Sustainable Technology to Reduce Energy Use in Travelling Sprinkler Irrigation

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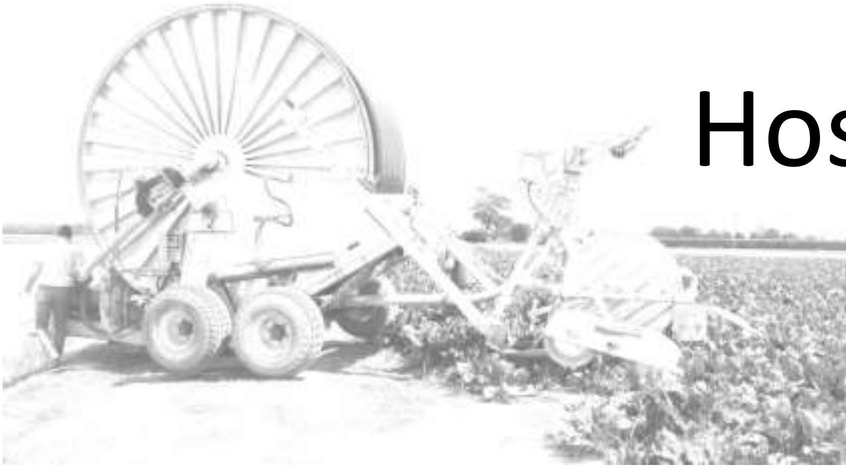
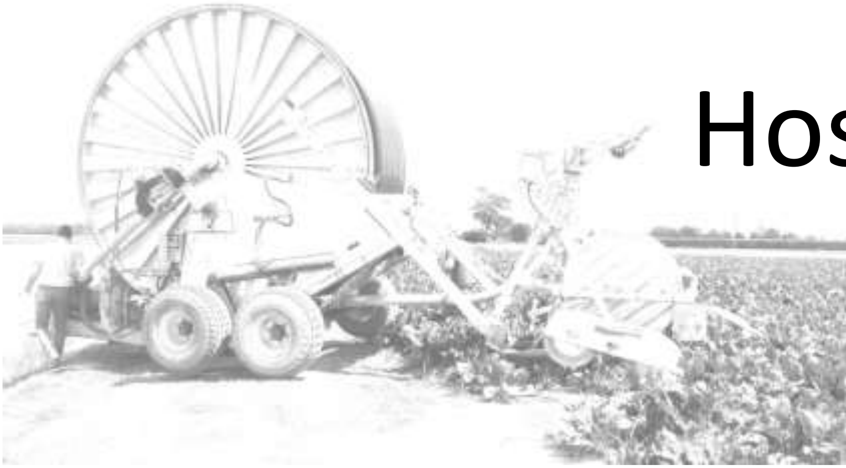


Hose Reel Irrigation (HRI)

- ✓ Travelling sprinkler irrigation using Hose Reel Irrigation machines is widely used worldwide (about 800,000 ha supplied by HRI systems in Italy)
- ✓ Among advantages of HRI: low cost per hectare, flexibility
- ✓ Among disadvantages of HRI: energy demand during field operations (i.e., water application and cart movement along the field), possible damage to system components due to applied traction force



Hose Reel Irrigation (HRI)

ENERGY USED TO:

- ✓ supply high pressure when big sprinklers are used ;
- ✓ unroll and rewind the travelling components (i.e., cart and HDPE pipe along the field).

DAMAGE ON:

- ✓ HDPE pipe (applied traction force exceeds yield strength);
- ✓ mechanical components of the machine;
- ✓ machine stability.

Mitigate disadvantages of HRI

- ✓ Applied traction force is mainly affected by:
  - friction between field surface and sliding components (i.e., HDPE pipe and cart);
  - weight of the same components (e.g., unrolled pipe and cart).

- ✓ Reducing traction force by reducing friction during HDPE pipe sliding onto the field proved to be a key strategy to cope with these issues.

