Improving Water Resources Management Efficiency For Cranberry Production

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Scope of this Study

Cranberry evapotranspiration is relatively low (2mm/day), however, the plant is very sensitive to weather conditions and requires extensive amount of water to [1]:

- **Prevent frost**
  - When temperature at ground level < 0˚C (30 mm/day)
- **Prevent heat stress**
  - When temperature at ground level > 32˚C (2 mm/day)
- **Maintain optimal soil matric potential in the root zone**
  - -7 kPa < ψ < -3 kPa [2]
- **Protect the vegetative cover during winter** (203 mm)
- **Protect against invasion of insects** (10 mm/day)
- **Harvest the fruits** (406 mm)

The scope of this study is to:

- Improve current water management practices of existing farms
- Assess water requirements under changing climate conditions

Field Monitoring and Modelling

Field Monitoring

Cranberry fields are monitored throughout the growing season. Recorded data include:

- Weather conditions
  - Wind speed, solar radiation, temperature, precipitation, relative humidity
- Soil matric potential at depths (15 & 40 cm)
- Water height level in irrigation/drainage channel

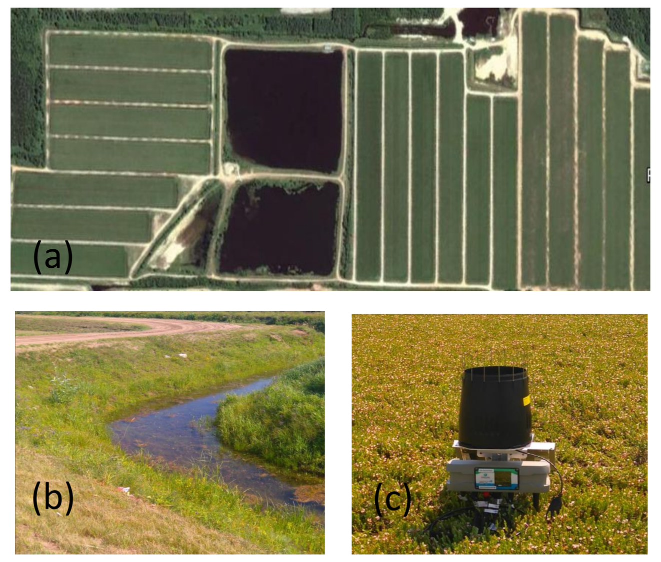


Fig. 1. (a) Cranberry farm (image from Google Earth); (b) water level in subirrigation channel; (c) Irrigation and precipitation instrumentation

Model Development

The methodological approach is based on the development of a mathematical model capable of simulating water requirements for an extended period of time (*e.g.*, 30 years). The model is built at the cranberry farm scale and simulates the water budget of the major control volumes, including:

- Cranberry fields
- Drainage and irrigation network
- Reservoir units

The control volume are further described by various fluxes using a daily time step such as:

- Evaporation
- Evapotranspiration
- Field water storage and drainage,
- Channel and reservoir water storage
- Deep percolation

The model balances daily the water budget equation for each control volume and the whole farm system:

