MOTION DYNAMICS OF UTOPUS PUSH-PULL VEHICLE WITH NARROW TINES FOR TRACTION

Volker Nannen[a,b], Damian Bover[a], and Dieter Zöbel[b]

[a] Sedewa Technologies, Finca Son Duri, Palma-Manacor KM 40, Vilafranca de Bonany 07250 Spain
[b] University of Koblenz-Landau, Koblenz 56070, Germany

vnannen@gmail.com, utopusproject@gmail.com, zoebel@uni-koblenz.de

UTOPUS is a new locomotion system based on crampons which are periodically inserted into the soil. Here we investigate the energy profile of the resulting motion cycle.

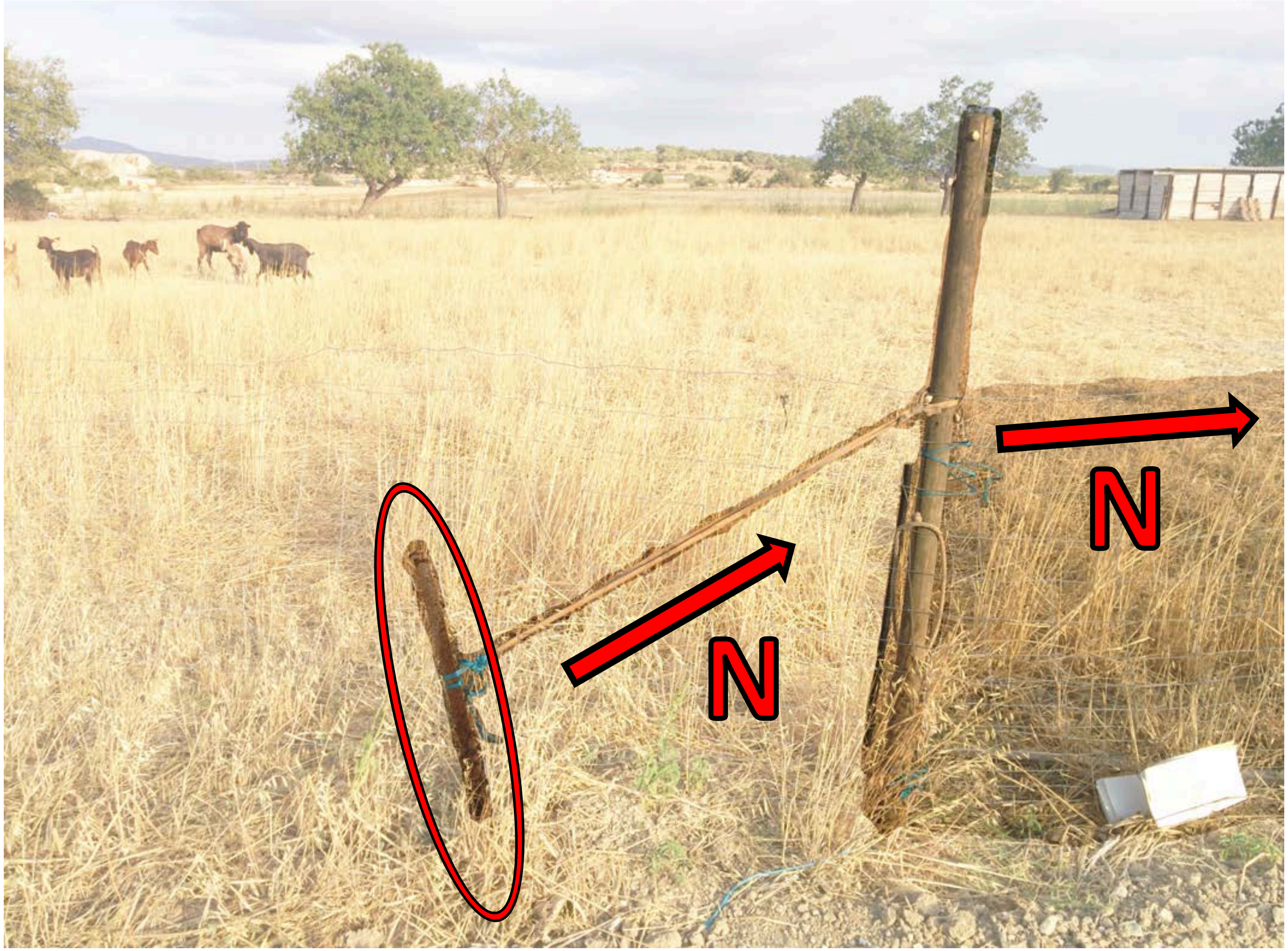
Introduction: traction by crampon

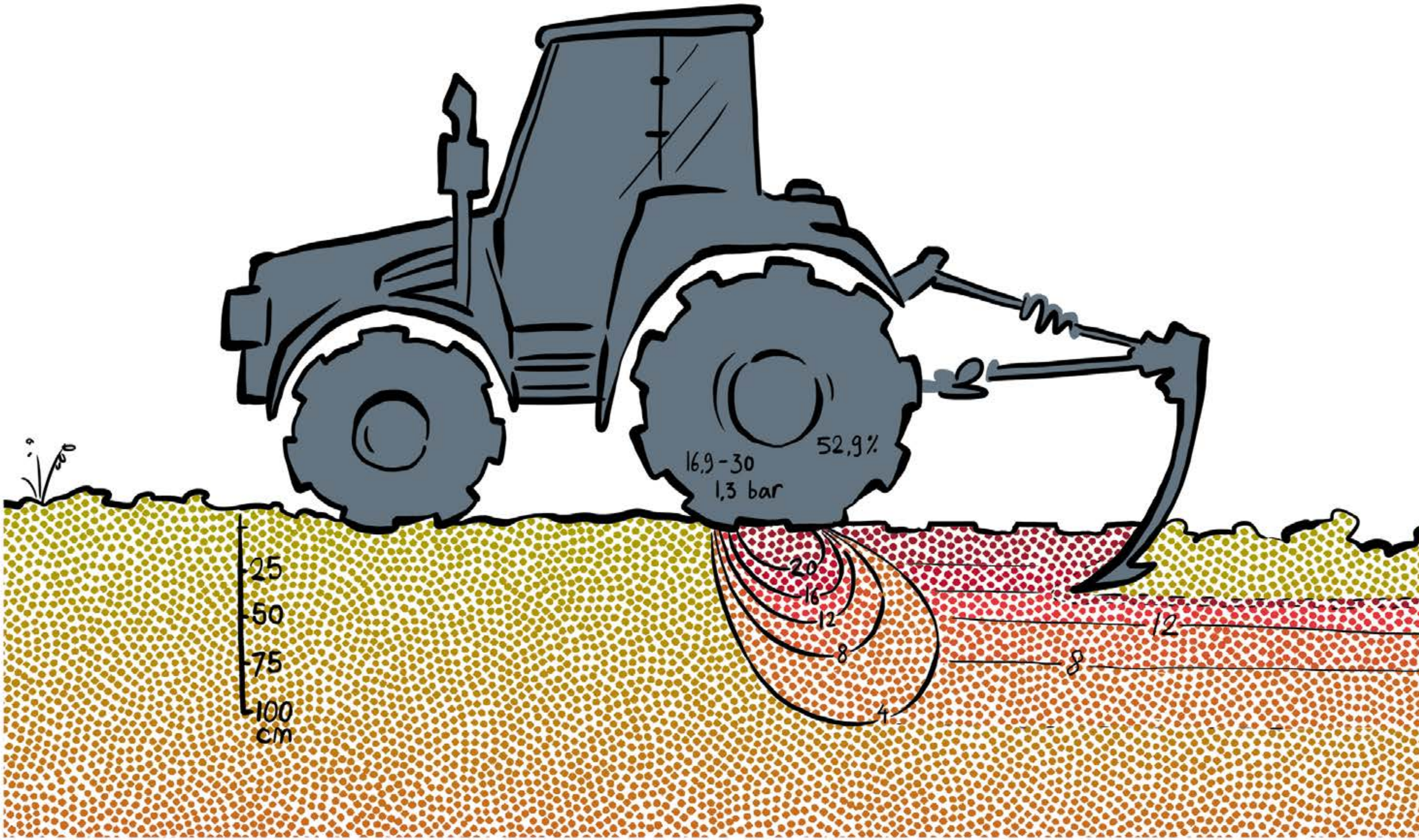
Introduction: traction by crampon

Inspiration:
Pole or peg which holds fence

Introduction: traction by crampon

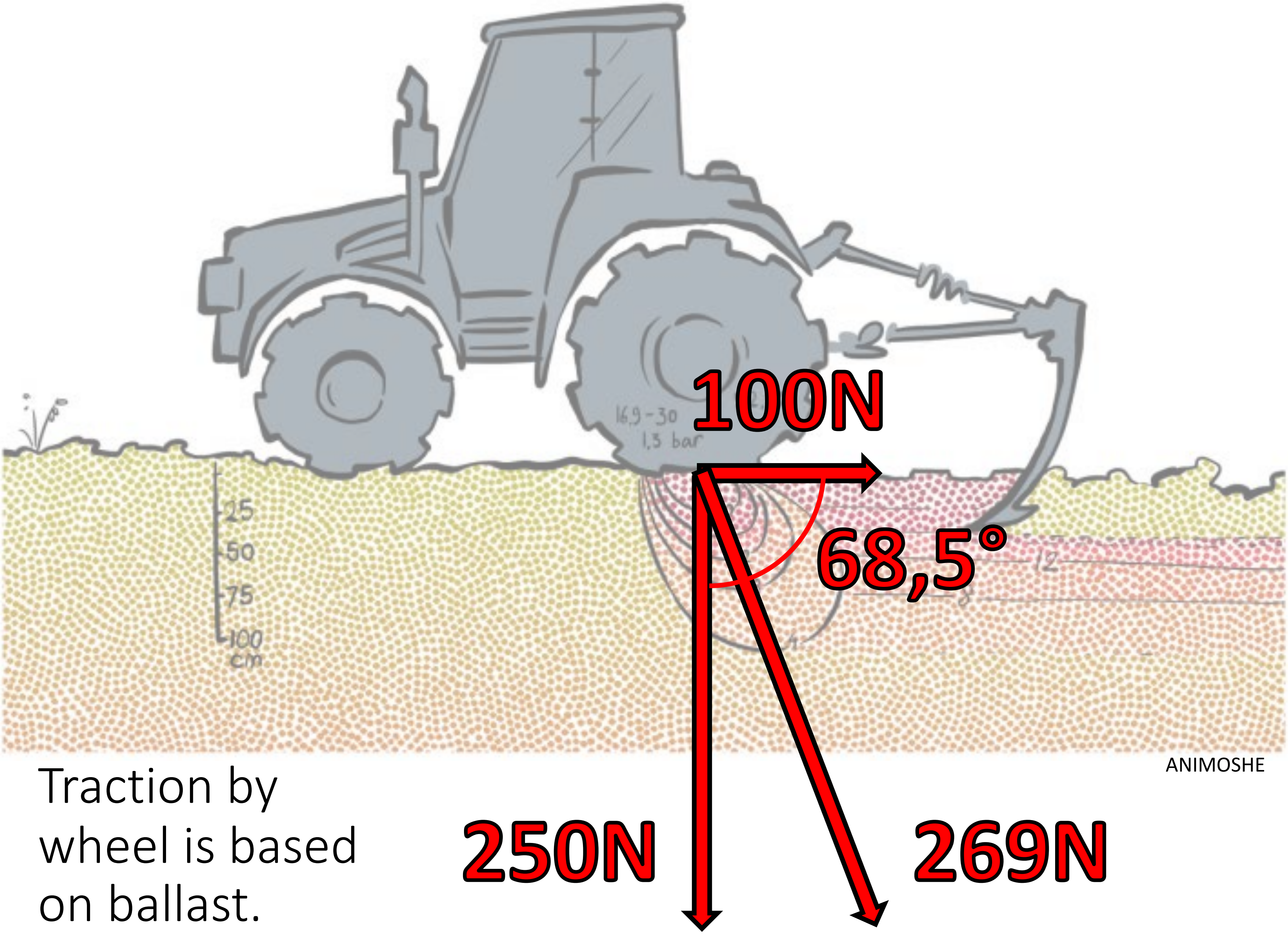
Inspiration:
Pole or peg
which holds
fence



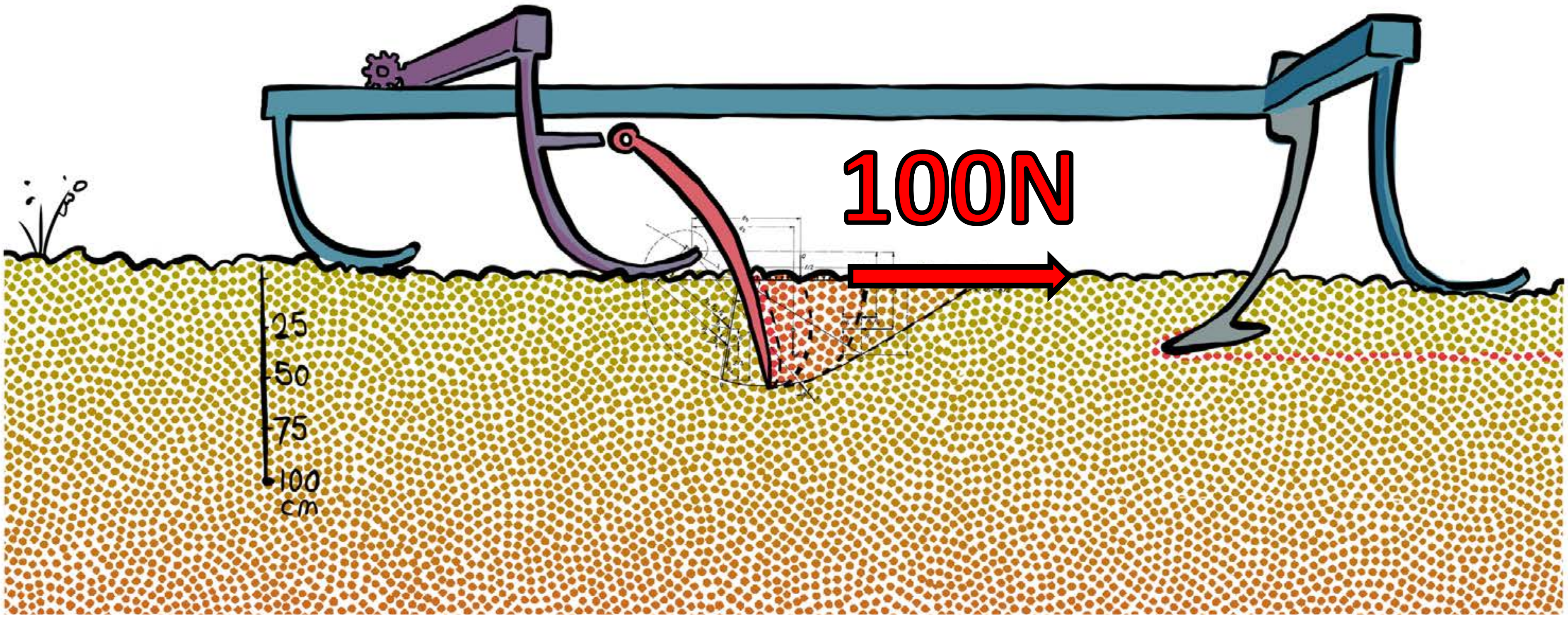


ANIMOSHE

Traction by wheel is based on ballast.



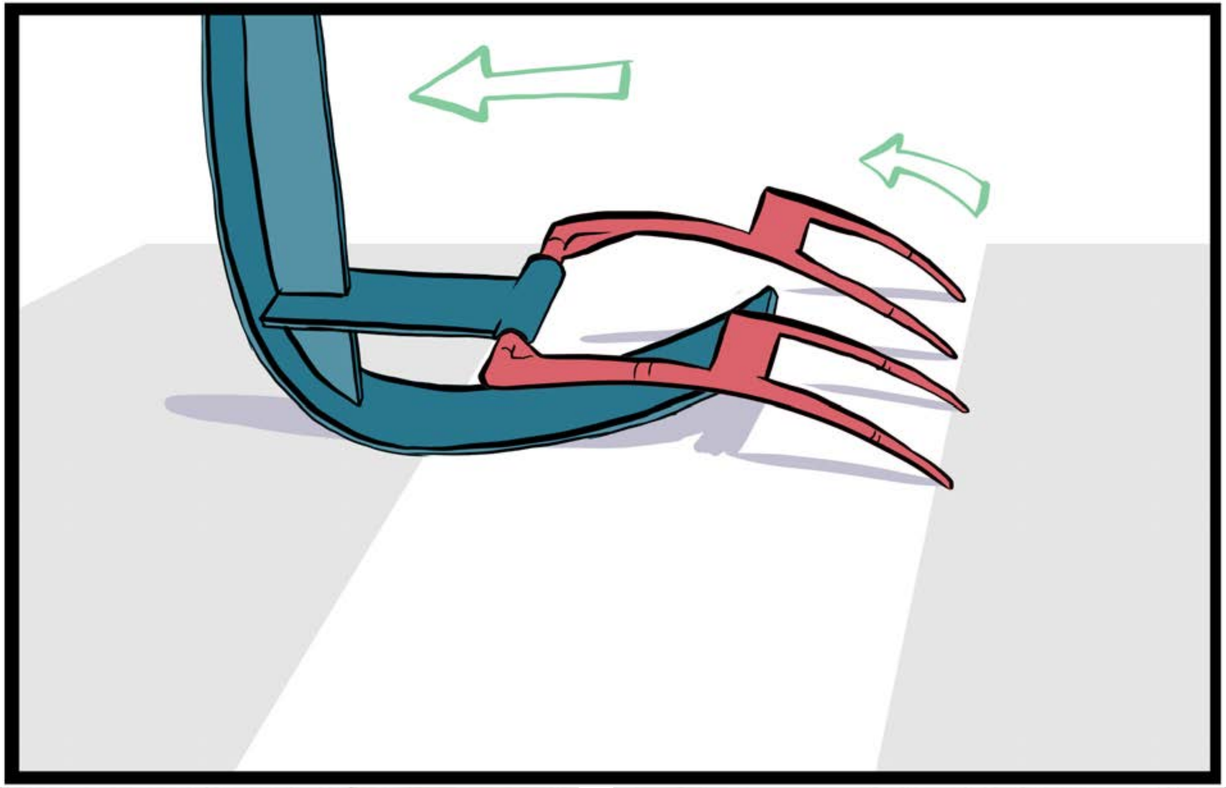
Traction by wheel is based on ballast.

