# Pushing the Boundaries with Research in Forest Engineering

44th International Symposium on Forestry Mechanisation

## Skidder with single-drum or double-drum winch in mountainous areas – A case study from selective forests of Croatia

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# Introduction

- **annual production of wood assortments in forests of Croatia is around 5.5 mil. $m^3$**
  - of that amount 88% in produced in state forests
  - felling and processing is mainly performed by chain-saws
  - about two-thirds of the wood produced is skidded by skidders and by adapted agricultural tractors
  - the remaining third is almost entirely forwarded by forwarders and tractor assemblies
  - cable-yarding is only occasionally used, on steep slopes and unopened areas

- **almost half of the total production, about 2 mil. $m^3$, is hauled by the mechanization of "Croatian Forests" Ltd. Zagreb, a company that manages state forests**
  - with their heavy skidders (mass greater than 5 t) about 0.9 mil. $m^3$ is annually skidded, mainly in hilly and mountainous regions
  - of their 183 heavy skidders 45 are type Timberjack 240C, 30 with double-drum winch and 15 with single-drum winch (Krpan and Zečić, 2001a); these skidders, haul between 0.25 mil. $m^3$ and 0.30 mil. $m^3$ per year

# Research goal

- **determine productivity differences in single-drum equipped and double-drum equipped Timberjack 240C half-length skidding by analysing the load volume and time consumptions for different work elements**

# Materials and Methods

- **felling site characteristics**
  - beech-fir stand
  - area of 54.47 ha
  - altitude of 630 m to 785 m
  - slope from 0 ° to 25 °
  - standing trees:
    - 374 trees per hectare
    - growing stock was 378 $m^3$/ha
  - growing stock:
    - silver fir 68.83%
    - beech 22.65%
    - spruce 8.20%
    - other hard broadleaves 0.41%
  - marked trees:
    - 1689 trees (31 trees/ha)
    - 4005 $m^3$ gross (73.53 $m^3$/ha)
    - DBH 51 cm for conifers and 44 cm for broad-leaves

- **exploatation characteristics**
  - selective cut
  - half-length harvesting method was used
  - two groups of workers
    - two cutters at the felling site
    - one tractor driver
    - one choker-man
    - one cutter at the landing site
  - skidding was done by two Timberjack 240C skidders (length 5860 mm, width 2590 mm, height 2911 mm, engine power 75 kW and mass 8409 kg)
    - standard Timberjack's single-drum T40 winch (nominal pulling force 125 kN)
    - double-drum Konrad Adler HY16 winch (nominal pulling force 2 x 80 kN)

# Materials and Methods

- skidding work was investigated by time and motion study
- 99 single-drum winch skidder skidding cycles and 103 double-drum winch skidder skidding cycles
- time consumptions of individual work elements, as well as the delay times, were recorded using snap-back chronometry method:
    - unloaded tractor on skid road travel
    - felling site work (positioning, line pulling, choking, winching, load manoeuvring, mounting)
    - loaded tractor on skid road travel (and travel winching)
    - loaded tractor on landing travel
    - landing work (unchoking, bunching, skidder turning, mounting)
    - unloaded tractor on landing travel
- skidding distances, line pulling/winching distances and skidded load date were recorded

- the analysis of recorded delays provided allowance time
- T-test of differences between SDS and DDS mean values per cycle:
    - travel speeds
    - consumptions of fixed times at the felling site and at the landing
    - the sizes of the load
    - in accordance with the T-test results recorded data was in further processing treated as one or two separate groups
- regression analysis:
    - travel time consumptions dependence on skidding distance
    - line pulling and winching time consumptions dependence on line pulling/winching distance
- times of all the other work elements ware calculated as the average time consumptions
- by dividing the total time consumption for projected skidding cycle with an average load volume standard time was calculated; daily output was expressed for the eight-hour work time

