Smart technology to reduce energy consumption for water spreading and pipe production in Hose Reel sprinkler Irrigation

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- Hose Reel sprinkler Irrigation
- Device to reduce energy consumption during field operations
- Field evaluations
- Results
- Conclusions

Hose Reel sprinkler Irrigation

- ✓ 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

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).

MECHANICAL STRESS AND POSSIBLE DAMAGE ON:

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

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

Device to reduce energy consumption during field operations

The antifriction device

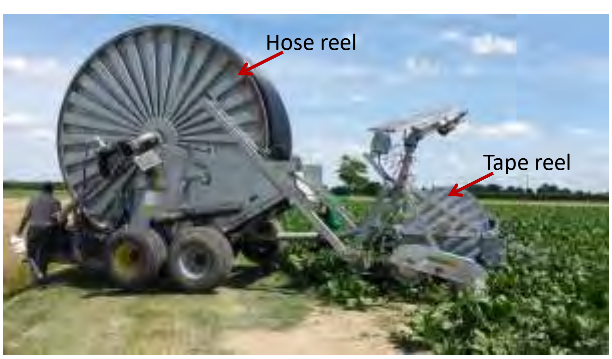
- ✓ Conceived, designed and manufactured by *Irriland srl*
- ✓ Still at the prototype stage, named *Protector*
- ✓ Developed with the support of GESAAF Department, University of Florence
- ✓ Awarded as best technical innovation at the International Exposition of Agricultural Machines (EIMA 2016, Bologna)
- ✓ Industrialization funding supported by the EU Horizon 2020-SMEInst
- ✓ Patented system: the patent is valid in many Countries worldwide

How does *Protector* work

The system consists of a tape, about 60 cm wide, made by different materials, still on test, 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, hose & tape unroll from respective reel. The tape lays underneath between the polyethylene hose and the ground



How does *Protector* work

During irrigation, hose & tape roll up in respective reel

Field evaluations

Field test –still in progress- carried out in June 2017 and summer 2018 in some farms located in the Padana plain.
Aim to assess:

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

Some prototypes, used separately on:

- Sugar beet;
- Alfalfa;
- Bare hard/dry soil surface.

Test carried out:

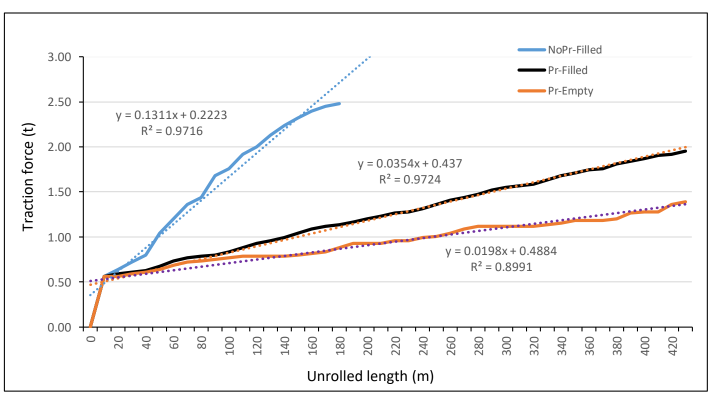
- with (Pr) and without (NoPr) *Protector*;
- Filled and Empty hose.

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

Applied traction force along the cart lane increases almost linearly (e.g., same friction coefficient, constant speed) in all test conditions.

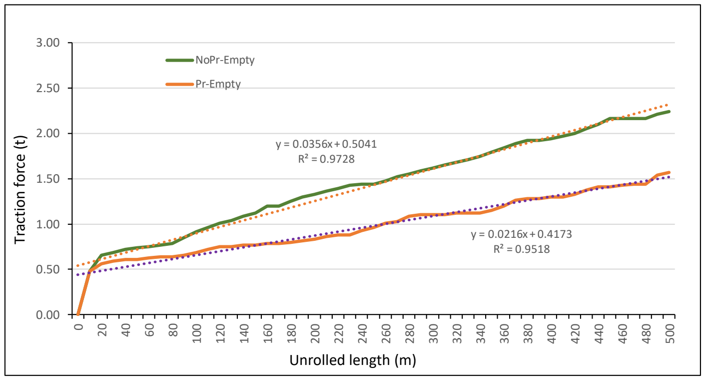
Results

Sugar beet



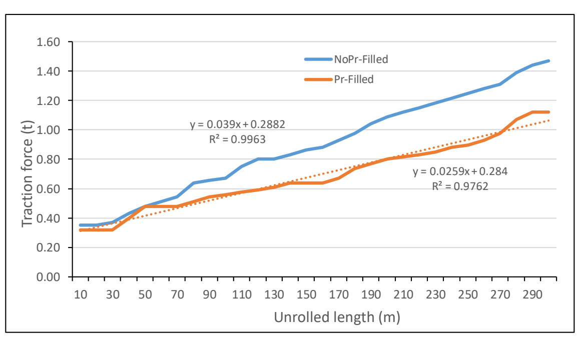
Field slope: <0.5%
Hose: HDPE 135x12.5 mm Ø
Unrolling speed: 5 km/h
Hose weight: 14.1 kg/m when filled, 4.6 kg/m when empty