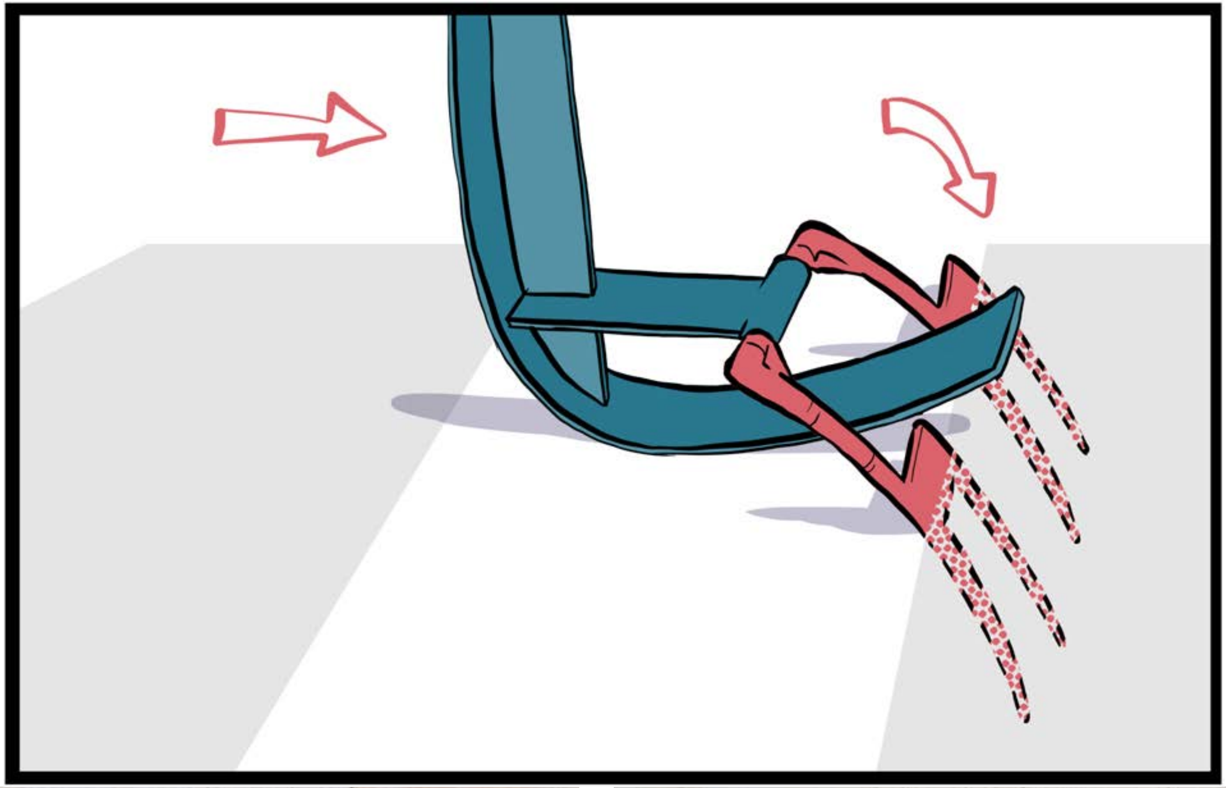


ANIMOSHE

Traction by wheel is based on ballast,

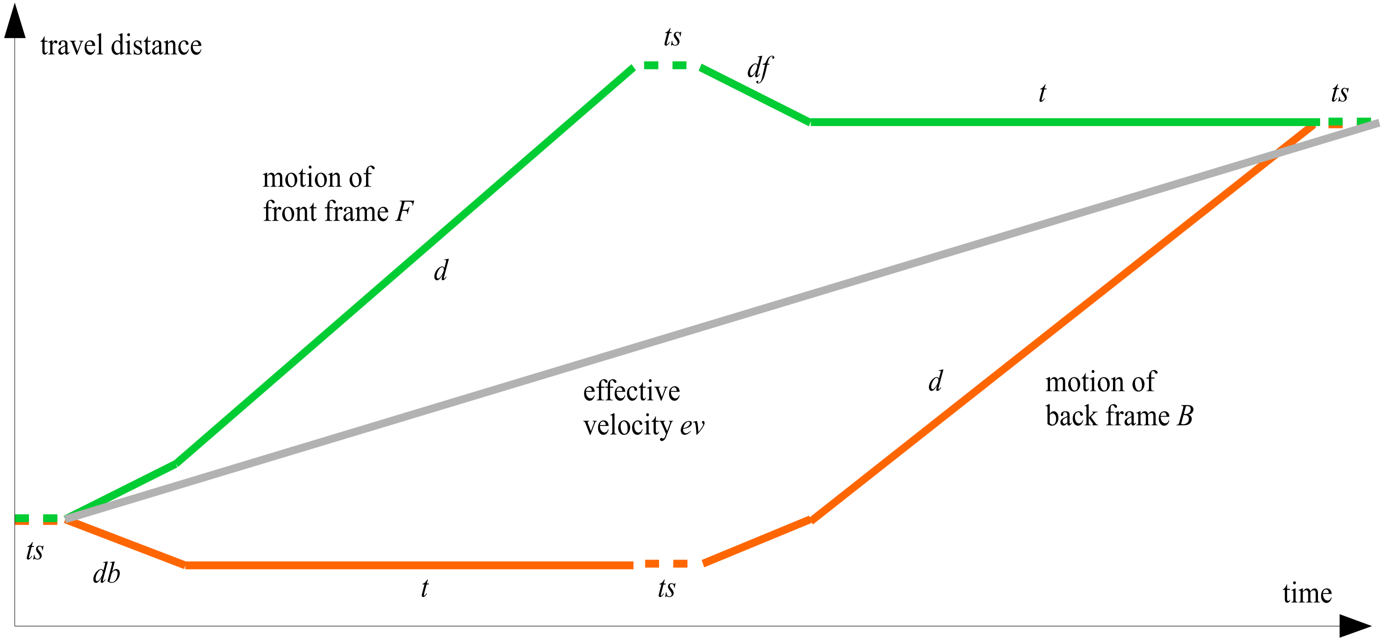
while crampons press only sideways.





