consequently large number of nodes in the road network, matrix generation was taxing, requiring 12 to 20 hours per region, utilising a 1.8 GHz processor. This prohibited stand level computations, which in the case of region North, would require the calculation of over 40 million shortest routes.

Cluster analysis

Hierarchical cluster analysis was carried out on the distance matrices using the cluster procedure in SAS[®] (Anon. (1989)). This procedure is commonly used in similarity analyses using co-ordinate data, potentially avoiding having to calculate the distance tables. However, because of large variation in the difference between euclidean and road distances amongst, and within regions (**Figure 3**), the analysis was done on road distance data. The single-linkage method of clustering was chosen as it is most relevant to the purpose of the study, i.e., classifying the effect of distance between stands themselves, and not, for example, between cluster centroids. The single-linkage method can be defined by:

$$D_{KL} = \min_{i \in C_K} \min_{j \in C_L} d(x_i, x_j) \quad (1)$$

which states that the distance between any two clusters (K, L) is given by the shortest distance of all possible combinations of elements in those clusters.

In a second analysis, the distance matrix was weighted by the inverse of the area at the destination. Thus, grid cells with small concentrations of coniferous forest area are penalised in a manner reminiscent of the expense of relocating forest machines to small stands, or large but distant stands.

Simulation

A Monte-Carlo style simulation was carried out in SAS. This involved generating stands, harvesting and forwarding timber, then relocating the machines to the next stand. Time consumption was calculated for each activity. The process was repeated 2500 times for each region. Each element of the simulation is described separately below.

Stand Generator

Stand sizes (ha) were generated from Weibull distributions fitted to the empirical GIS data, the parameters of which are shown in Table 2.

Mean extraction distances were calculated as the square root of the size of the stand generated by the Weibull function (Aedo-Ortiz *et al.*, 2000), with a standard deviation arbitrarily set at 20 % of the mean. Individual tree volumes and the number of stems removed per hectare differ for each of three thinning types, as in

Talbot *et al.* (2003), originally derived from (Anon., 2001). In first thinnings they are normally distributed around $0.05 \text{ m}^3 \text{ stem}^{-1}$ ($1050 \text{ stems ha}^{-1}$) incrementing through $0.16 \text{ m}^3 \text{ stem}^{-1}$ ($560 \text{ stems ha}^{-1}$) to $0.27 \text{ m}^3 \text{ stem}^{-1}$ ($390 \text{ stems ha}^{-1}$) in the third thinning. Thinning number is determined from a uniform distribution.

Table 2. Parameters of empirical stand size distributions, by region

Parameter	North	Mid	South	East
Number of stands (n)	9172	7698	7231	5068
Mean size (ha)	2.61	3.05	1.89	1.70
Shape parameter: Weibull.	2.592	2.962	1.912	1.766
Scale parameter: Weibull	0.990	0.943	1.015	1.0947
Kolmogorov-Smirnov*	0.082	0.078	0.079	0.070

*at 99 % certainty.

Time consumption model

A time consumption regression model for a harvesting system comprising a harvester and forwarder were derived by Talbot *et al.* (2003) and implemented directly in the simulation as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3, \quad (2)$$

where: Y – System time-consumption (min m^{-3}); X_1 – Harvest volume ($\text{m}^3 \text{ ha}^{-1}$); X_2 – Stem-volume (m^3); X_3 = Lead distance (m).

Parameters are given in **Table 3**.

Table 3. Parameters for the harvesting system time consumption model

Thinning	β_0	β_1	β_2
1 st	25.72	-0.07023	-119.3
2 nd	12.95	-0.02026	-16.34
3 rd	9.820	-0.01507	-4.137

Graphical representations of the influence of each variable are given in figures 3 and 4 (Talbot (2002)). The time consumption models are used in determining utilisation rates on the machines. Equation (2) essentially provides E_{15} hours, which are effective hours including delays of up to 15 minutes (Samset *et al.* (1978)). In this analysis, E_{15} hours are equated to Productive Work Time (PW), as proposed by Björheden *et al.* (1995), although this is more representative of E_0 . However, doing this allows for a comparison at Work Time (WT) level which comprises both PW and Supportive Work Time (SW), here only measured as relocation. Thus utilisation is measured as the ratio of PW to WT.

