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Abstract Book

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Soil Health: Linking comprehensive soil assessment with agronomic management decisions

Harold M. van Es

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A soil's health is generally understood to relate to its ability to function with regard to a suite of ecosystem services - including food production - which in turn are supported by soil processes. In the past, intrinsic soil health was an important factor in determining agricultural sustainability and successful civilizations were generally located in geographical areas where biogeochemical convergence created optimum soil environments. Recent technological developments - notably in crop genetics and fertilizer technology - reduce the dependence on natural soil health, but have created concerns about physical and biological degradation. In soil health assessment, we are using indicators that represent physical, biological, and chemical processes and offer guidance for management approaches that improve soil functioning. The US scientific community is converging on a suite of best indicators for soil health assessment and associated standardized measurement protocols. In addition, research results are offering greater insights into the value and meaning of such soil health indicators in the context of different farming systems, allowing us to link specific soil constraints to agronomic management practices. This health-focused paradigm has re-awakened awareness with farmers and the public of soil as a critical natural resource for agricultural and environmental sustainability and offers opportunities for soil enhancement. But this holistic approach is also more knowledge intensive and less amenable to simplified management approaches, requiring a longer-term commitment to research and education.

Understanding and mitigating environmental footprints of food production systems in tropical and subtropical regions

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Agricultural production of food and feed is seriously negatively affecting our global environment. GHG emissions from the agricultural sector are one of the main drivers of global climate change. The use of nitrogen fertilizer for boosting agriculture production has doubled the global nitrogen cycle, thereby driving eutrophication of terrestrial and aquatic ecosystems with consequences for soil acidification and biodiversity losses, changed the sink/source strength of ecosystem for atmospheric greenhouse gases, but also affected human health via effects on water quality, increased production of aerosols and increases in tropospheric O3 levels in rural areas (Sutton et al., 2013). While in temperate regions and for many OECD countries information on environmental footprints of agricultural production become increasingly available, such information is still largely missing for tropical and subtropical regions. However, these regions are currently experiencing highest growth rates of the human population and are a key resource area for food production. Thus, sustainable solutions for agricultural production need to be identified, which on the one hand have a lower environmental footprint as conventional systems, and on the other hand help to sustaining or even increasing yields.

During the last decade IMK-IFU in cooperation with partners in China, Philippines or East Africa, started to run a number of project focusing on the environmental footprints of rice, vegetable and livestock production systems in tropical/subtropical regions. In most projects the focus was on GHG emissions and soil carbon sequestration, though,

effects on nitrate leaching losses were considered as well in some studies. Here we will specifically report about findings in three projects which were focusing on comparing the environmental footprint of traditional with innovative crop growing systems:

a) Environmental benefits of ground rice production systems (GCRPS) versus conventional paddy rice systems,

b) Potential impacts of introducing upland crops such as maize in rice-rice systems in SE Asia on soil N_2O and CH_4 emissions and soil C sequestration, and

c) Lowering nitrate leaching losses and N_2O emissions in greenhouse vegetable production systems by drip fertigation.

In China, rice production is facing unprecedented challenges, including the increasing demand, looming water crisis and on-going climate change. Thus, producing more rice at lower environmental cost is required for future development, i.e., the use of less water and the production of fewer greenhouse gas (GHG) per unit of rice. In Ground cover rice production systems (GCRPSs) the soil is covered with a plastic film and soils are kept at water saturation, but not flooded. Our studies show that relative to conventional paddy, GCRPSs had greater rice yields and nitrogen use efficiencies (8.5% and 70%, respectively), required less irrigation (−64%) and resulted in less total CH_4 and N_2O emissions (−54%) (Yao et al., 2017). We also observed that GCRPS results in increases of soil SOC and N stocks (Liu et al. 2015).

Paddy rice is the main cropping system in Southeast Asia. However, water scarcity arising from competition from other sectors, rainfall variability and climate change increasingly challenges global rice production. One option to adapt to lower water availability is switching from paddy rice to less irrigation intensive upland cropping systems. Such land management change (LMC) is likely to significantly affect ecosystem carbon and nitrogen cycling and its greenhouse gas (GHG) balance. In a measuring and modelling study for rice based cropping systems on the Philippines, we therefore compared the short- and long-term effect of different cropping systems (double-cropped paddy rice, aerobic rice–paddy rice and maize–paddy rice systems) on the systems GHG balances. Our studies show that on short time scales of a few years, a severe pollution swapping can be observed. I.e. three years after LMC GHG emissions are highest for upland crop -

paddy rice rotations due to pronounced decomposition of soil organic carbon and increased N_2O emissions, while CH_4 emissions decreased. However, on decadal time scales, total GHG emissions are highest for double cropping of paddy rice and are clearly dominated by CH4 emissions (Weller et al., 2016; Kraus et al., 2016).