UTOPUS in motion

1. Full contraction

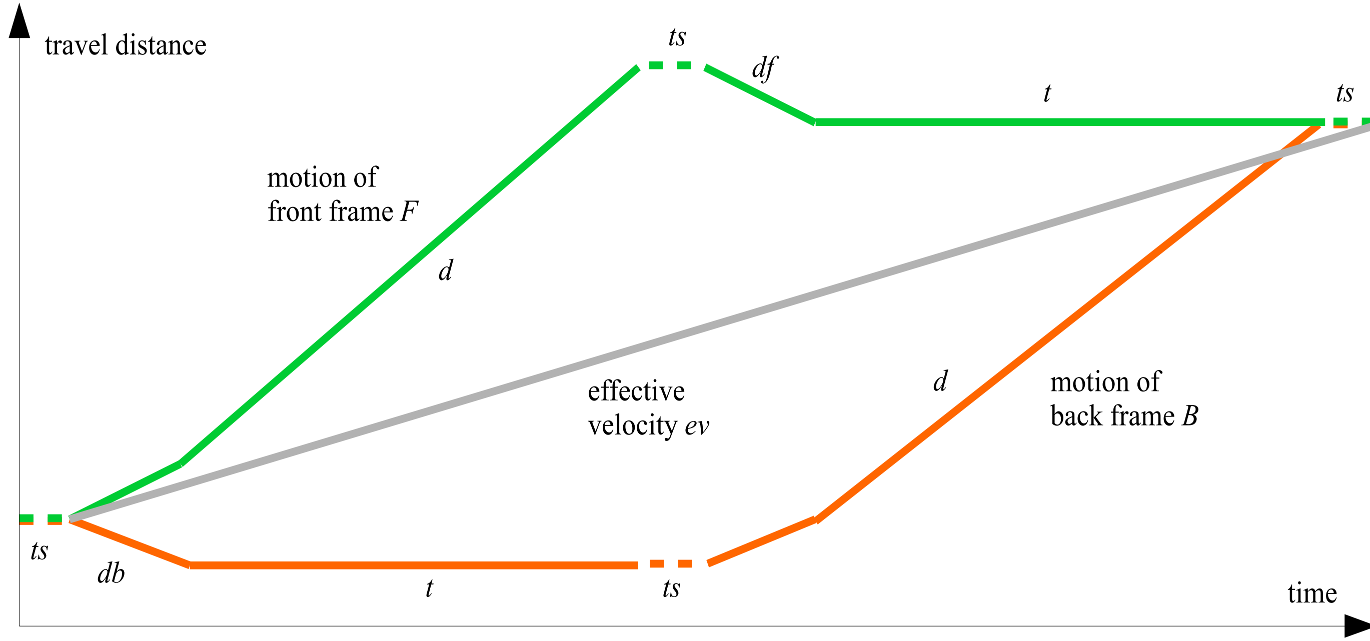


Crampon of rearward moving frame OUT OF soil

Crampon of fixed front frame INSIDE soil

UTOPUS in motion

2. Starting expansion



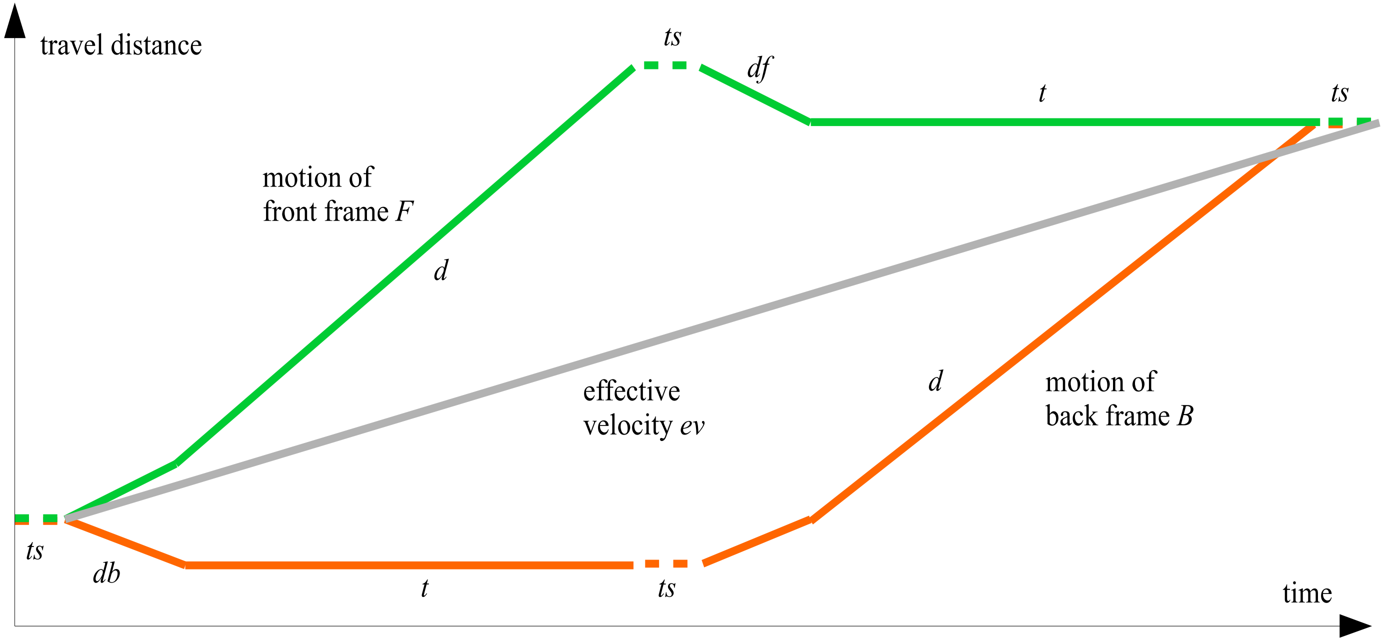
Note how this frame moved ~ 5 cm BACKWARDS to anchor

Crampon of rearward moving frame INSIDE soil

Crampon of fixed front frame OUT OF soil

UTOPUS in motion

3. Full expansion

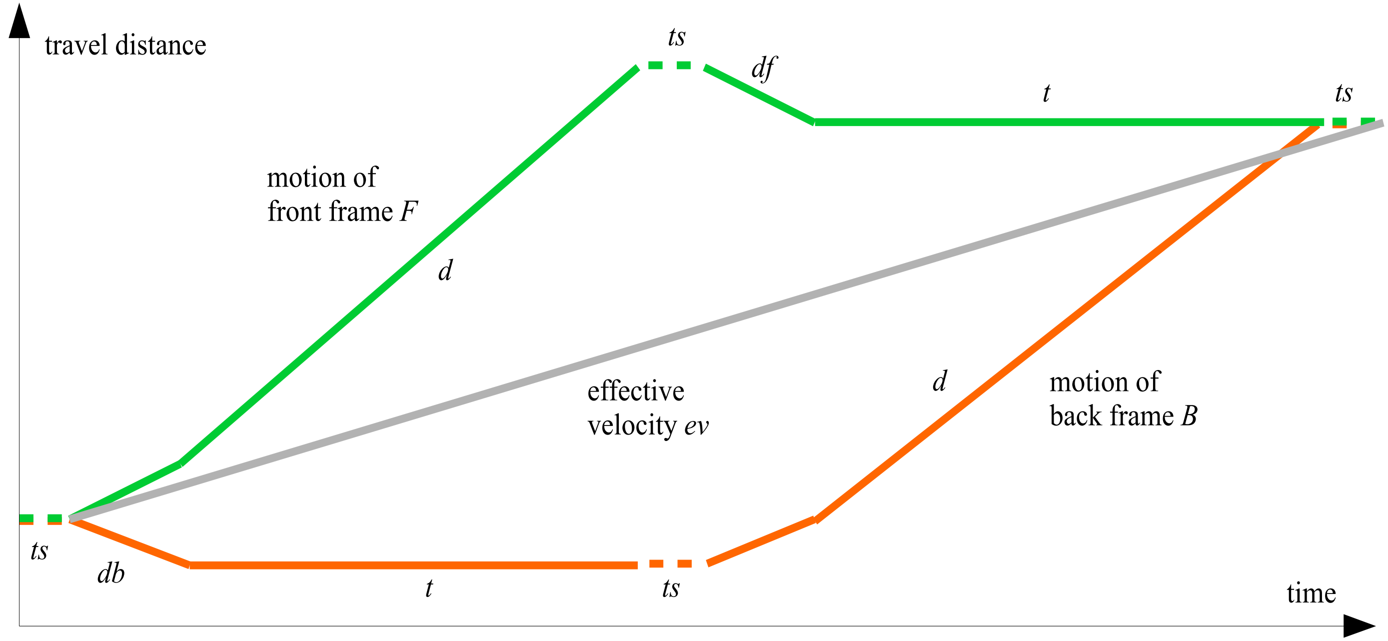


Crampon of rearward moving frame INSIDE soil

Crampon of fixed front frame OUT OF soil

UTOPUS in motion

4. Starting contraction



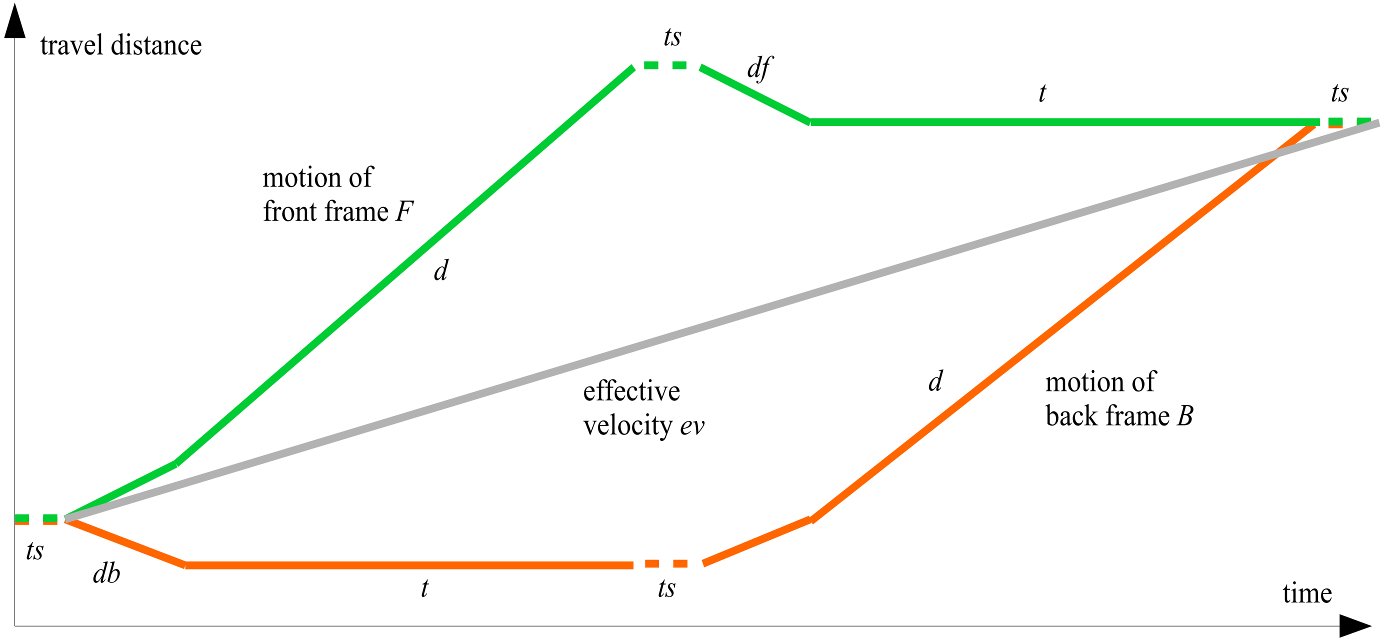
Crampon of rearward moving frame OUTSIDE soil