Relocation

Because the distributions of distances between grid cells are multimodal, and therefore not easily fitted to a common distribution, cumulative density functions (**Figure 3**) were used, applying the inverse transformation method described by Hillier and Lieberman (2001). This involves generating a random, uniformly distributed number which represents the probability of an observation, then reading the value from the x-axis. The density functions were based on 1 km interval histograms, plotted from the original distance matrices.

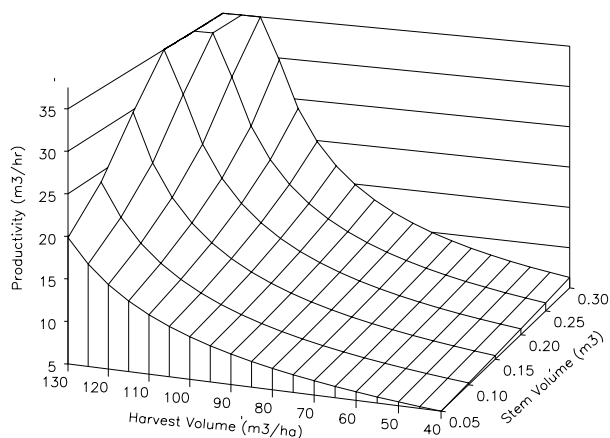


Figure 3. Harvester productivity as a function of harvest volume, and stem volume

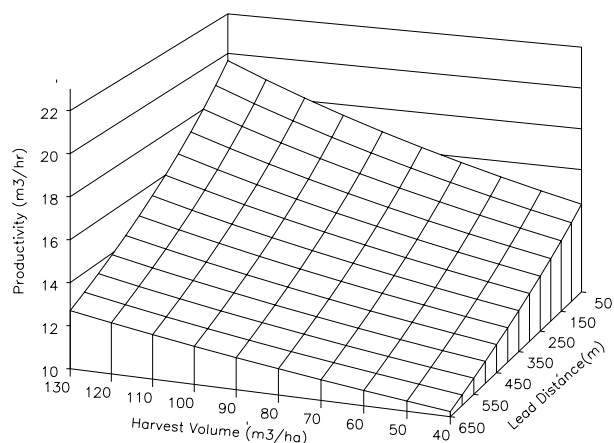


Figure 4. Forwarder productivity as a function of harvest volume and lead distance

Relocation refers to the movement of machines from one working tract (object) to another, and allows for specific time consumption (min.m^{-3}) to be calculated. This highlights the negative effects of long distances or small volumes (object volumes) on machine utilisation rates. The relocation model is duplicated directly from Talbot et al. (2003) and illustrated in **Figure 4**. At distances under 20 km, relocation always occurs under own power, while between 20 and 40 km, 50 % of the relocations are done by low-bed truck, which also accounts for all relocations exceeding 40 km. Movement on road occurs at an average velocity of 15 km hr^{-1} (under own power) alternatively 60 km.hr^{-1} (low-bed truck), and each move incurs a fixed time penalty of 30 minutes per machine. The 'set-up' time is constant irrespective of relocation distance, and includes preparing to relocate as well as orientation on arrival in the new stand. Relocating outside of normal working hours does not influence machine utilisation. A random timestamp ranging between 10:00 and 19:00 was used to generate task-completion time. The rationale being that tasks that could have been completed before 10:00 would have been done so on the evening prior to the move (16:00-19:00 agreed overtime), and therefore only the time period 10:00 to 19:00 is of interest. A variable was used to retain the frequency and distance of low-bed truck relocations.