The antifriction device

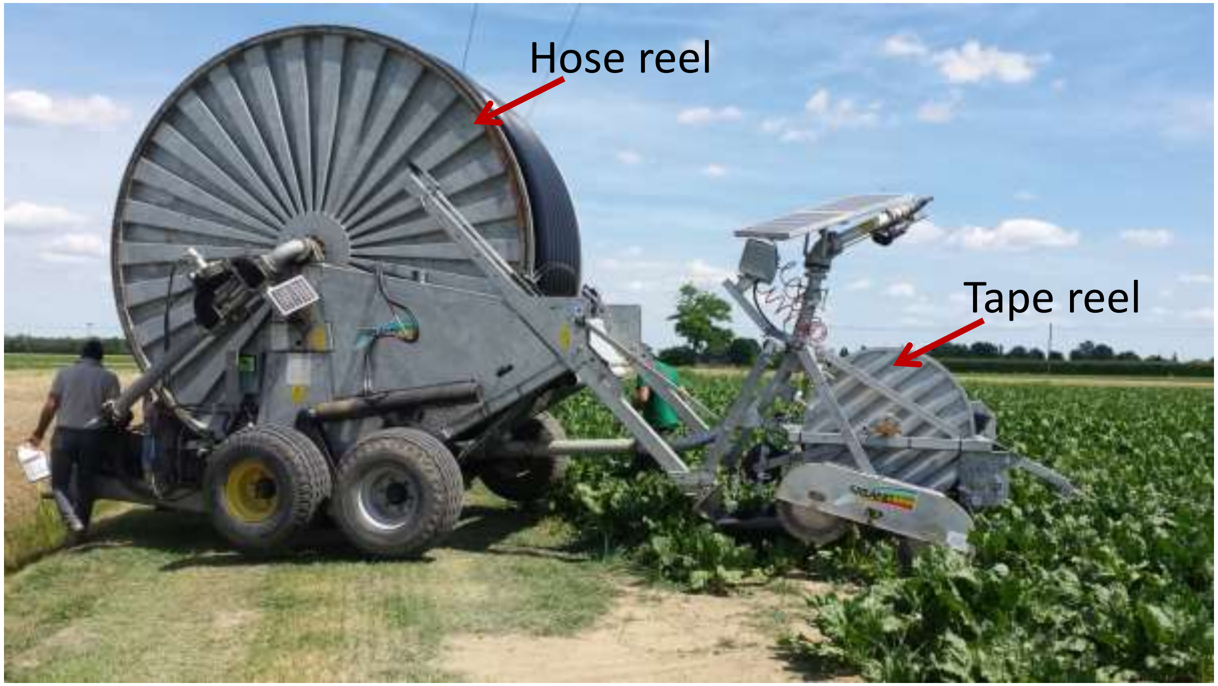
- ✓ Conceived, designed and manufactured by *Irriland srl*
- ✓ Still at the prototype stage, named *Protector*
- ✓ Developed with the support of GESAAF Department, University of Florence
- ✓ Awarded as best technical innovation at the International Exposition of Agricultural Machines (EIMA 2016, Bologna)
- ✓ Industrialization funding supported by the EU Horizon 2020-SMEInst with more than 1M euro (official start of the project: August 1, 2018)

How does *Protector* work

The system consists of a tape, about 60 cm wide, made of recycled plastic, rolled up in a small reel positioned in the travelling cart. The tape has to be connected to the irrigation machine

How does *Protector* work

During cart pulling for positioning, pipe & tape unroll from respective reel. The tape lays down on the ground, under the hose



How does *Protector* work

During irrigation, pipe & tape roll up in respective reel

Performance evaluation

Field test –still in progress- carried out in June 2017 and July 2018 in a farm located in the Padana plain. Aim to assess:

- ✓ influence of *Protector* on applied traction force;
- ✓ use of thinner pipes (same outside diameter, OD, given);
- ✓ impact on energy use during the economical lifetime of the machine.

Performance evaluation

Two prototypes, used separately on:

- Sugarbeet (Field 1);
- Alfalfa (Field 2);
- Bare soil (Field 3).

Test carried out:

- with (Pr) and without (NoPr) *Protector*;
- pipe Filled and Empty.

