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

➢ 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.

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 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:

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

Where:
- $\sigma_y$ = 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:

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

Where:
- $\mu$ = friction coefficient;
- $\rho_{PE}$ = 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$_2$eq.) and energy cost per hectare

<table>
<thead>
<tr>
<th>L/O D (m)</th>
<th>d (mm)</th>
<th>H (m)</th>
<th>Q (l/s)</th>
<th>R (m)</th>
<th>V (m/h)</th>
<th>A (ha)</th>
<th>Y (m)</th>
<th>Hm (m)</th>
<th>P (kW)</th>
<th>E (kWh/ha)</th>
<th>D (kg/ha)</th>
<th>D€ (€/ha)</th>
<th>D€tot (€/yr)</th>
<th>Δ (%)</th>
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</table>

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 (ƞ=50%);  
E=seasonal energy used by the pump;  
D= seasonal diesel used by the pump;  
CO$_2$ eq.=environmental impact;  
D€=cost of diesel;  
D€tot=cost of diesel;  
Δ=variation.

Impact on climate due to fuel consumption is given as kg CO$_2$eq. 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)

<table>
<thead>
<tr>
<th>L/OD (m)</th>
<th>Weight</th>
<th>Pipe impact</th>
<th>Pipe cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kg/m</td>
<td>Kg CO₂ eq.</td>
<td>€/m</td>
</tr>
<tr>
<td>200/50</td>
<td>0.52</td>
<td>104.0</td>
<td>241.5</td>
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<tr>
<td>SDR17</td>
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<tr>
<td>200/50</td>
<td>0.63</td>
<td>126.0</td>
<td>294.8</td>
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<tr>
<td>500/110</td>
<td>2.32</td>
<td>1,160.0</td>
<td>2,712.6</td>
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<tr>
<td>SDR17</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>500/110</td>
<td>3.75</td>
<td>1,875.0</td>
<td>4,390.2</td>
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<tr>
<td>SDR11</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>820/140</td>
<td>3.18</td>
<td>2,607.6</td>
<td>6,111.0</td>
</tr>
<tr>
<td>SDR17</td>
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<tr>
<td>820/140</td>
<td>5.32</td>
<td>4,256.0</td>
<td>10,208.2</td>
</tr>
<tr>
<td>SDR11</td>
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</table>

Impact on climate due to HDPE hose is given as kg CO₂eq.. Reference period is the production phase.

## Case 1

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

<table>
<thead>
<tr>
<th>L/OD (m)</th>
<th>Water lifting (kg CO₂ eq.)</th>
<th>Pipe impact (kg CO₂ eq.)</th>
<th>Total impact (kg CO₂ eq.)</th>
<th>Δ (%)</th>
<th>Water lifting cost (€)</th>
<th>Pipe cost (€)</th>
<th>Total cost (€)</th>
<th>Δ (%)</th>
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<tr>
<td>200/50</td>
<td>21,297.6</td>
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<td>21,539.4</td>
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<tr>
<td>200/50</td>
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<tr>
<td>500/110</td>
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<td>2,712.6</td>
<td>99,216.0</td>
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<td>29,040</td>
<td>2,430</td>
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</tr>
<tr>
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<tr>
<td>820/140</td>
<td>241,023.6</td>
<td>6,111.0</td>
<td>247,134.6</td>
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</table>

Impact on climate due to fuel consumption (use phase) and hose (production phase) is given as kg CO₂eq.. 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

<table>
<thead>
<tr>
<th>L/OD (m)</th>
<th>Weight</th>
<th>Pipe impact</th>
<th>Pipe cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kg/m</td>
<td>Kg</td>
<td>Kg CO₂ eq.</td>
</tr>
<tr>
<td>200/50 SDR17</td>
<td>0.52</td>
<td>104.0</td>
<td>241.8</td>
</tr>
<tr>
<td>200/50 SDR11</td>
<td>0.63</td>
<td>126.0</td>
<td>589.5</td>
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<td>2,712.6</td>
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<tr>
<td>500/110 SDR11</td>
<td>3.75</td>
<td>1,875.0</td>
<td>8,780.4</td>
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<tr>
<td>820/140 SDR11</td>
<td>5.32</td>
<td>4,256.0</td>
<td>20,416.4</td>
</tr>
</tbody>
</table>

Impact on climate due to HDPE hose replaced is given as kg CO₂eq. 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)

<table>
<thead>
<tr>
<th>L/OD (m)</th>
<th>Water lifting Impact (kg CO₂ eq.)</th>
<th>Pipe impact (kg CO₂ eq.)</th>
<th>Total impact (kg CO₂ eq.)</th>
<th>Δ (%)</th>
<th>Water lifting cost (€)</th>
<th>Pipe cost (€)</th>
<th>Total cost (€)</th>
<th>Δ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200/50 SDR17</td>
<td>21,297.6</td>
<td>241.8</td>
<td>21,539.4</td>
<td>13.0</td>
<td>6,405</td>
<td>232</td>
<td>6,637</td>
<td>15.4</td>
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<tr>
<td>200/50 SDR11</td>
<td>24,163.8</td>
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<td>18,007</td>
<td>107,932</td>
<td>126,940</td>
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</table>

Impact on climate due to fuel consumption (use phase) and hose (production phase) is given as kg CO₂eq. 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