Crampon of fixed front frame INSIDE soil

Note how frame moved ~ 20 cm BACKWARDS to anchor

UTOPUS in motion

5. Contracting

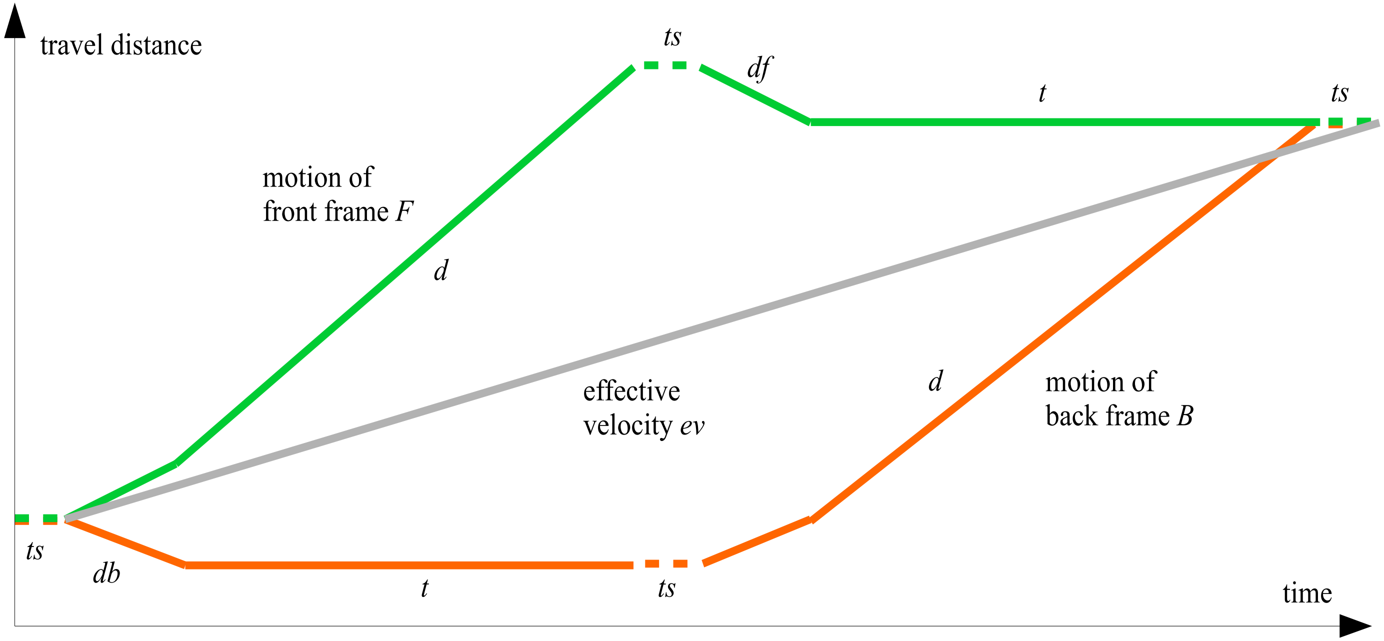


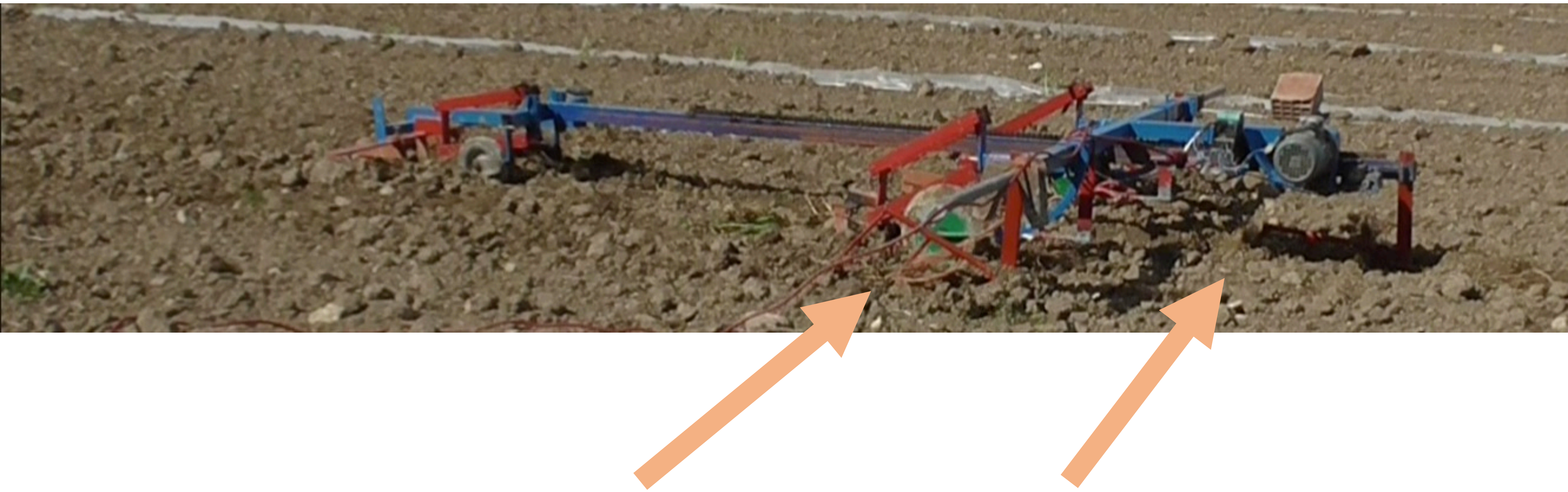
Crampon of rearward moving frame OUTSIDE soil

Crampon of fixed front frame INSIDE soil

UTOPUS in motion

6. Full contraction





Crampon of rearward moving frame OUTSIDE soil

Crampon of fixed front frame INSIDE soil

Experiment: energy profile of a push-pull motion cycle

Several experiments on agricultural land in Vilafranca de Bonany, Mallorca, Spain.

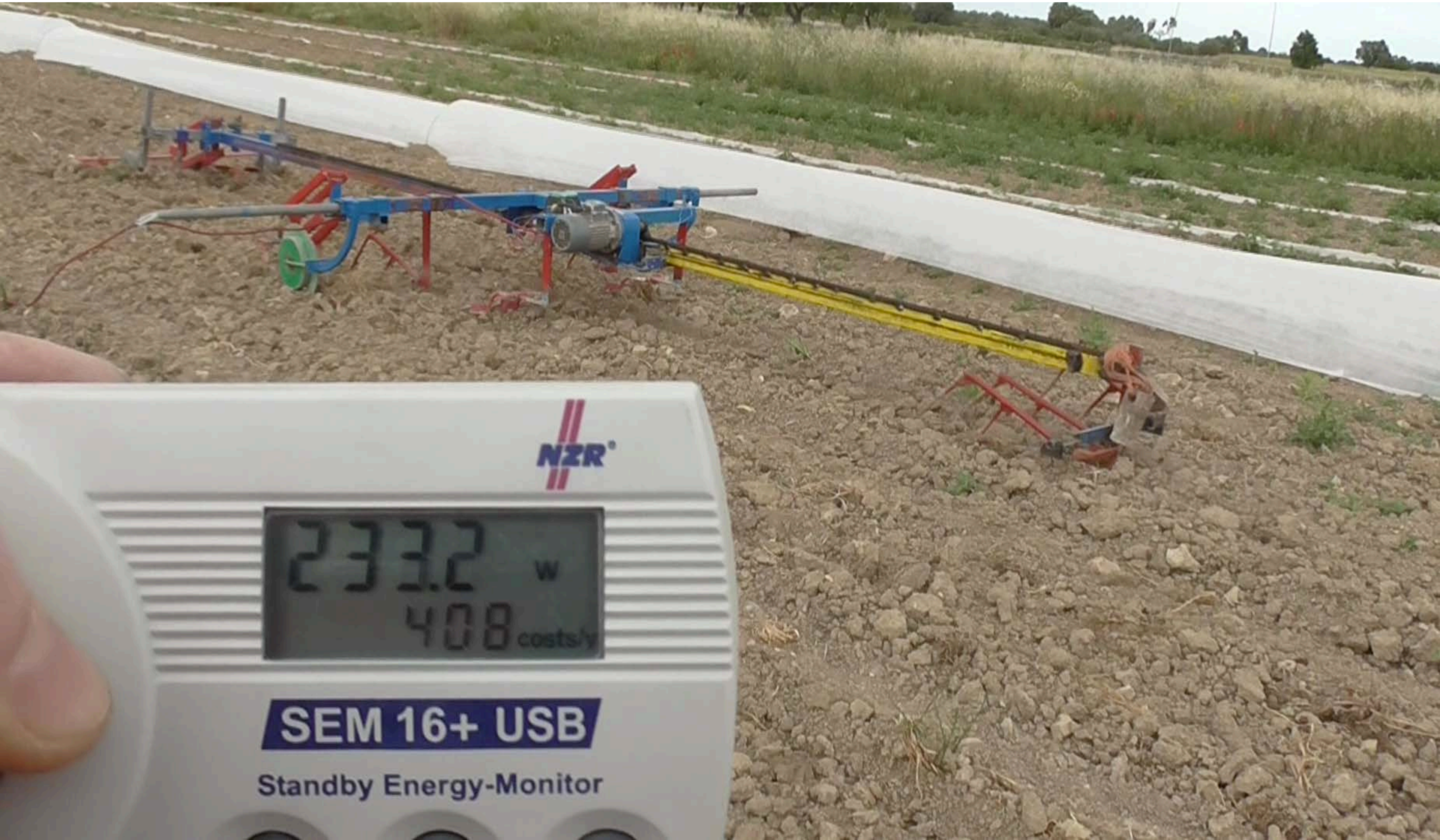
Electrical machine.

Accurate Watt meter with 0.83 s resolution.

Plow depth is 3–5 cm.

Length of central axis is 4.025 m
(vehicle length: 5m).