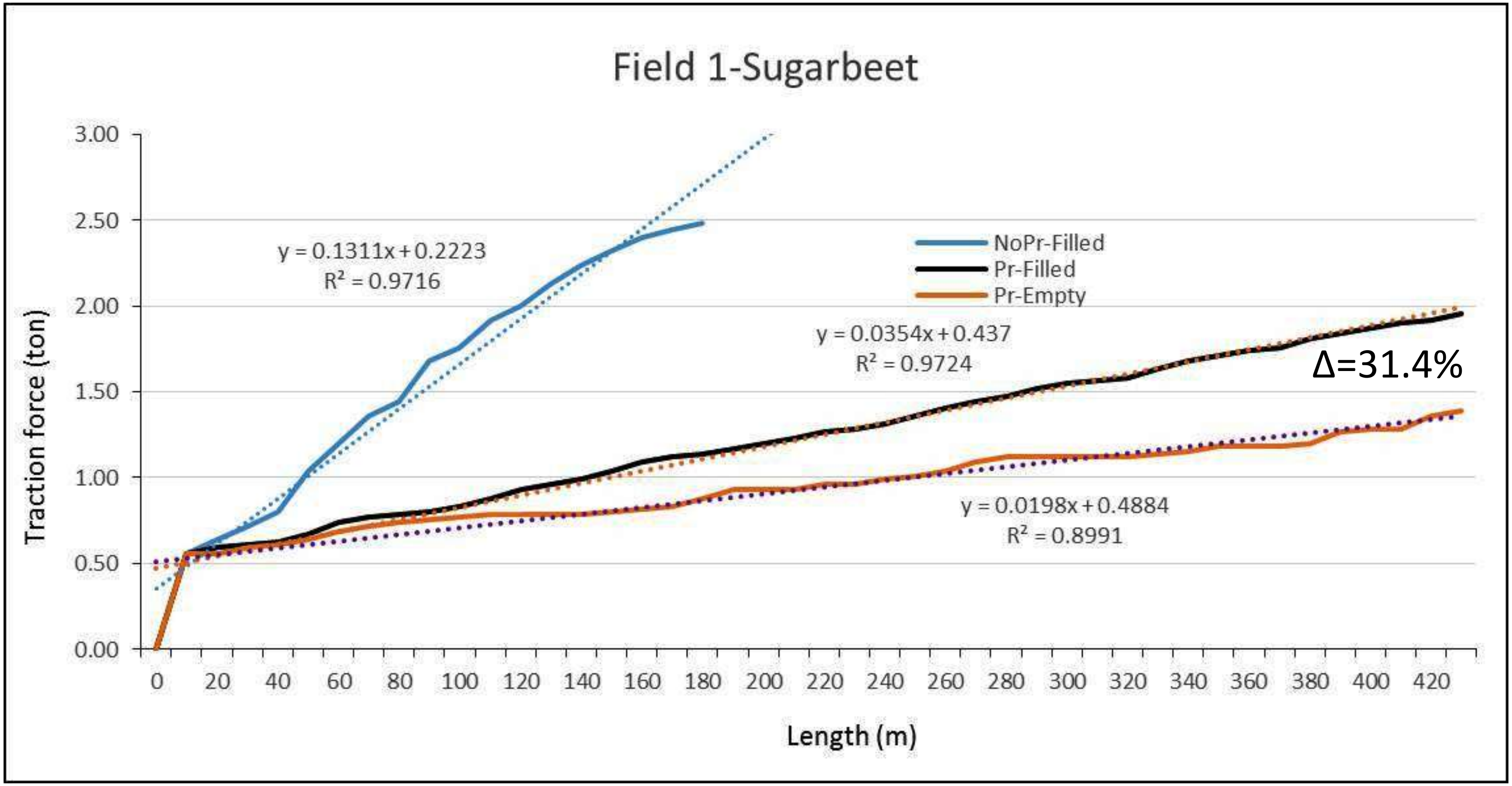
Performance evaluation

During pipe unrolling, readings made every 10 m from the starting point using a hydraulic dynamometer

Performance evaluation

Applied traction force along the cart lane increases almost linearly (e.g., same friction coefficient) in all test conditions. Therefore, energy can be calculated as the average applied force multiplied by the distance traveled by the cart

Results - Sugarbeet (Field 1)