$$\frac{\partial s}{\partial t} = \int (Input - output)dt$$

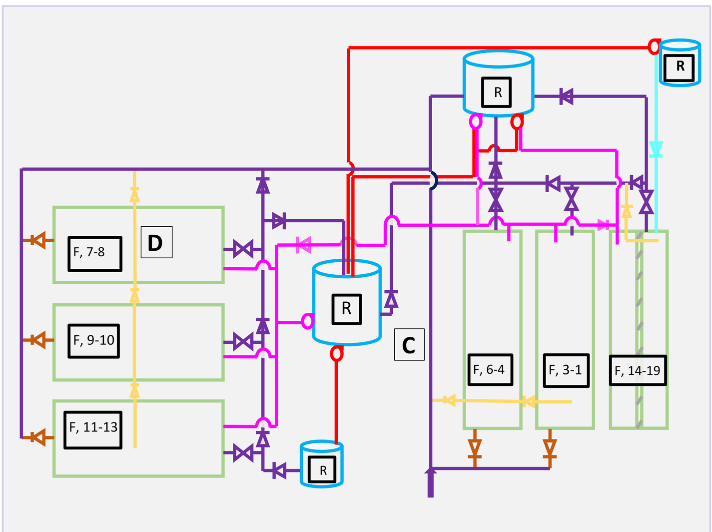


Fig. 2 (a) Farm system

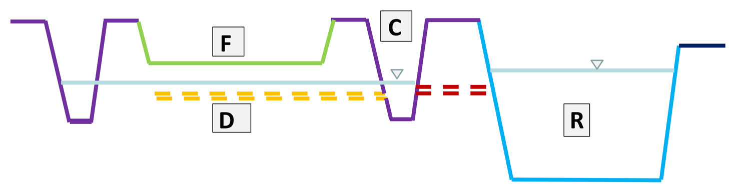


Fig. 2(b) Field and drainage network

Legend

Cranberry fields ; Reservoirs, Sub-irrigation and valve , Irrigation pipe and valve (growth, frost et excessive heat), Bidirectional Valve (flooding and recycling); Channel and Simple Valve, Simple valve ; Hydraulic pumps

Cranberry Field Model

- The cranberry field water balance equation is solved analytically, assuming a static matric potential distribution in the unsaturated soil derived from Yuan and Lu's [4] equation for shallow water table.
- The soil moisture is derived using Brooks and Corey [3] water retention function.
- The soil profile is discretized into several points and the upper and lower boundaries are submitted to the processes described in the water budget equation.

Cranberry field water balance equation

$$\frac{dV_F}{dt} = \int_{dt} (P + IRR - Q_{dr} - ET - G_{out})dt$$

Matric flux and potential [4]

$$\Phi(z) = ({K_s}/{\alpha}) e^{-\alpha * z}$$

$$\psi(z) = \frac{1}{\alpha} * \ln\left[\frac{\alpha * \Phi(z)}{K_s}\right]$$

Soil moisture [2]

$$\theta(z) = \theta_r + (\theta_s - \theta_r)\left({\psi_a}/{\psi}\right)^{\lambda}, \quad 0 > \psi < \psi_a$$

$$\theta(z) = \theta_s, \quad \psi \geq \psi_a$$

Cranberry field storage volume

$$V_F(t) = n * \int \theta(z,t)dz$$

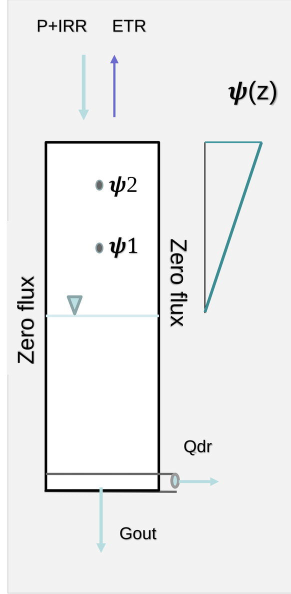


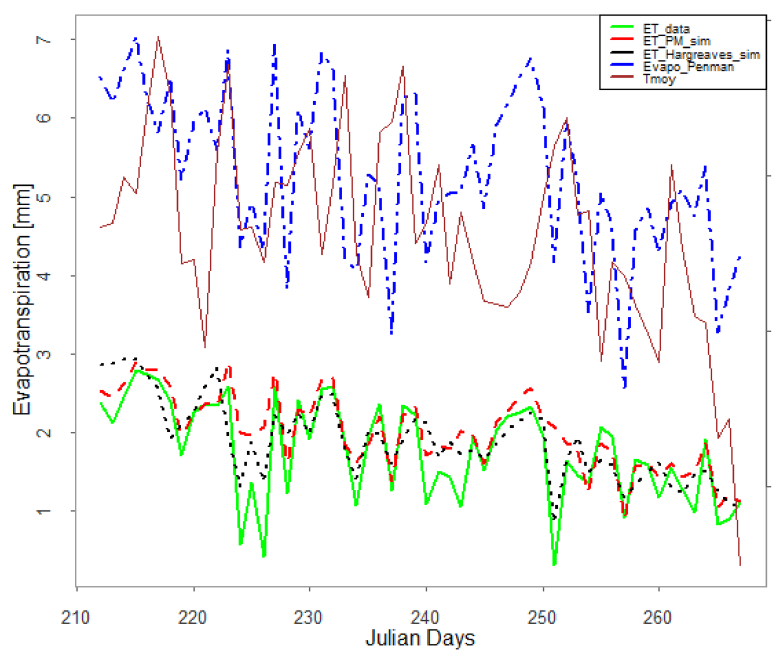
Fig.3. Cranberry field soil profile

P=precipitation, *IRR*=irrigation, *ETR*=real evapotranspiration, *Qdr*=drainage rate, *Gout*=deep percolation, α =Gardner's coefficient, θ=soil moisture, n =soil effective porosity, K_s= saturated hydraulic conductivity, θ_r =residual soil moisture, θ_s=saturated soil moisture, ψ_a= air-entry pressure head, λ=slope of soil moisture profile