Alfa alfa



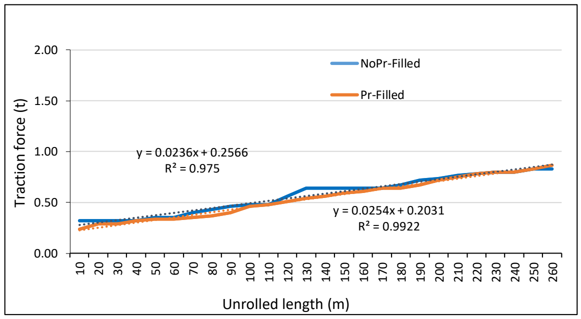
Field slope: 1.5%
Hose: HDPE 140x12.0 mm Ø
Unrolling speed: 5 km/h
Hose weight: 4.6 kg/m when empty

Alfalfa



Field slope: <1%
Hose: HDPE 140x12.0 mm Ø
Unrolling speed: 3 km/h
Hose weight: 15.2kg/m when filled

Bare dry soil



Friction coefficient values (roughly) under test conditions:
-Hose/Protector: 0.13÷0.25
-Hose/Field surfaces: 0.16÷0.88

Energy use during retrieval

- ✓ Energy for cart retrieval is in charge of the irrigation machine (energy taken from irrigation water)
- ✓ Retrieval speed is about 25 m/h
- ✓ Compared to unrolling, energy variation is similar (as expected)

Protector and hose selection

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

I. water pressure does not exceed threshold value suggested by hose manufacturer (e.g., 10 bar);
II. applied traction force, F_t, is less than hose 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 (Nupi: 23 Mpa at 20 °C);
- SDR (Standard Dimension Ratio)= OD/Th.

Therefore, maximal hose 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;
-hose OD: 140 mm;
-hose internal diameters:
- ❖ 112 mm (SDR 11);
- ❖ 124 mm (SDR 17);

-nozzle diameter (ND, related to hose OD): 36 mm;
-pressure at the sprinkler inlet (related to ND): 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;
-max HDPE hose length by allowed pressure: 820 m;
-max HDPE hose length by allowed traction force: 854 m;
-overall efficiency (i.e., engine-transmission-pump): 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	

d=nozzle diameter;
H=water pressure at the sprinkler inlet;
Q=water flow;
R=actual wetted radius;
V=rewind speed of the cart to supply irrigation depth;
A=max irrigated area per season;

Y=head loss along the hose;
Hm=total head at the hose inlet;
P=power absorbed by the pump (η=50%);
E=seasonal energy used by the pump;
D=seasonal diesel used by the pump;
CO_2eq.=environmental impact;
D€=cost of diesel;
D€tot=cost of diesel;
Δ=variation.

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** (%)
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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 system performance is constant during that period.

Case 1
Impact and cost due to HDPE hose at the end of the economic lifetime of the machine (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 hose is given as kg CO_2eq.. Reference period is the production phase.

Case 1
Total impact and cost at the end of the economic lifetime of machine and hose

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	

Impact on climate due to fuel consumption (use phase) and hose (production phase) is given as kg CO_2eq.. Both impacts calculated at the end of the economical lifetime of the machine (15 years). Cost for water lifting and hose purchase refers to use phase.

Case 2
Impact and cost due to HDPE hose replaced during the economic lifetime of the machine

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	59	1.16	232	59
200/50 SDR11	0.63	126.0	589.5		1.43	572	
500/110 SDR17	2.32	1,160.0	2,712.6	69	4.86	2,430	69
500/110 SDR11	3.75	1,875.0	8,780.4		7.76	7,760	
820/140 SDR17	3.18	2,607.6	6,111.0	70	6.66	5,461	70
820/140 SDR11	5.32	4,256.0	20,416.4		10.98	18,007	

Impact on climate due to HDPE hose replaced is given as kg CO_2eq.. Reference period is the production phase.

Case 2
Total impact and cost at the end of the economic lifetime of the machine (HDPE hose replaced)

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	13.0	6,405	232	6,637	15.4
200/50 SDR11	24,163.8	589.5	24,753.3		7,275	572	7,847	
500/110 SDR17	96,503.4	2,712.6	99,216.0	28.4	29,040	2,430	31,470	32.8
500/110 SDR11	129,747.6	8,780.4	138,528.0		39,045	7,760	46,805	
820/140 SDR17	241,023.6	6,111.0	247,134.6	22.6	72,525	5,461	77,986	27.7
820/140 SDR11	298,841.4	20,416.4	319,257.8		89,925	18,007	107,932	

Impact on climate due to fuel consumption (use phase) and hose (production phase) is given as kg CO_2eq.. Both impacts calculated at the end of the economical lifetime of the machine (15 years).

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
- Money savings allowed by thinner HDPE hose correspond to the purchase value of Protector
- Both environment and farm economy can significantly benefit from *Protector* technology
- Research on Protector is still in progress and improved performance are expected


Thank you