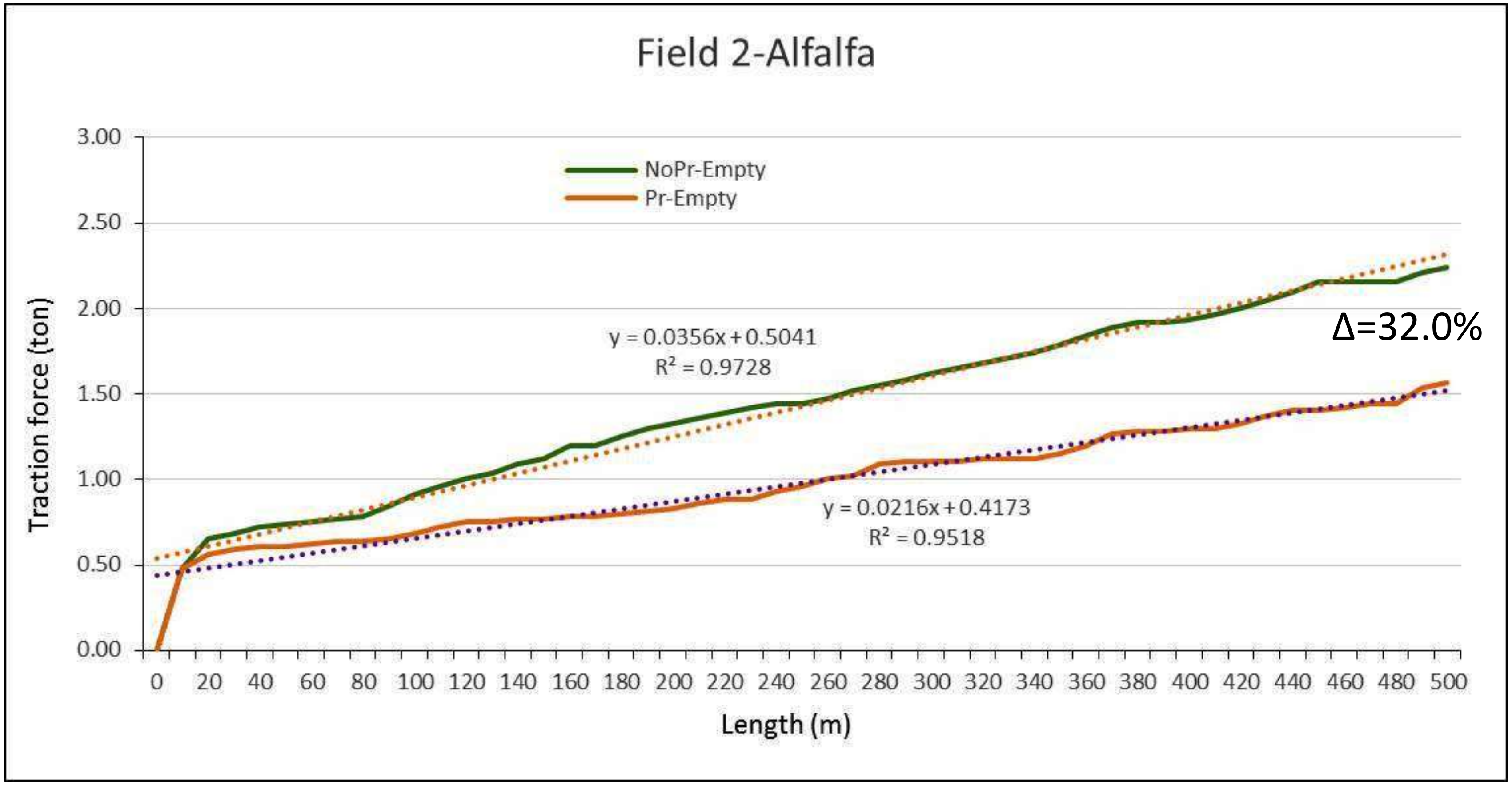
Field slope: <0.5%

Pipe: HDPE 135x12.5 mm Ø

Unrolling speed: 5 km/h

Pipe weight: about 15 kg/m when filled, 6 kg/m when empty

Results - Alfalfa (Field 2)



