# Reducing nitrate leaching with a simple model for nitrogen and irrigation management of fertigated vegetable crops

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**Abstract**

The greenhouse-based vegetable production system of south-eastern Spain is associated with appreciable $NO_3^-$ contamination of underlying aquifers. There is a requirement for management practices that reduce $NO_3^-$ leaching loss from soil-grown crops. The widespread use of computer-controlled drip irrigation and fertigation systems provides growers with the technical capacity to spoon-feed water and nutrients as required. This work developed and assessed a combined modelling and monitoring approach to manage N and irrigation of a sweet pepper crop. A simple spreadsheet model, that integrated two sub-models of irrigation and N management, was used to plan irrigation volumes and the concentration of applied N in individual irrigations. Monitoring of soil solution $NO_3^-$ concentration and soil matric potential were used to adjust subsequent applications of, respectively, N and water. Applied N equalled estimated N uptake. The calculations of both sub-models were based on historic climate data. Sweet pepper crops were grown in two separate, identical greenhouses, one with conventional management (CM), the other with combined modelling/monitoring management (MMM). Using MMM, applied N and $NO_3$-N leaching were, respectively, 35% and 50% less than with CM. Fruit production was very similar for both treatments.

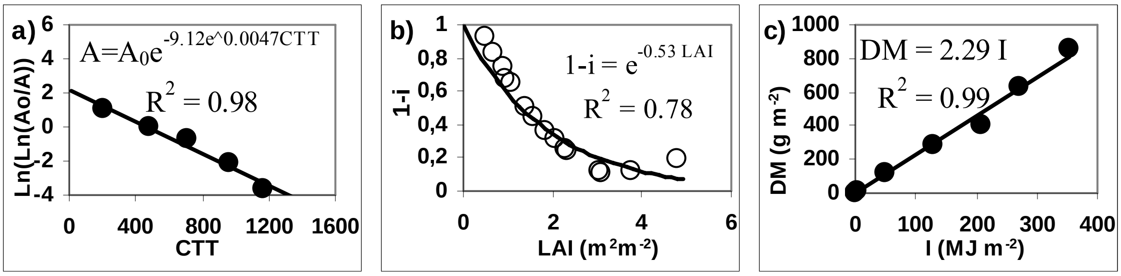
## Background and Objectives

The greenhouse-based vegetable production system of south-eastern Spain is associated with appreciable $NO_3^-$ contamination of underlying aquifers. Much of the area where greenhouses are located has been declared Nitrate Vulnerable Zones (NVZ) in accordance with the Nitrate Directive of the European Union. There is a requirement to develop and implement improved management practices to reduce $NO_3^-$ leaching loss. Eighty percent of crops are grown in soil, the rest in hydroponic systems. The combined use of fertigation, high frequency (every 1-3 days), drip irrigation and computer controlled irrigation programmers provide growers with the potential to spoon-feed nutrients and water to their crops as it is required. However, current management of soil-grown crops is largely based on experience (Thompson *et al*., 2007). In this system, the indigenous soil N supply is likely to vary considerably on account of large and variable manure applications (Thompson *et al*., 2007). An approach to N and irrigation management that exploits the technical capacity for precise management, and responds to variable N supply is required for this system.

This work assessed a combined modelling and monitoring approach to manage both N and irrigation of a sweet pepper crop. A spreadsheet model, that integrated two sub-models of irrigation and N management, was used to plan irrigation volumes and the concentration of applied N in individual irrigations. Monitoring of soil solution $NO_3^-$ concentration and soil matric potential ($\Psi_m$) were used to adjust subsequent applications of, respectively, N and water.

## Material and Methods

The spreadsheet model consisted of two sub-models; one of daily crop N uptake (Nup) and the other the PrHo model which calculates daily crop $ET_c$ for crops in this system (Fernandez *et al.*, 2001). For daily time steps, the Nup sub-model estimated sequentially leaf area index (LAI) from cumulative thermal time (CTT) (Fig.1a), the proportion of intercepted photosynthetically active radiation (PAR), referred to as 'I' (Fig. 1b), above-ground dry matter (DM) production from intercepted PAR radiation (I) (Fig.1c), and N uptake from DM production and a fixed N content of 2.8%. The Nup mathematical relationships were determined empirically from a previous crop grown under very similar conditions. Historical (23 year) climatic data are used for inputs of thermal time and incident radiation for both the Nup and PrHo sub-models.




Note: In Fig. 1b, i= I / I°; where I° is incident PAR radiation and I is intercepted PAR radiation.

Figure 1. Sequential estimation of: (a) leaf area index (LAI) from cumulative thermal time (CTT), (b) proportion of intercepted photosynthetically active radiation (PAR) (as 1-i) from LAI, and (c) biomass dry matter (DM) production from intercepted PAR (I), for a sweet pepper crop.