# Results

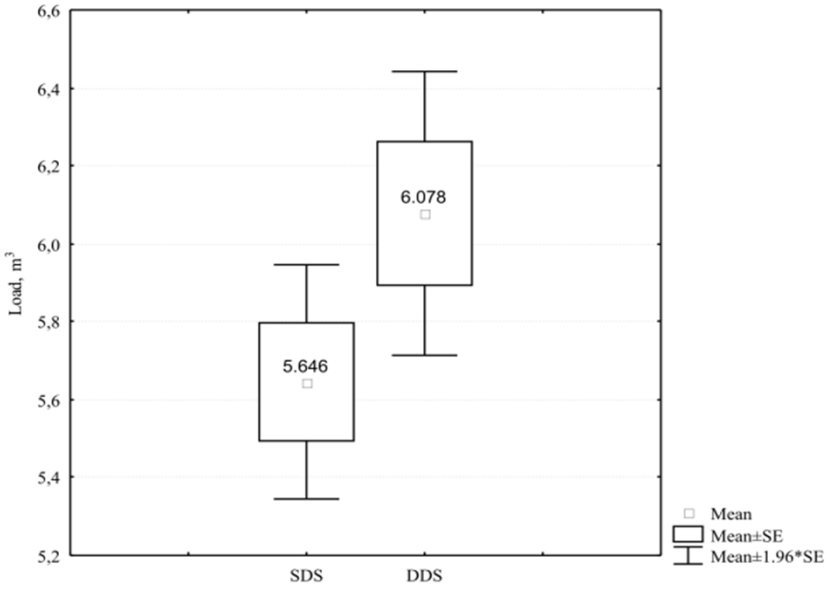
• in total 4231.61 min of single-drum winch skidder time consumption, and 4067.68 min double-drum winch skidder time consumption was recorded

• 2709.60 min of effective time for single-drum winch skidder and 2619.15 min of effective time for double-drum winch skidder

• allowance time was 976.21 min for single-drum winch skidder, and 859.36 min for double-drum winch skidder; unique allowance time factor is 1.35

• results of the T-test (p = 0.074478) indicate that there is no significant difference between the load volume skidded with single-drum winch skidder and the load volume skidded with a double-drum winch skidder

• $\bar{x}$ = 5.866; min = 1.007; max = 9.877;
Std. Dev. = 1.724087



# Results

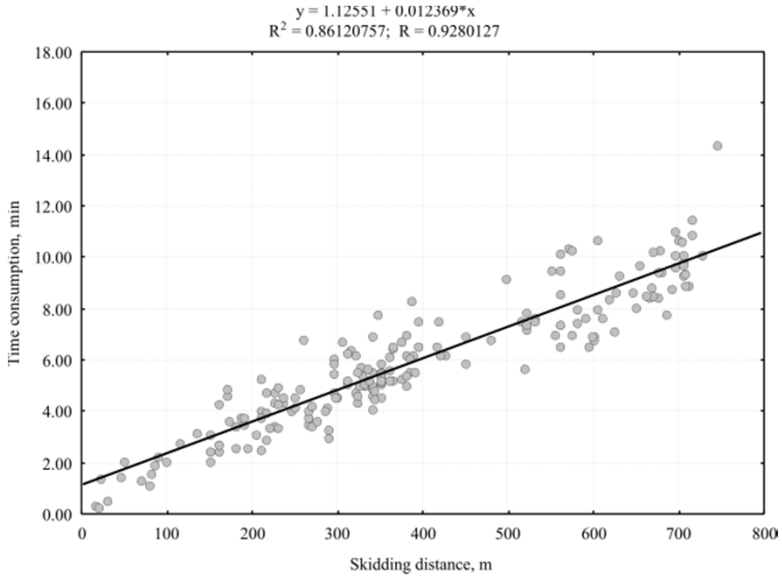
- **Travel speed T-test resaults**

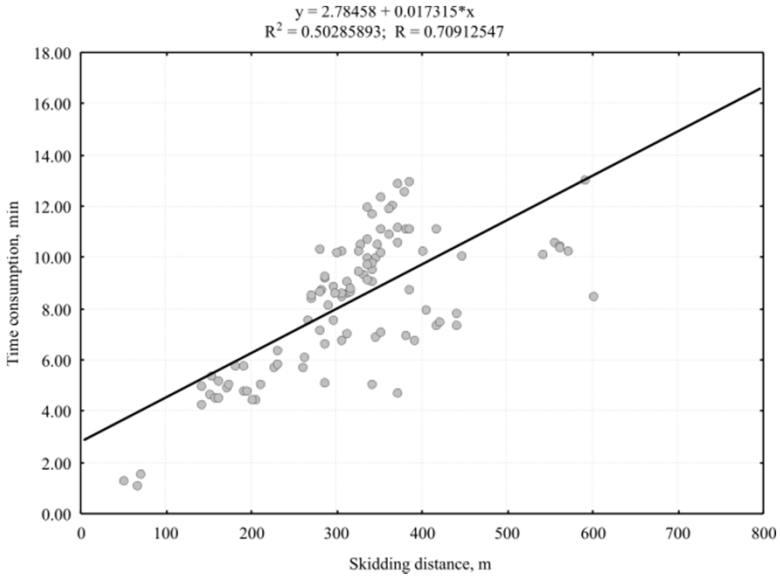
| Data group | Mean | | t-value | df | p | Valid N | | Std.Dev. | | F-ratio Variances | P Variances |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SDS | DDS | | | | SDS | DDS | SDS | DDS | | |
| Travel unloaded landing site [km/h] | 4.677598 | 4.149093 | 2.161766 | 177 | 0.031979 | 77 | 102 | 2.055564 | 1.190139 | 2.983094 | 0.000000 |
| Travel unloaded skid road [km/h] | 3.796094 | 3.899731 | -0.937696 | 196 | 0.349555 | 99 | 99 | 0.676105 | 0.867297 | 1.645534 | 0.014425 |
| Travel loaded skid road [km/h] | 2.359133 | 2.673224 | -3.29105 | 194 | 0.001186 | 99 | 97 | 0.615309 | 0.717869 | 1.361145 | 0.130315 |
| Travel loaded landing site [km/h] | 3.136228 | 2.482093 | 4.327235 | 196 | 0.000024 | 96 | 102 | 1.175278 | 0.945439 | 1.545305 | 0.031861 |