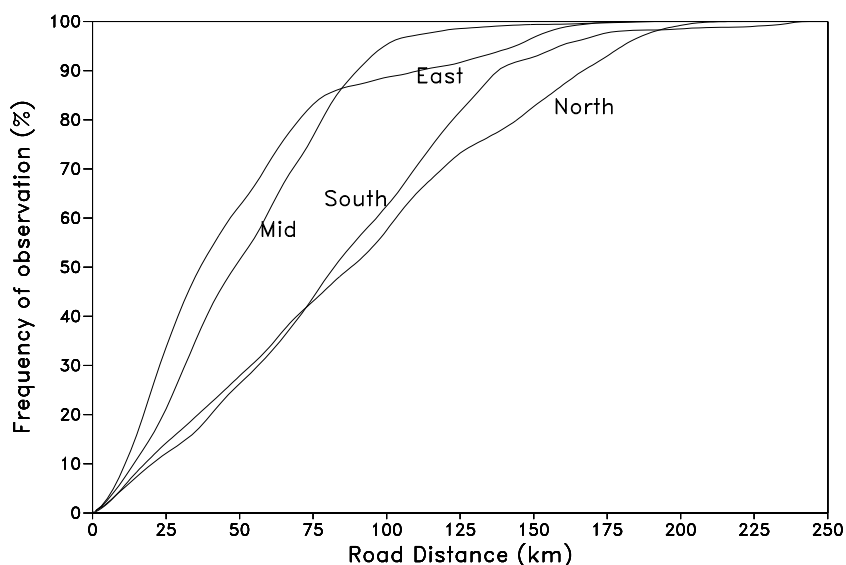


Figure 5. Cumulative density functions for relocation distances for each region

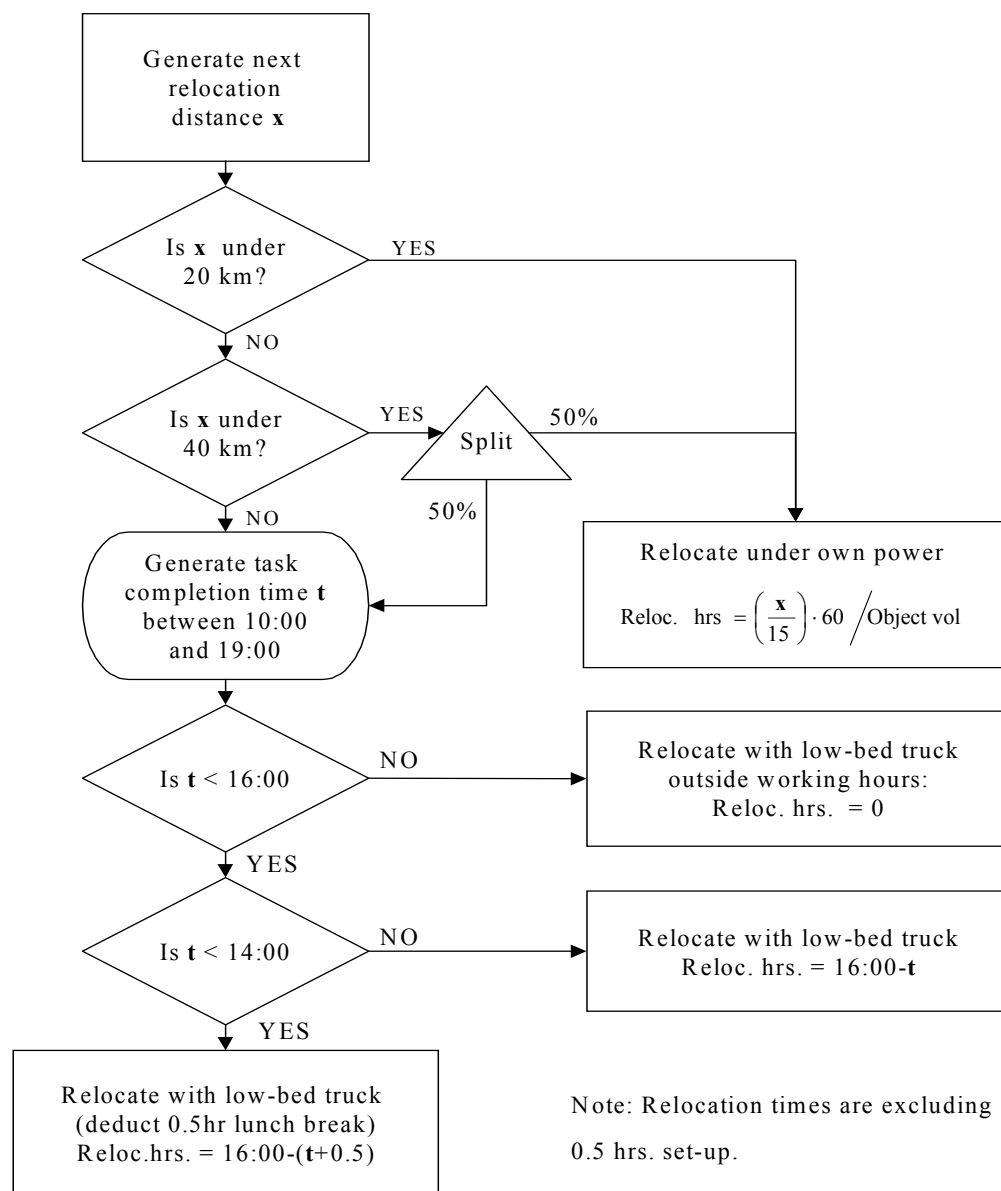


Figure 6. Flow diagram of the relocation model

Shortest Path

Network Analyst in ArcView was used in determining the shortest path linking all stands within each region.

Results

For the non-weighted analysis, region 'East' has the lowest mean distance between stands (**Table 4**). This can be corroborated in Figure 7, where the majority of stands are 'joined' under the 10 km mark. The area-weighting procedure reverses the ranking, making 'North' the most dense region, while 'Mid' which has the largest stands, is less affected.

The shortest route density estimate produced surprisingly similar results in terms of distance, but differences in stand sizes mean that in region East, one has to travel 0.24 times further per hectare of coniferous forest.

Despite differences in stand sizes and relocations distances amongst regions, there were no discernable differences in machine utilisation levels. In thinning, forwarders have a considerably higher productivity than harvesters.