Crop recovery of applied N was assumed to be 100% to allow for appreciable soil N mineralisation. The N uptake amount for each week was divided by the corresponding estimated weekly irrigation volume to calculate the applied N concentration (in m*M*) for the corresponding week. Nitrogen was applied in all irrigations, generally with 95% as $NO_3^-$, and 5% as $NH_4^+$. Sweet pepper crops were grown in two identical greenhouses, in a clay soil. Six-week seedlings were transplanted on 20/7/2006 and were grown until 6/2/2007. In one greenhouse, the combined Nup/PrHo model, in combination with monitoring, was used for N and irrigation management (Model and Monitoring Management; MMM); in the other, local practices were followed (Conventional Management; CM). Soil matric potential ($\Psi_m$) at 15 cm depth was measured daily with tensiometers, at 9:00 before irrigation. Soil solution (15 cm depth) was sampled weekly and analysed for [$NO_3^-$]. In the MMM treatment, irrigation and N applications were modified to maintain $\Psi_m$ at -40 to -10 kPa, and soil solution [$NO_3^-$] at 8–12 m*M*.

## Results and Discussion

Between 20/7/2006 and 6/2/2007, irrigation volumes and applied N were, respectively, 19 and 35% less with MMM compared to CM (Fig. 2a,b). During this period, total drainage volumes from MMM and CM were, respectively, 58 and 122 mm (Fig. 3a). Drainage [$NO_3^-$] was, respectively, 10.4 and 13.9 m*M*. Total $NO_3$-N leaching loss from the MMM and CM treatments was, respectively, 86 and 203 kg N $ha^{-1}$ (Fig. 3b); the total loss from MMM was 58% of that from CM.

There were no statistically significant differences between MMM and CM in total and marketable fruit production (respectively, 10.4 and 9.7 kg $m^{-2}$ for total, and 9.9 and 9.1 kg $m^{-2}$ for marketable production). Total above-ground dry matter production was similar, being 5.8 and 5.6 t $ha^{-1}$, respectively for the MMM and CM treatments.

For the MMM treatment, $\Psi_m$ and soil solution [$NO_3^-$] were, respectively, maintained at -40 to -10 kPa and 7–13 m*M* (Fig. 4), very similar to the target ranges. Throughout the study, the actual amounts of irrigation and N applied in the MMM treatment were very similar to the amounts estimated using, respectively, the PrHo and Nup models (Fig. 2a,b). The agreement between the estimated amounts and amounts actually applied, of irrigation and N, together with the maintenance of $\Psi_m$ and soil solution [$NO_3^-$] within pre-defined ranges, demonstrated that the management objectives of the MMM treatment were achieved.

The larger N application (Fig. 2a) and higher soil solution [$NO_3^-$] (Fig. 4) for the CM compared to MMM, despite very similar production and biomass data demonstrated the excessive N addition of the CM treatment

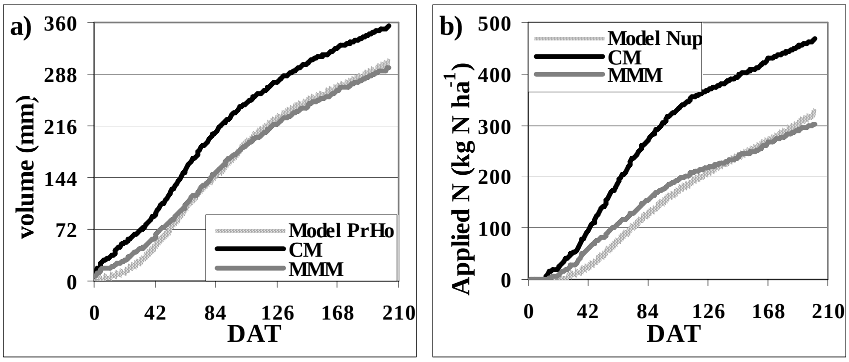



Figure 2. (a) Applied irrigation volumes, and (b) amounts of fertiliser N for CM and MMM treatments; the model estimates for MMM are also included. DAT: days after transplanting.

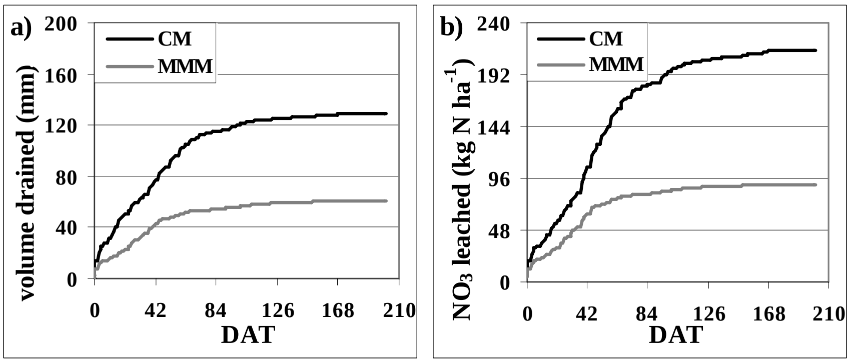



Figure 3. (a) Volumes of cumulative drainage, and (b) amounts of $NO_3^-$-N leached from CM and MMM treatments. DAT: Days after transplanting.

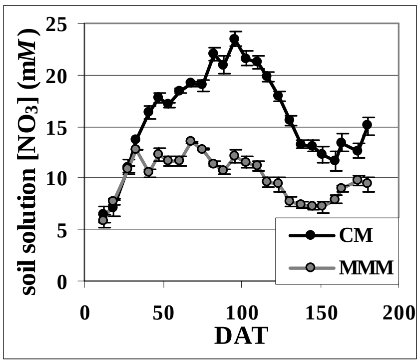



Figure 4. Nitrate concentration in soil solution (15 cm depth) from CM and MMM treatments. DAT: Days after transplanting.

## References

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