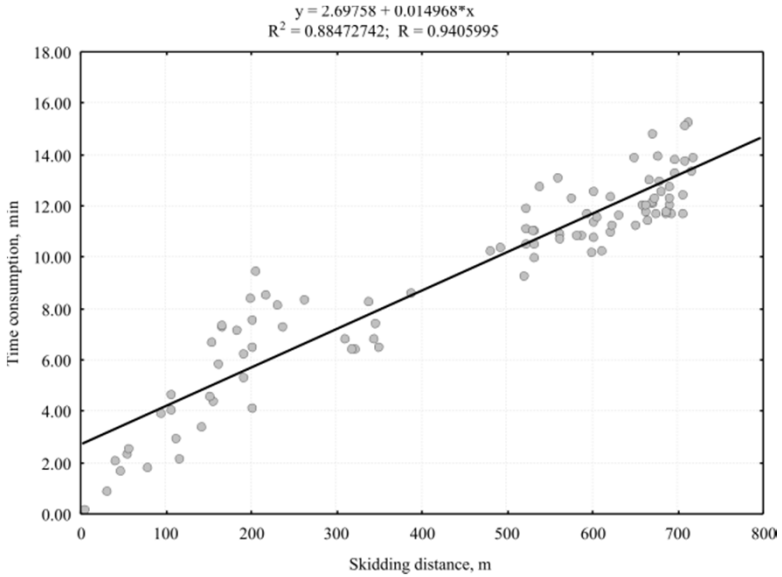



# Results

- **Travel time consumption vs. skidding distance**
  - skid road – unloaded
  - skid road – SDS loaded
  - skid road – DDS loaded