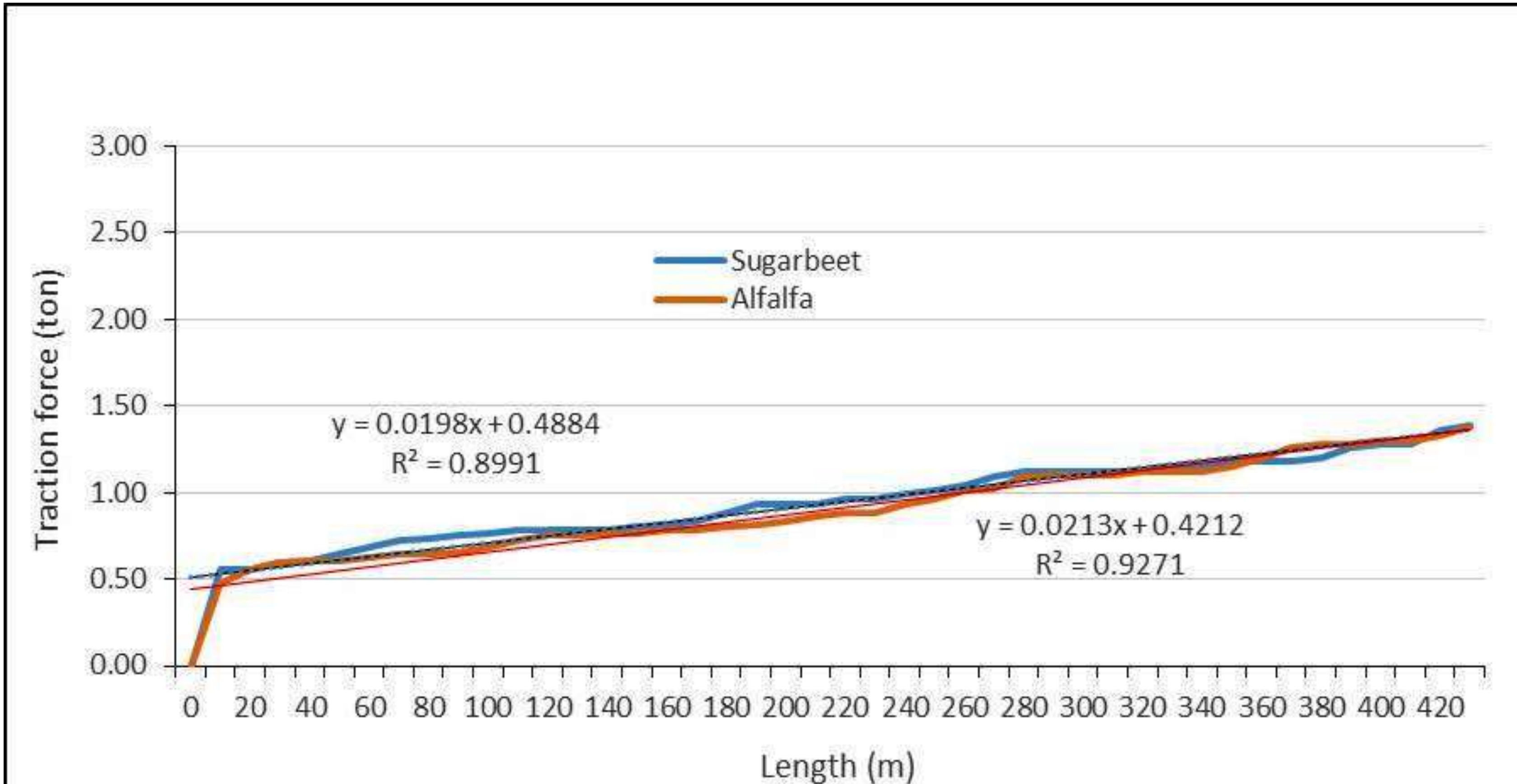
Field slope: 1.5%

Pipe: HDPE 140x12.0 mm Ø

Unrolling speed: 5 km/h

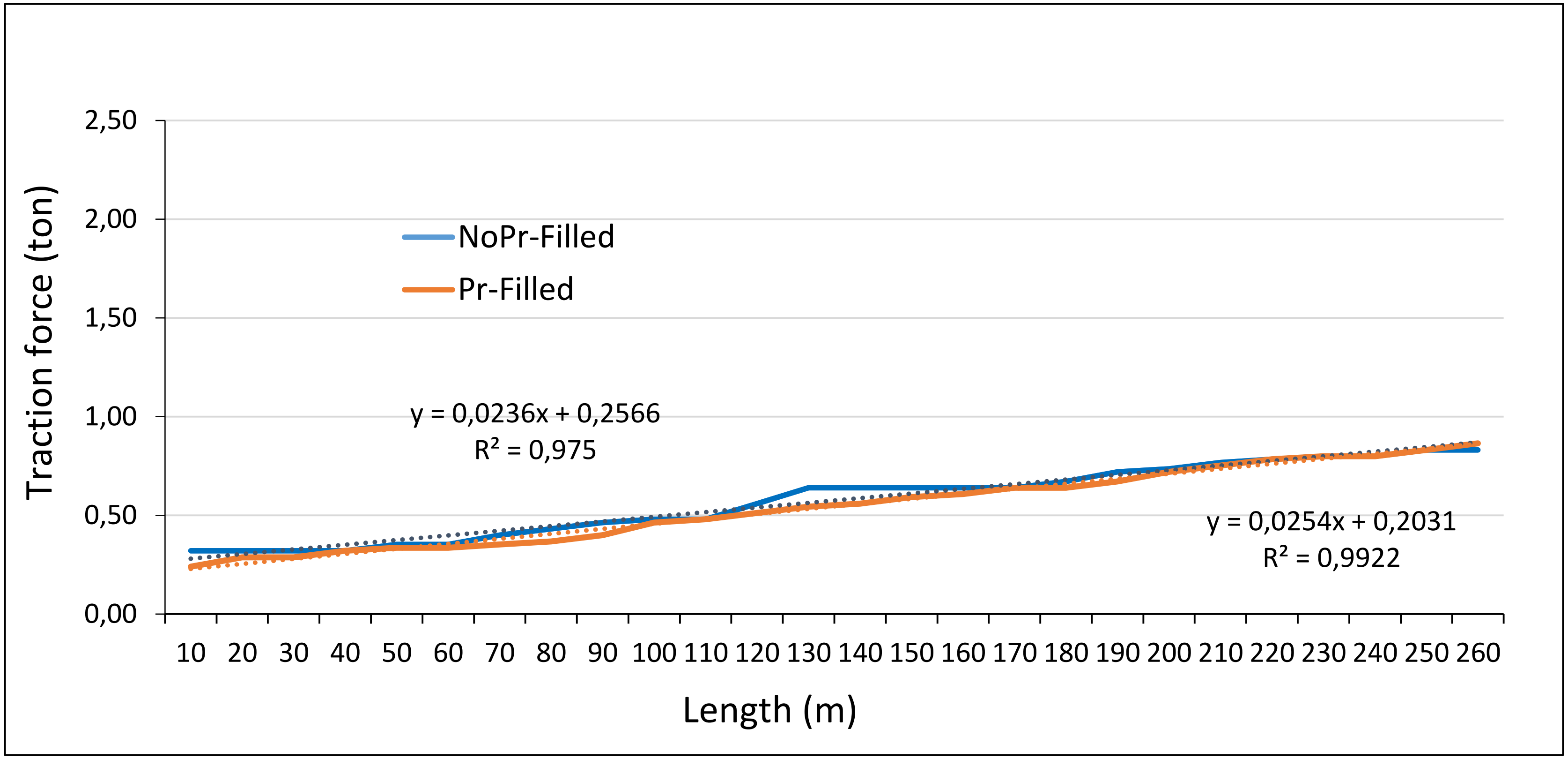
Pipe weight: about 15 kg/m when filled, 6 kg/m when empty

Results – Pr-Empty (Field 1 & Field 2)



Using *Protector*, variation of applied force during unrolling is similar, regardless of field slope and type of ground cover

Results - Bare soil (Field 3)



When friction coefficient is low (about 0.5), the influence of *Protector* seems not evident

Energy use during retrieval

- ✓ Energy for cart retrieval is in charge of the irrigation machine (energy taken from irrigation water)
- ✓ Compared to unrolling, preliminary output show similar pattern of energy variation (linear)

Protector and pipe selection

By reducing applied traction force, *Protector* allows the use of pipes having thinner thickness (Th) given the same outside diameter (OD), on condition that:

I. water pressure does not exceed threshold value suggested by pipe manufacturer (e.g., 10 bar);
II. applied traction force, F_t, is less than pipe yield strength:

$$F_t < 0.35 * \pi * \sigma_y * OD^2 * \left(\frac{1}{SDR} - \frac{1}{SDR^2}\right)$$

Where:

- σ_y = yield strength of PE at given temperature;
- SDR = OD/Th.

Therefore, maximal pipe length, L, that can be pulled should be:

$$L < \frac{0.35 * \sigma_y}{\mu * g * \rho_{PE}}$$

Where:

- μ = friction coefficient;
- ρ_{PE} = density of PE.