Preliminary Results and Discussion

Evapotranspiration (ET) and Evaporation (E)

- ET simulation are tested for August and September 2016.
  - A benchmark ET was calculated using the ETo Calculator Software v3.1 [6] and a cranberry transpiration coefficient of 0.5 [7].
- The simulated results show that the ET computed either by means of Penman-Monteith [7] or Hargreaves and Samani [8] performed well.
  - It can be assumed that the cranberry average ET is about 2 mm/day.
  - The Hargreaves [8] equation also provides a good approximation of the Penman-Monteith equation.
- Evaporation of surface water bodies computed using the Penman equation [7] is similar to that of ET with a ratio of 2.71.



	ETo FAO	PM simulated	Hargreaves Simulated	Evaporation (Penman)
Median ET	1.92	1.99	1.90	5.20
Ratio Simulated / Reference	1.00	1.04	0.99	2.71

Fig. 4. Evaporation and Evapotranspiration

Matric Potential and Soil Moisture

- Data collected show that the matric potential profile can, to some extent, be approximated by a linear model.
- The result illustrates that the range of optimal matric potential (-7kPa to -3kPa) within the plant root zone can be achieved if the water table is between 30- and 60-cm deep.
- For efficient and safe water table management the lower limit of 60 cm depth represents a better choice. The soil pore size distribution affects the aforementioned limits.

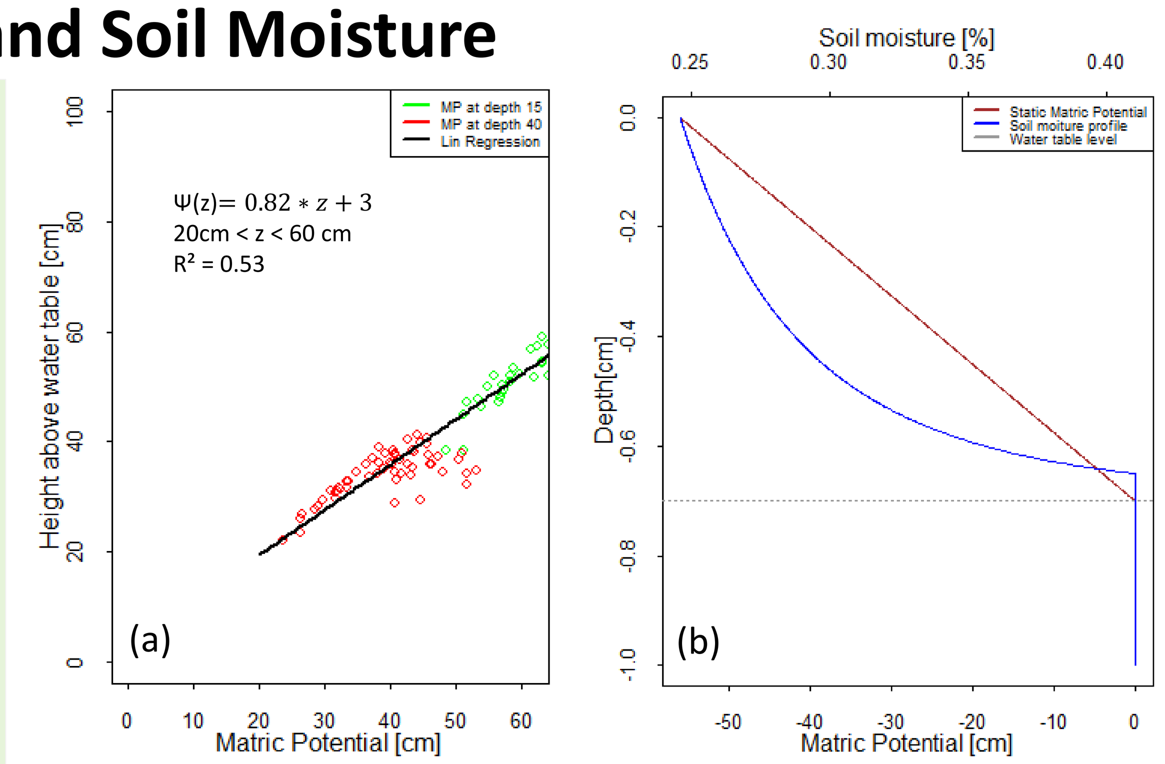


Fig. 5. (a) Monitored soil matric potential at a depth of 15 cm (green points) and at a depth of 40 cm (red points) and linear regression with an average of 50% variation K_s= 20cm/day, α =0.019 ; (b) Soil moisture computed assuming a static matric potential distribution , θ_r =0.07, θ_s=0.38, ψ_a= -5 cm, λ=0.2