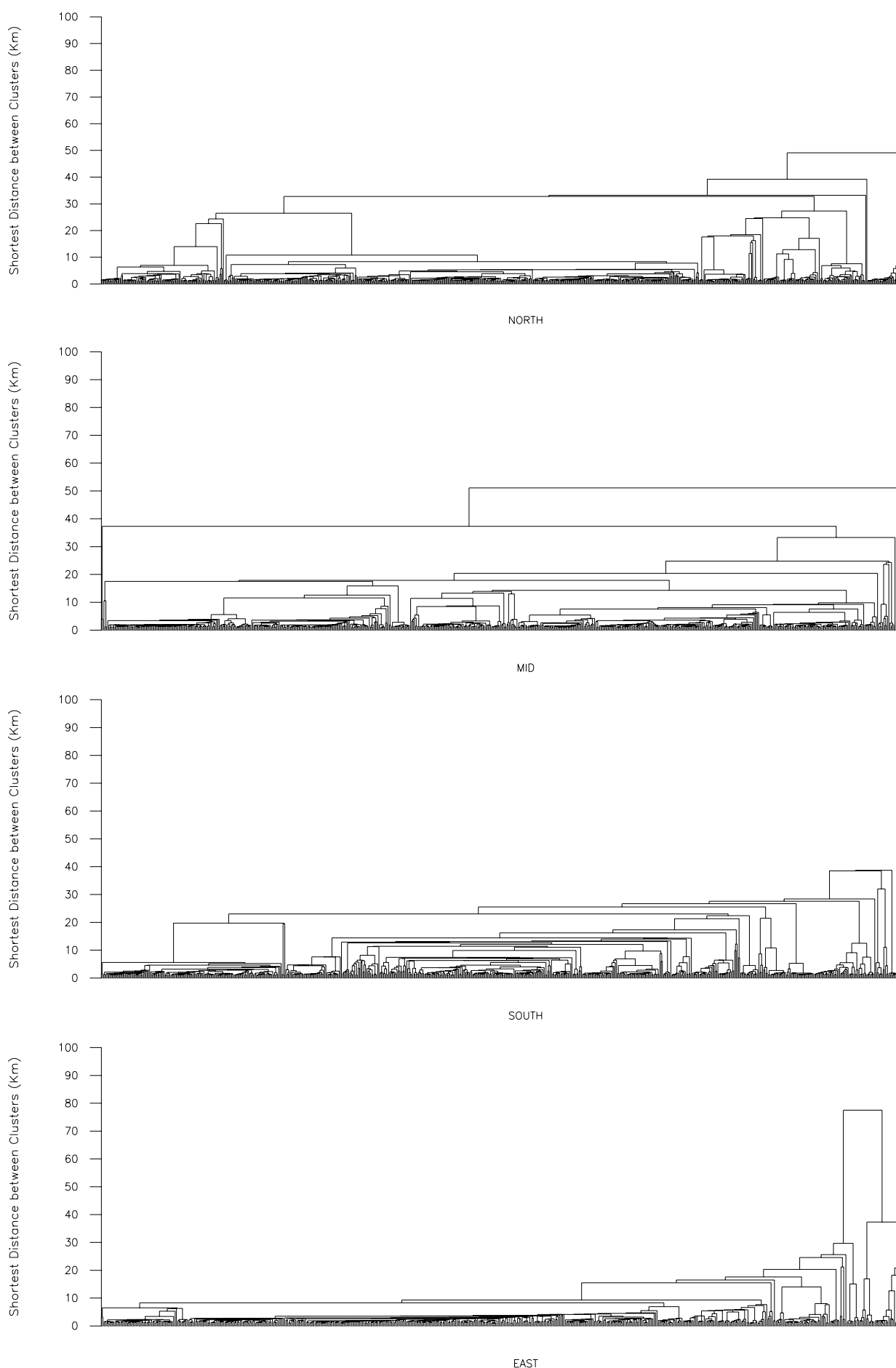


Figure 7. A graphic representation of the results of the non-weighted cluster analysis

Table 4. Results of the cluster analysis and shortest route density estimate

Results	North	Mid	South	East
Cluster Analysis				
Mean distance between obs non weighted.	90.2	52.5	84.9	49.4
Mean distance between obs weighted	17.7	19.2	39.4	38.7
Shortest Route				
Distance (km)	2487	2191	2684	2083
Density (km ha ⁻¹)	0.10	0.09	0.19	0.24

Table 5. Time consumption for harvesting, forwarding, and relocation, by stand, as well as utilisation levels for the harvester and forwarder

Region	Harvester Hrs.	Forwarder Hrs.	Reloc hrs.	Utilisation harvester	Utilisation forwarder
North	7.36	4.18	1.78	0.80	0.70
Mid	7.13	4.03	1.97	0.78	0.67
South	7.68	4.28	1.75	0.81	0.71
East	7.97	4.50	1.99	0.80	0.69

Discussion

The cluster analysis chosen here provides a good graphical overview of operational areas, effectively showing both density and distance between stands. The single-linkage method is too simple to use in further analysis, for example, for generating solution sets for a sequencing algorithm.

The simulation failed to show any significant differences in the effect forest topology might have on machine utilisation. This could partly be explained by the relatively high set-up time at each stand (30 min.) which possibly disguises some variation.

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MECHANICAL SEPARATION OF SEEDS

Economic aspects of nursery production require seeds of high genetics quality and high germination ability. Thanks to the separation process, full and well developed seeds are separated from empty and damaged ones. Nevertheless, this process cannot cause loss of lighter seeds (the presently used separation methods often lead to such results), as owing to the