Experiment: energy profile of a push-pull motion cycle



Experiment: energy profile of a push-pull motion cycle

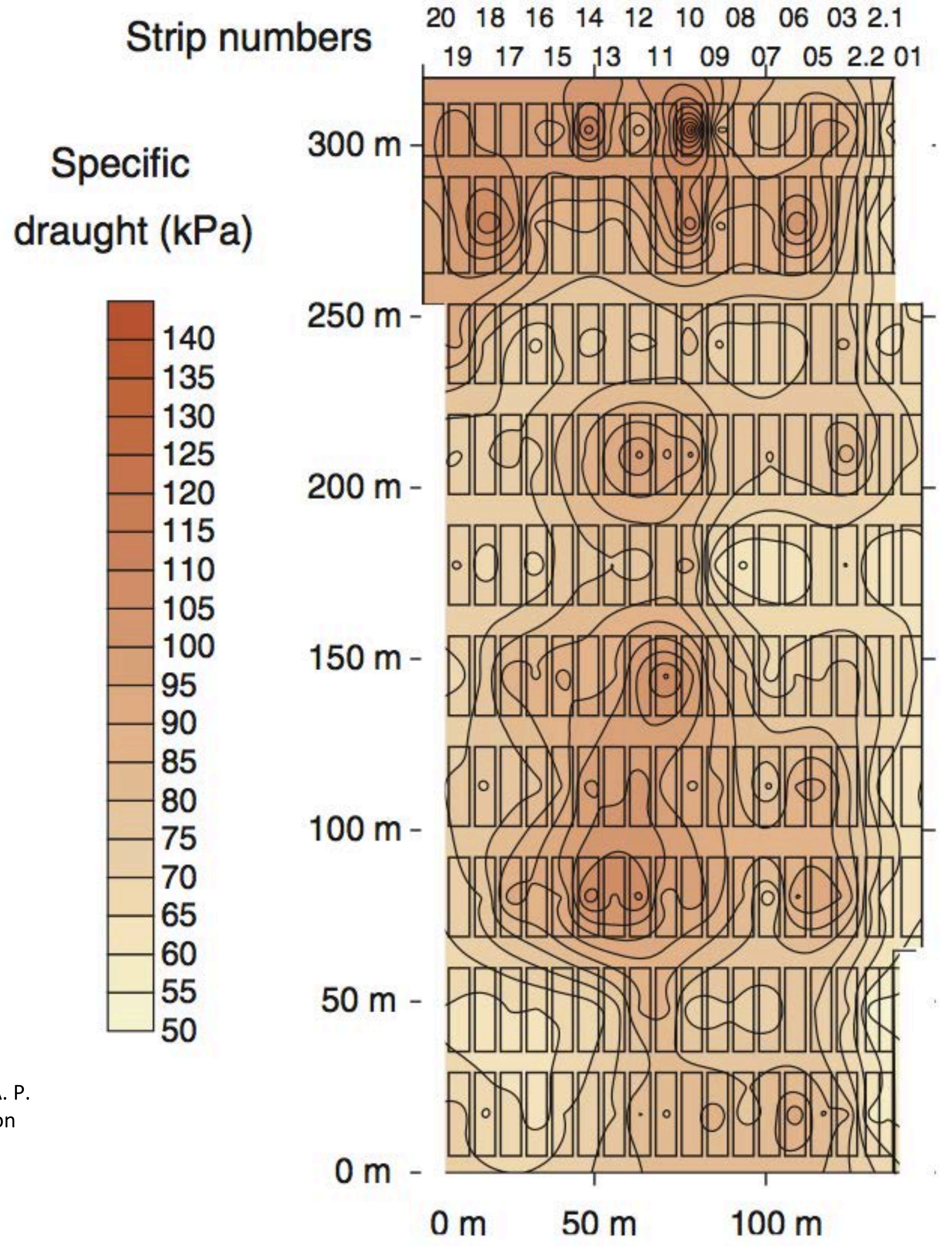
The drive train consists of an asynchronous electric motor, cogwheel, chain, and variable frequency drive.

The tillage tools tools are optimized for low speed:

Local designs from horse drawn implements.

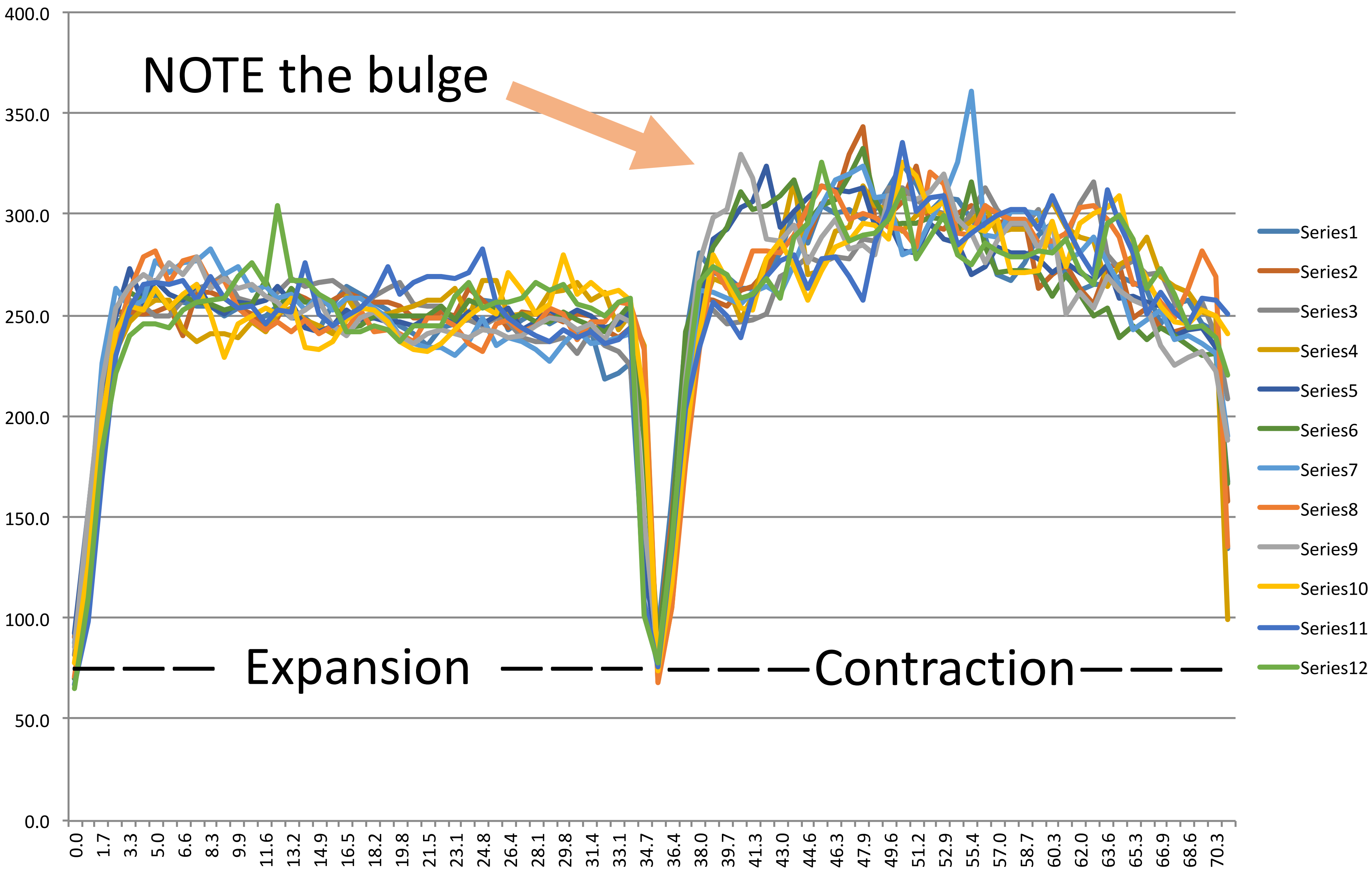
Soil resistance is very heterogeneous.

Draft varies
+/- 50%
within 10m.