Cranberry Field Daily Water Budget

- Both matric potentials at depths of 15 cm and 40 cm are linked to the water table level. They increase when the latter rises and *vice versa*. However, the root depth is more sensitive to variation since the former receives less upward flux and is subjected to higher root uptake.
- The frequency of irrigation events confirms that significant amount of water is used during August and September to maintain enough water in the field. However, the water table constantly drops; indicating significant deep percolation.

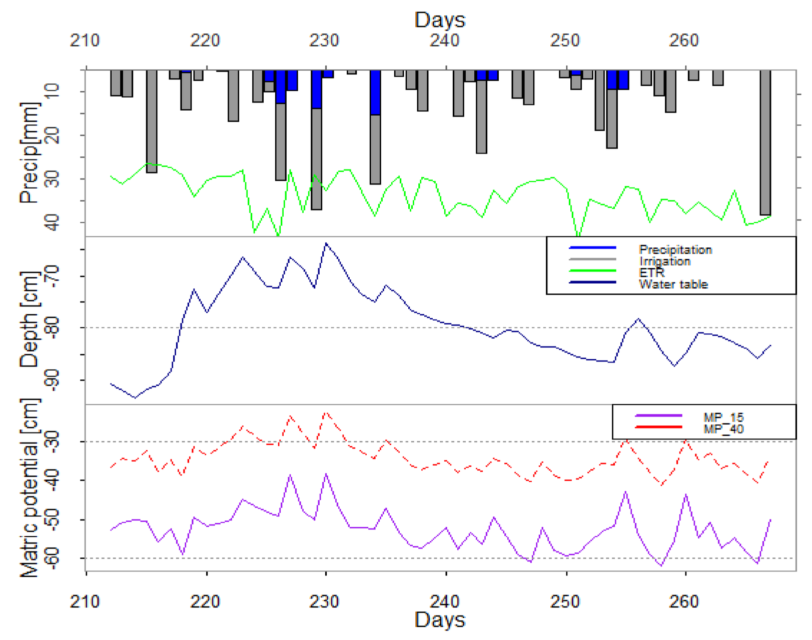


Fig. 6. Field monitoring data: irrigation, ETR, soil matric potential and water table level (field storage)

Other Processes

Drainage

- Using Guyon's model [9], it is shown that the drainage rate follows well the water table behavior.
- Cranberry field data,
  - a 30-cm water table drops to 59 cm the first day.

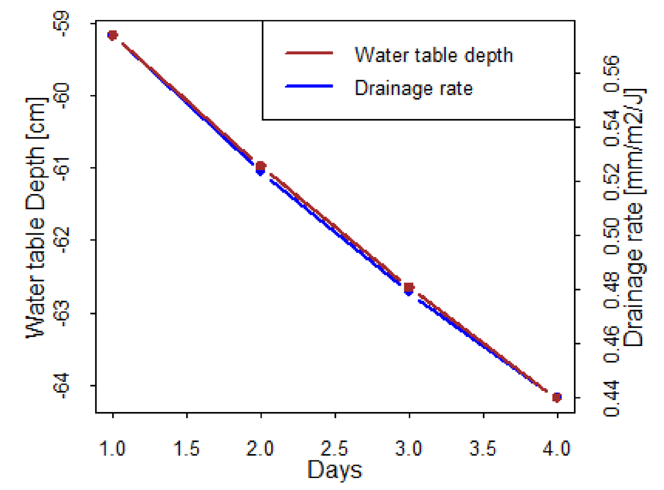


Fig. 7. Four-day drainage simulation, Initial water table at 30 cm

Deep percolation

The deep percolation subroutine has not been developed yet. It will either be computed using an infiltration model or simply be calibrated for each site.

Conclusion and Expected Outcomes

- Soil characteristics are site-specific. They condition the upward flux and the depth of water required to maintain optimal soil moisture conditions within the root zone.
- Primary results are encouraging, even though they are obtained using simplified models instead of numerically solving Richard's equation coupled with root water uptake and drainage models.
- The model is still under development. Once validated it will be used to assess water requirements of the farms contributing to the study.

Acknowledgments

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