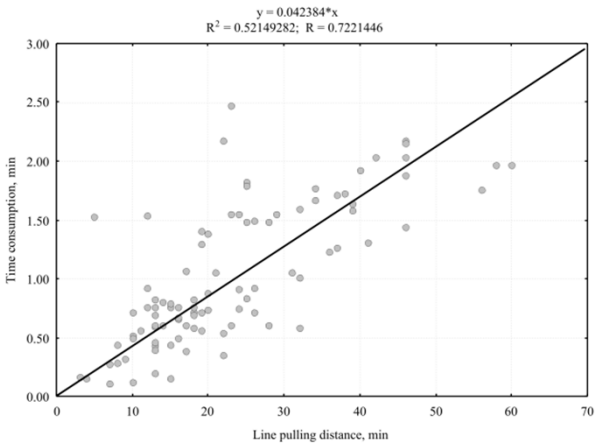


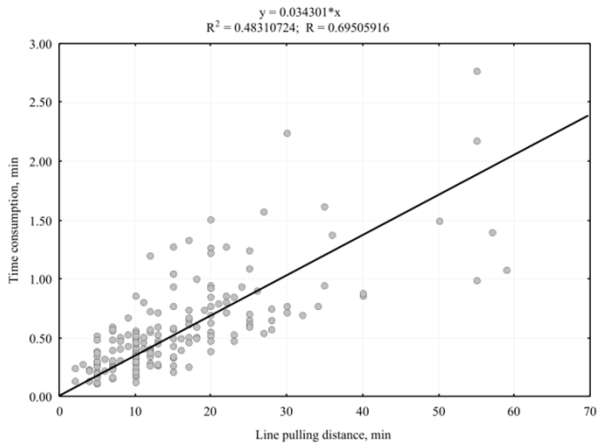



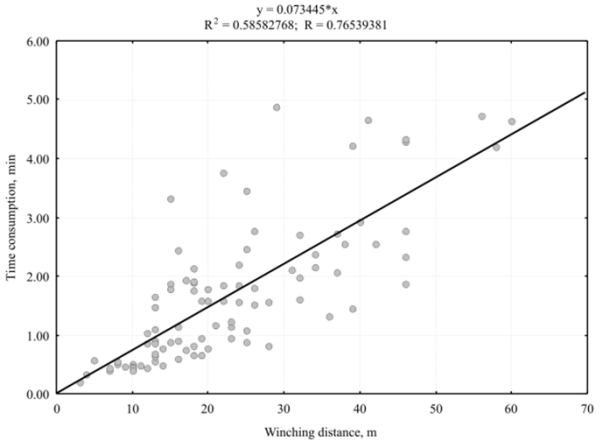
# Results

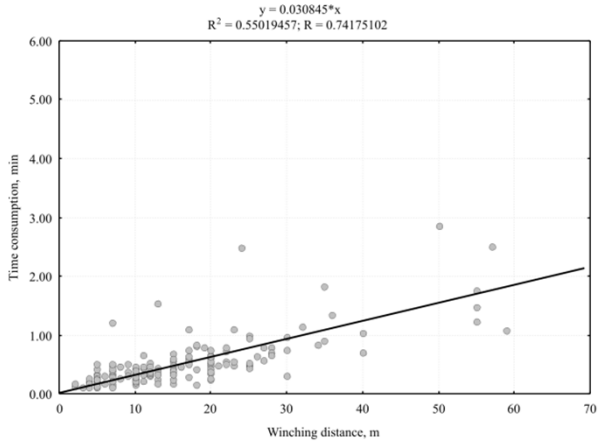
- **Line pulling time consumptions**
  - SDS (23 m)
  - DDS (2 x 15 m)




- **Winching time consumptions**
  - SDS (23 m)
  - DDS (2 x 15 m)



# Results

- **Felling site fixed times T-test resaults**

| Data group | Mean | | t-value | df | p | Valid N | | Std.Dev. | | F-ratio Variances | P Variances |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SDS | DDS | | | | SDS | DDS | SDS | DDS | | |
| Skid road loaded travel winching [min] | 1.283402 | 1.294369 | -0.049416 | 198 | 0.960637 | 97 | 103 | 1.348934 | 1.750278 | 1.683575 | 0.010443 |
| Positioning [min] | 0.610928 | 0.676214 | -0.701027 | 198 | 0.484109 | 97 | 103 | 0.721068 | 0.593022 | 1.478468 | 0.052483 |
| Choking [min] | 2.569175 | 1.685437 | 5.402827 | 198 | 0.000000 | 97 | 103 | 1.374642 | 0.903320 | 2.315771 | 0.000037 |
| Load manoeuvring [min] | 0.341753 | 0.580971 | -2.90346 | 198 | 0.004109 | 97 | 103 | 0.238026 | 0.777779 | 10.67737 | 0.000000 |
| Felling site mounting [min] | 0.00 | 0.106602 | -6.49401 | 198 | 0.000000 | 97 | 103 | 0.00 | 0.161649 | 0.00 | 1.000000 |