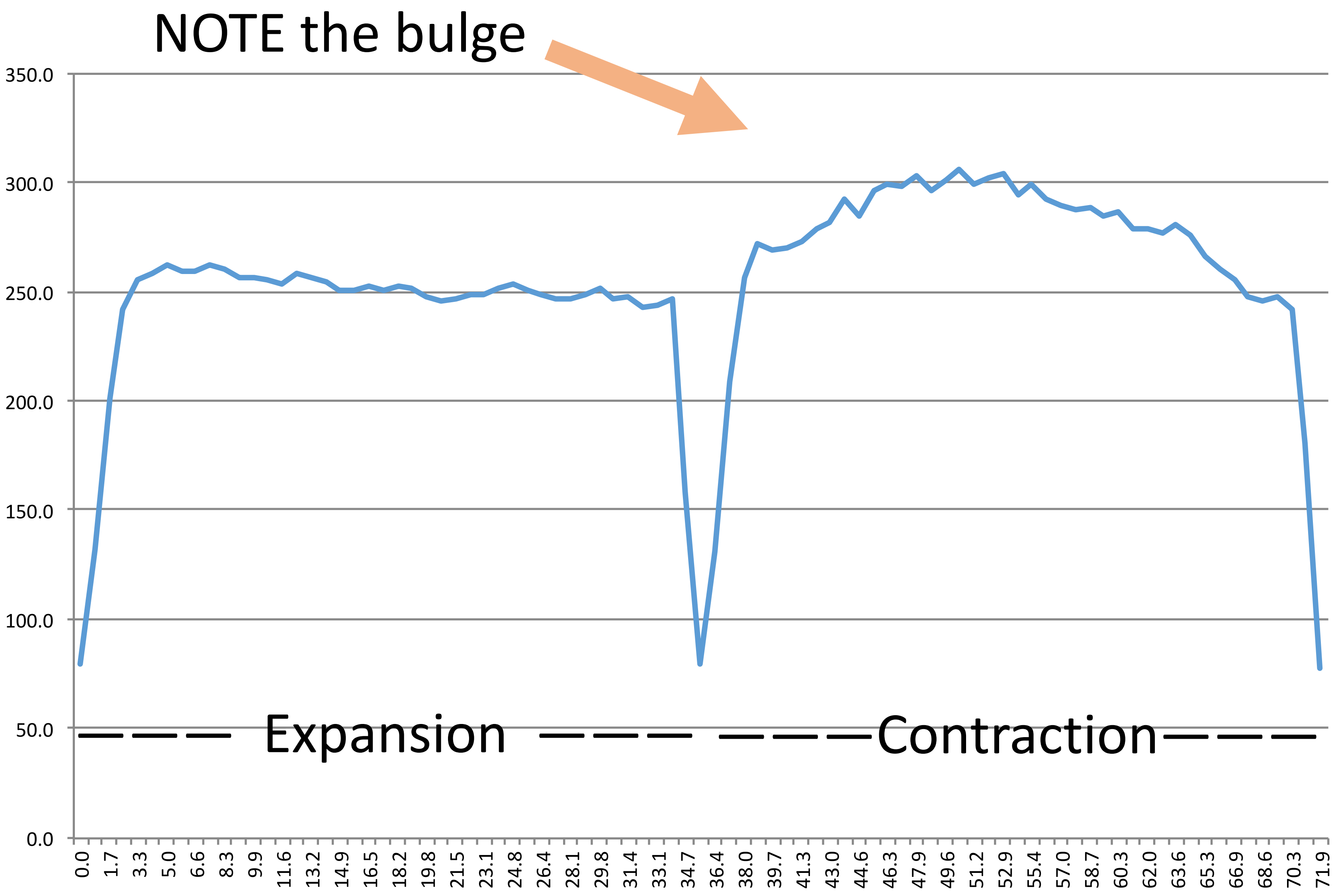


Watts, C. W., Clark, L. J., Poulton, P. R., Powlson, D. S., & Whitmore, A. P. (2006). The role of clay, organic carbon and long-term management on mouldboard plough draught measured on the Broadbalk wheat experiment at Rothamsted. Soil Use Manag., 22(4), 334–341. http://doi.org/10.1111/j.1475-2743.2006.00054.x

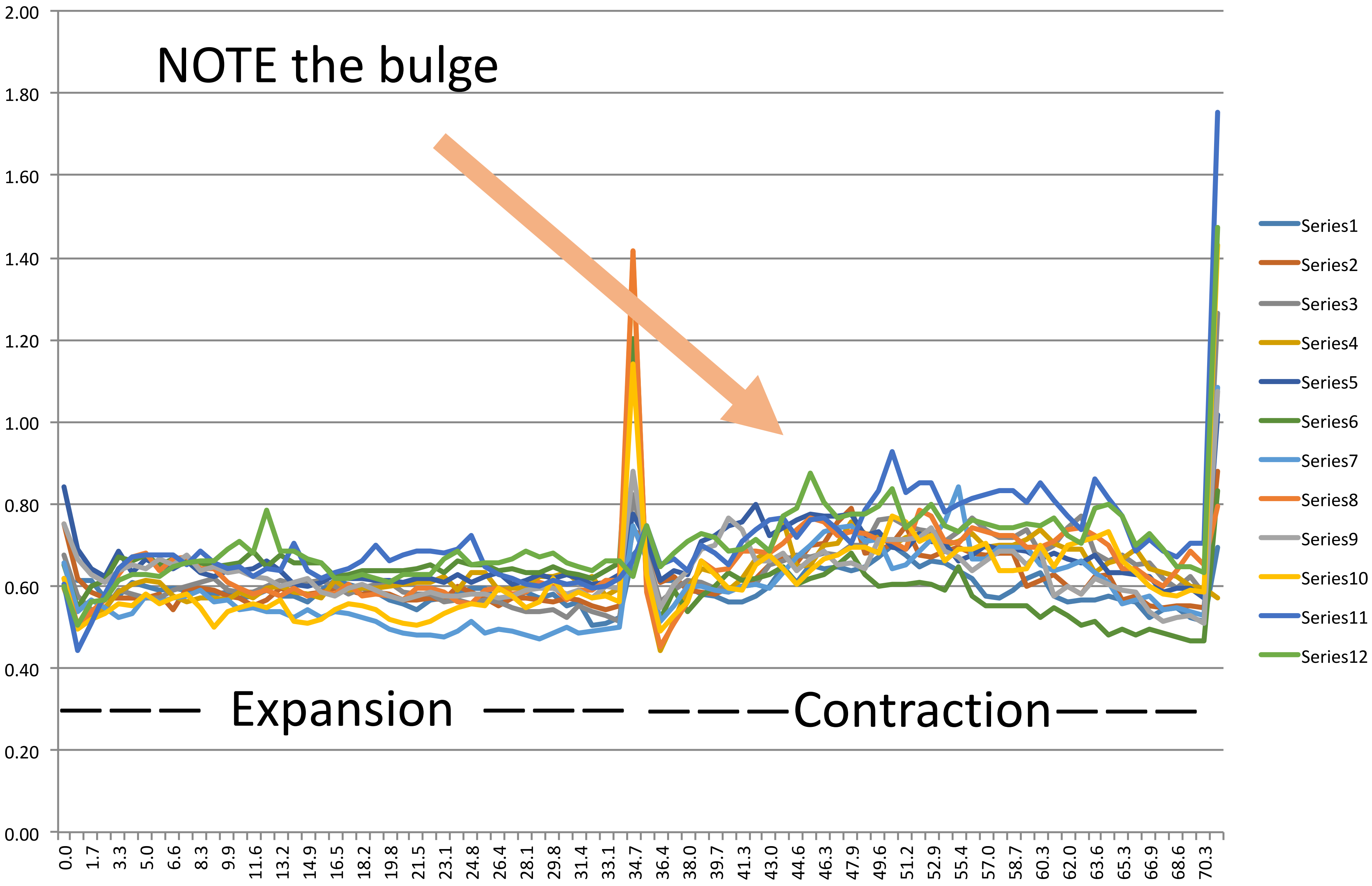
Electricity consumption over 12 motion cycles



