Ground pressure is a poor indicator for ecological and technical compatibility

Jörn Erler

FORMEC 2015 Linz, 06. Oct. 2015
The vicious circle of ground pressure

- In forestry specific ground pressure is regarded to be a fine key indicator for
  - ecological compatibility and
  - technical traffic ability
  of forest machines

- To obtain lower ground pressure
  - Option 1: lower wheel load
  - Option 2: increase contact area

- this seems to be a vicious circle
Question: Is specific ground pressure an appropriate indicator?

- physical and ecological basic assumptions
- model structure and assumptions
- 3 hypotheses:
  - ecological compatibility
  - minimization of soil compaction
  - minimization of rut depth
- conclusion
First step of degradation of forest soils by machinery
Ecological recreation

- possible as long as biological processes can take place
- depends on oxygen in the air tubes inside the soil

**model assumption**
- ecological recreation happens when the maximum impact is not higher than **50 kPa**
Second step of degradation of forest soils by machinery

biologically active forest soil

ground with technical functionality

destroyed ground
Technical repair

- technically destroyed soils need mechanical input for repairing technical function
- In practice ruts should not be so deep that water will transform them to pits

**model assumption**
- the rut depth is a rough but accepted indicator for technical bearing capacity of the soil
- for modeling a rut depth of **20 cm** will be seen as acceptable limit
The basic model assumptions

**Machine model**
- Key indicator is the load per wheel
- The machine weight is equally spread over all wheels
- The stamp of the wheel on the ground has a round shape with diameter = width of the wheel
- Ground pressure is measured in kPa as average of contact zone
- The deviation of the ground pressure follows roughly a normal deviation = maximum in the center of the wheel

**Soil model**
- The soil is homogenous and on even terrain
- The ground pressure on 10 by 10 cm plots is calculated every 3 cm top down
- The power propagates from top to the next lower level in a fixed relationship
  - 60% vertical down
  - 20% diagonal to the neighboring plot on each side (only two dimensions!)
Different stability of soils in the model

- stability indicated in kPa
- impact indicators
  - green = impact at bearing capacity or less
  - red = impact over bearing capacity
- 4 classes
  - soft soil 50 kPa
  - moderate soil 100 kPa
  - tight soil 150 kPa
  - adamant soil 200 kPa
- example tractor
  - machine weight 10 t
  - 4 wheels
  - wheel width 45 cm = 0.16 sqm contact area per wheel
  - on soft soil: area of impacted soil increases, machine will get stuck
  - on tight or adamant soil: rut depth is 15 or 3 cm, respectively
H1: Ecological compatibility

Heavy machines can be ecologically compatible by means of wider wheels.
H1: Ecological compatibility

Heavy machines can be ecologically compatible by means of wider wheels.

- Fixed: 4 wheels, 50 kPa
- Variables: machine mass and adequate contact area per wheel
  - 1: 10 t, 0.50 sqm
  - 2: 15 t, 0.75 sqm
  - 3: 20 t, 1.00 sqm
- Results:
  - Impact in upper 20 cm and upper 60 cm increases with machine weight
  - Only light machines fulfill the demand for ecological sound mechanization
H1: Ecological compatibility

biologically active forest soil

Theses 1: Only light machines fulfill the demand for ecological sound mechanization

ground with technical functionality

destroyed ground
H2: Minimal degradation of fertile soil

The volume of compacted soil can be minimized by using wider wheels. Ground with technical functionality can be maintained biologically active forest soil. Theses 1: Only light machines fulfill the demand for ecological sound mechanization.
H2: Minimal degradation of fertile soil

The volume of compacted soil can be minimized by wider wheels.

- Moderate soil
  - 15 t, 8 wheels, 0.19 sqm = 100 kPa
  - Compacted: 0.04 sqm

- Moderate soil
  - 25 t, 8 wheels, 0.31 sqm = 100 kPa
  - Compacted: 0.07 sqm

- Result: soil compaction increases with absolute wheel load
H2: Minimal degradation of fertile soil

- fixed: ground pressure 100 kPa, 8 wheels
- variable: different weights and adequate wheel widths
  - 1: 10 t, 0.13 sqm
  - 2: 15 t, 0.19 sqm
  - 3: 20 t, 0.25 sqm
  - 4: 25 t, 0.31 sqm
  - 5: 30 t, 0.42 sqm

- In face of invariable ground pressure, light machines cause significantly less soil compaction
H2: Minimal degradation of fertile soil

biologically active forest soil

Theses 1: Only light machines fulfill the demand for ecological sound mechanization

ground with technical functionality

Theses 2: Only light machines cause less soil compaction

destroyed ground
H3: Lowering the rut depths

biologically active forest soil

Theses 1: Only light machines fulfill the demand for ecological sound mechanization

ground with technical functionality

Theses 2: Only light machines cause less soil compaction

Rut depth can be limited by wider wheels.

destroyed ground
H3: Lowering the rut depths

Rut depth can be limited by wider wheels.

- Moderate soil
  - 15 t, 8 wheels, 0.19 sqm = 100 kPa
  - Rut depth: 0.18 cm

- Moderate soil
  - 25 t, 8 wheels, 0.31 sqm = 100 kPa
  - Rut depth: 0.27 cm

- Result: ruts get deeper with increasing wheel load
H3: Lowering the rut depths

- fixed: ground pressure 100 kPa, 8 wheels
- variable: different weights and adequate wheel widths
- Increasing weights cause deeper ruts
H3: Lowering the rut depths

- Theses 1: Only light machines fulfill the demand for ecological sound mechanization
- Theses 2: Only light machines cause less soil compaction
- Theses 3: Only light machines can keep the rut depth on acceptable level
Conclusion

• Is specific ground pressure an appropriate indicator?

• The vicious circle ... will not end as long as we only look at the specific ground pressure

• In future in addition to specific ground pressure the absolute axle load has to be regarded as well