# Results

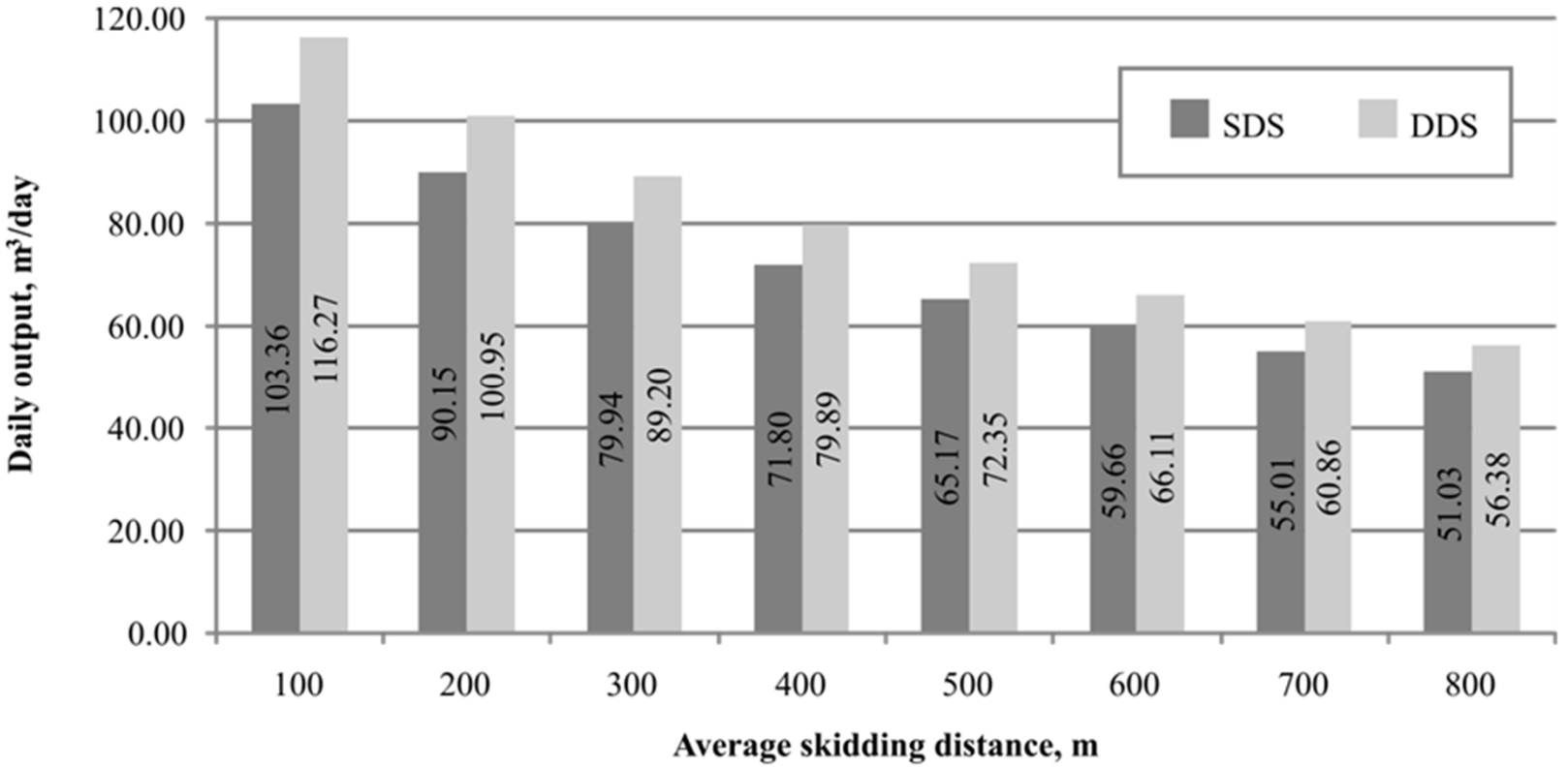
- **Landing fixed times T-test resaults**

| Data group | Mean | | t-value | df | p | Valid N | | Std.Dev. | | F-ratio Variances | P Variances |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SDS | DDS | | | | SDS | DDS | SDS | DDS | | |
| Unchoking [min] | 0.731546 | 0.636796 | 2.065880 | 198 | 0.040142 | 97 | 103 | 0.391669 | 0.244136 | 2.573805 | 0.000004 |
| Bunching [min] | 3.311649 | 2.410777 | 2.025791 | 198 | 0.044128 | 97 | 103 | 3.061241 | 3.218243 | 1.105204 | 0.621467 |
| Skidder turning [min] | 0.497113 | 0.474563 | 0.389192 | 198 | 0.697552 | 97 | 103 | 0.506347 | 0.290253 | 3.043296 | 0.000000 |
| Landing site mounting [min] | 0.068557 | 0.117184 | -2.14816 | 198 | 0.032915 | 97 | 103 | 0.143120 | 0.174392 | 1.484749 | 0.051383 |




# Results

- **Daily output vs. average skidding distance**



# Discussion

- reasons for differences in productivity:
    - lower time consumption of DDS for work at the felling site
        - lover time consumption for line pulling, choking and winching
    - lower time consumption of DDS for work at the landing
        - lover time consumption for unchoking and bunching
    - higher skid trail loaded travel speed of the DDS
        - differences in speeds, if impact of human factor is disregarded, may lie in the characteristics of the load and condition of the skid roads, which was not further investigated
    - differences in the load volume were not statistically significant and were disregarded in the calculation of daily output

- In selective forests of Croatia we are generally compelled to use skidders for the primary transport of wood, because of the stand and extraction factors.

- It can be concluded that the investigated skidder, in both winch versions, is a highly productive means of work which due to its size and construction, with obligatory professional planning and supervision of work, can effectively perform the tasks of wood hauling in our conditions.

- When procuring new skidding machines, the key role in the selection of single or double-drum variant will be, beside the difference in productivity, the difference in the purchase price and the expected lifetime in which the more expensive (double-drum) version can on a long-term be the more profitable one.

# Thank You for your attention