Electricity consumption over 12 motion cycles AVERAGED

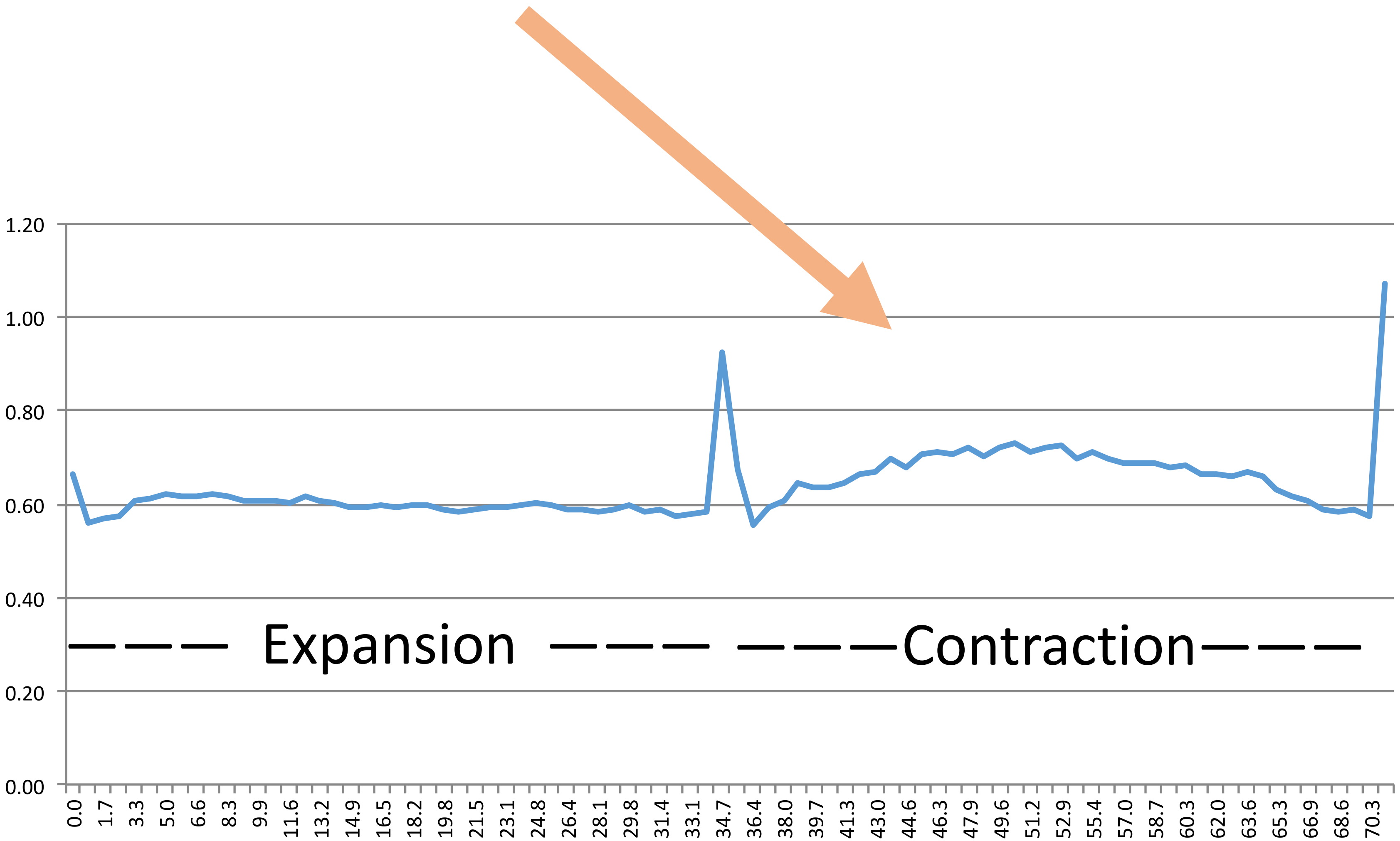


Drawbar pull for 12 motion cycles



Drawbar pull for 12 motion cycles, AVERAGED

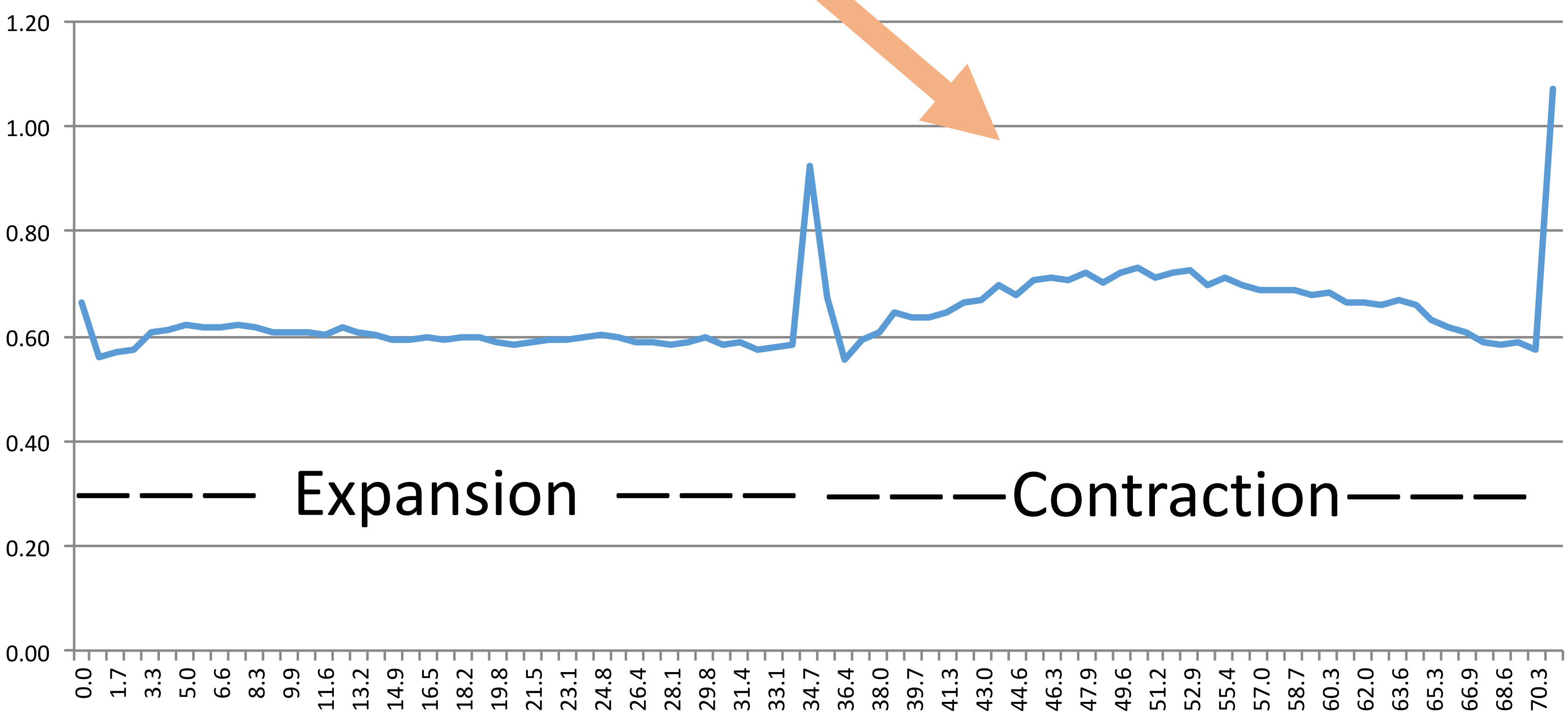
NOTE the bulge.



Drawbar pull for 12 motion cycles, AVERAGED

Possible explanations include change in depth of the front plow.

In any case: PUSH-PULL means less steady state and more transient phenomena.



After 12 cycles:
The cogwheel has travelled 48.3 m.
The plow has travelled 45.2 m.

On average 13 cm are lost to anchor the crampons.

Travel reduction: 6.4%

To calculate tractive efficiency, we need a good estimate of drawbar pull but drawbar pull does not reach a steady state during contraction.

Each expansion and each contraction lasts 35 seconds.

Based on seconds 25–35, tractive efficiency is 90%.

Based on seconds 15–35, tractive efficiency is 93%.

Based on seconds 5–35, tractive efficiency is 94%.

Tractors have tractive efficiency of <80% (often 70%).

Conclusion for crampon based traction:

Tractive efficiency depends on vehicle length.

A tractive efficiency of 90%–94% can be achieved with a vehicle length of 5 m.

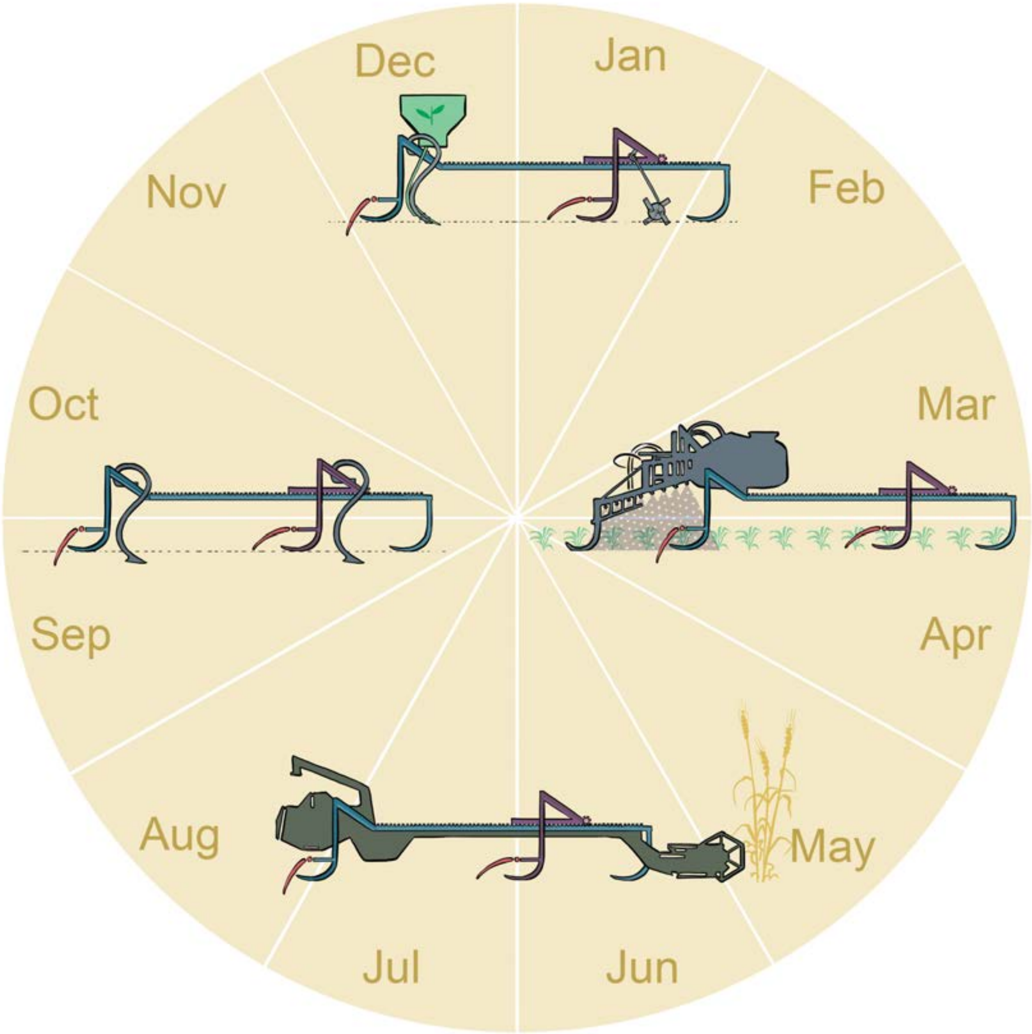
PUSH-PULL means less steady state and more transient phenomena.

The concepts of inserting crampons into the soil and then pushing or pulling from them cannot be treated as separate phases of the motion cycle.

The way the tines settle in the soil affects the motion dynamics and energy consumption of the vehicle during the push/pull phase.

This needs to be taken into account for low level motion control, and calls for special mounts for tools like plow shares to optimize interaction with the soil.

Thank you!



Please visit sedewa.com/utopus.html