genetics variability, big and heavy seeds are as important as small and light ones. Aiming at the optimisation of the seeds mechanical separation process, from among many distinguishing features such a feature should be chosen that for the given seed lot, secures the shortest technological line for carrying out cleaning and grading. The paper presents designs of two separators for forest tree seeds that were made in Department of Forest Work Mechanisation of Agricultural University of Cracow: pneumatic separator with a vertical air channel and column for separation of seeds, based on the difference in their elasticity.

Keywords: forest tree seeds, separation properties, sorting process

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Механічне відділення насіння

Економічні аспекти лісовідновлення вимагають насіння високої генетичної якості і доброї здатності проростання. Завдяки процесу відділення, повні і добре розвинуті зерна відокремлюються від порожніх і пошкоджених. Проте, цей процес може викликати втрату більш легких зерен (методи відділення, що тепер використовуються, часто приводять до таких результатів), як наслідок, до мінливості генетичних властивостей. Великі і важкі зерна такі ж важливі, як і малі та легкі. Напрямок оптимізації механічного процесу відділення зерен повинен бути вибраний так, щоб забезпечити найшвидше і найякісніше очищення та сортування насіння. В статті представлено два роздільники насіння лісових дерев, які розроблені на кафедрі механізації лісових робіт Аграрного ун-ту Кракова: пневматичний роздільник з вертикальним повітряним каналом і колона для відділення зерен, принцип дії яких базується на різниці еластичності насіння.

Ключові слова: насіння лісових дерев, властивості розділення, процес сортування

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