Reference scenario (north Italy)

-HRI with gun sprinkler;
-nozzle diameter: 36 mm;
-pressure at the sprinkler: 63 m;
-seasonal irrigation depth: 210 mm;
-applied depth per irrigation: 30 mm;
-number of irrigations in the season: 7;
-min irrigation interval: 6 days;
-max irrigation time per day: 22 h;
-OD: 140 mm;
-internal diameters:

- 112 mm (SDR 11);
- 124 mm (SDR 17);

-max HDPE pipe length: 820 m;
-pump efficiency: 50%;
-economical lifetime of the machine: 15 years;
-flat field.

Energy use, impact on climate (CO_2eq.) and energy cost per hectare

L/OD (m)	d (mm)	H (m)	Q (l/s)	R (m)	V (m/h)	A (ha)	Y (m)	Hm (m)	P (kW)	E (kWh/ha)	D (kg/ha)	CO_2eq. (kg/ha)	D€ (€/ha)	D€tot (€/yr)	Δ (%)
200/50 SDR17	16	28	4.3	28.6	9.0	6.8	39	67	5.65	767.7	65.1	208.8	62.8	427	12.0
200/50 SDR11							48	76	6.41	871.0	73.8	236.9	71.3	485	
500/110 SDR17	28	49	17.4	50.0	20.9	27.6	26	75	25.59	856.7	72.6	233.1	70.1	1,936	25.6
500/110 SDR11							46	95	34.41	1,152.0	97.6	313.4	94.3	2,603	
820/140 SDR17	36	63	32.6	64.3	30.4	51.6	37	100	63.92	1,144.6	97.0	311.4	93.7	4,835	**19.3**
820/140 SDR11							61	124	79.26	1,419.3	120.3	386.1	116.2	5,995	

Impact on climate due to fuel consumption is given as kg CO_2eq. according to system working conditions. Reference period is the use phase during the economical lifetime (15 years), assuming that system performance is constant during that period.

Impact and cost due to HDPE pipe during economic system lifetime (15 years)

L/OD (m)		Weight		Pipe impact		Pipe cost		
		Kg/m	Kg	Kg CO_2 eq.	Δ (%)	€/m	€	Δ (%)
200/50 SDR17		0.52	104.0	241.8	18	1.16	232	19
200/50 SDR11		0.63	126.0	294.8		1.43	286	
500/110 SDR17		2.32	1,160.0	2,712.6	38	4.86	2,430	37
500/110 SDR11		3.75	1,875.0	4,390.2		7.76	3,880	
820/140 SDR17		3.18	2,607.6	6,111.0	40	6.66	5,461	39
820/140 SDR11		5.32	4,256.0	10,208.2		10.98	9,004	

Impact on climate due to HDPE pipe production is given as kg CO_2eq. according to the Life Cycle Analisis (LCA) approach. Reference period is the production phase.

Total impact and cost at the end of the economic lifetime of pipe and machine

L/OD (m)	Water lifting Impact (kg $CO_{2eq.}$)	Pipe Impact (kg $CO_{2eq.}$)	Total impact (kg $CO_{2eq.}$)	Δ (%)	Water lifting cost (€)	Pipe cost (€)	Total cost (€)	Δ (%)
200/50 SDR17	21,297.6	241.8	21,539.4	11.9	6,405	232	6,637	12.2
200/50 SDR11	24,163.8	294.8	24,458.6		7,275	286	7,561	
500/110 SDR17	96,503.4	2,712.6	99,216.0	26.0	29,040	2,430	31,470	26.7
500/110 SDR11	129,747.6	4,390.2	134,137.8		39,045	3,880	42,925	
820/140 SDR17	241,023.6	6,111.0	247,134.6	20.0	72,525	5,461	77,986	21.2
820/140 SDR11	298,841.4	10,208.2	309,049.6		89,925	9,004	98,929	

Conclusions

- Compared to other field operations, energy used for water lifting during system economical lifetime is by far the greatest source of monetary cost and GHG emissions
- Preliminary results show the potential of Protector in reducing energy use (GHG emissions) and cost, given the same working performance of the HRI system
- Both environment and farm economy can significantly benefit from *Protector* technology
- Research on Protector is still in progress and improved performance are expected

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