Vegetable production in solar greenhouses in China goes along with an excessive use of nitrogen fertilizers as farmers aim to maximize yields. Water is usually supplied by flooding irrigation. Both factors results in low N use efficiency and high environmental costs, specifically with regard to leaching of N compounds and the contamination of groundwater with nitrates and emissions of the GHG N_2O from soils. Over four consecutive tomato cropping seasons we tested if drip fertigation and / or incorporation of maize straw might significantly reduce nitrate and dissolved organic nitrogen (DON) leaching losses and N_2O emissions, while increasing the water and N use efficiency of the tomato crop. Our study shows that by using drip irrigation with optimized fertilization (400 kg N ha^{-1} $season^{-1}$) nitrate and DON leaching can be reduced by on average 90% as compared to current farmer's practice. Comparable results were also obtained for reductions in soil N_2O emissions (from > 40 kg N_2O-N ha^{-1} yr^{-1} for fields managed by farmers practice to < 10 kg N_2O-N ha^{-1} yr^{-1} for fields receiving optimized drip fertigation).

Across all studies we could show that there are plenty of opportunities to reduce the environmental footprint of food production systems in tropical regions, but that the necessary quantification of these benefits require long-term studies and the disentangling of short-term and long-term effects.

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Session I

Precision agriculture, advanced monitoring and modeling (part 1)

Chaired by Nurit Agam

Integration of earth observation technologies into an advisory system for the collective management of crops

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In the framework of the environmental LIFE program of the European Union, Agrogestor project (www.agrogestor.es) aims to develop an online GIS-based platform that will support the collective management of crops to meet environmental and economic objectives. The system is designed to assist crop management decisions at field and local scales, providing Decision Support Tools (DST), sustainability indicators and the traceability of agricultural products and activities. It also allows for the evaluation of group management strategies to achieve environmental objectives, including controlled deficit irrigation, irrigation group networks governance and water quality parameters. The current version of the platform offers DST for the management of extensive crops, including fertilization and irrigation scheduling, crop cultivar selection, control of diseases, and computes performance and environmental indicators. Current developments are focused on designing collective planning and monitoring tools, used to evaluate alternative management strategies for groups of farmers, implementing governance strategies (e.g. incentive plans, tariff escalation) and in-season monitoring of environmental indicators and compliances.

Remote sensing (RS) data are integrated into the irrigation and fertilization DST to optimize water consumption and reduce diffuse pollution. Modelling approaches using RS complement continuous soil water and nitrogen balances, whenever remote images

are available, and are simple enough to allow for remote and on the fly calculations. They also adapt to the diverse conditions of agriculture found along the Iberian Peninsula. Daily meteorological information, weekly forecasts, provided by the Spanish Meteorological Agency (AEMET), and crop coefficients derived from Landsat-8 and Sentinel-2 satellites (González-Dugo et al., 2013; Mateos et al., 2013) are supplied to farmers and irrigation managers -together with classical tabulated FAO56 coefficients as an alternative choice- to compute the crop water requirements and schedule the irrigation. The methodology used to estimate nitrogen (N) application rates is currently being developed based on previous results in the study area (González-Piqueras et al., 2017; Villodre et al., 2017). The objective is to match crop nitrogen supply with crop uptake to ensure targeted yields while increasing N use efficiency. The MERIS Terrestrial Chlorophyll Index (MTCI) (Dash and Curran, 2004), combined with crop biomass estimations, provides a proxy for the nitrogen nutrition index employed to calculate application rates. This methodology explores the use of red-edge bands of Sentinel-2, exploiting the strong link between canopy nitrogen status and chlorophyll content. Remote sensing is also used to detect anomalies in crop growth, by comparing of the canopy growth of a single field with the average values in the area for the same crop. This work represents a joint effort of research and technology transfer groups to integrate remote sensing data into daily farmer's decisions for crop management.

González-Dugo M.P., Escuin S., Mateos L., Cano F., Cifuentes V., Padilla F.L.M., Tirado J.L., Oyonarte N., Fernández P., 2013, Monitoring evapotranspiration of irrigated crops using crop coefficients derived from time series of satellite images. II. Application on basin scale. Agricultural Water Management, 125: 92-104

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Precision irrigation –research & development directions

Ofer Beeri, Tal Shilo, Shay May-tal and Ran Pelta

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Advance local crop monitoring is required in order to improve global food production while reducing water consumption. A leading direction should focus on enhancing the water-use-efficiency (WUE) by increasing the yield and/or reducing the water consumption. Although the call is for global improvement, we think a critical component lies in the grower level, asking for a day to day reliable irrigation recommendation. This monitoring is important not only for refining a day-to-day decision making of water amounts but also by detecting crop stress in early stages. Although crop stresses, and especially minor to moderate water stress, are sometimes recommended to improve WUE, monitoring the degree of the stress is an important part to ensure its effectiveness while avoiding severe damage.

To answer these needs, precision irrigation looks for the following R&D directions:

1. To develop global coverage, high frequency, all-weather satellite monitoring, for small plots as 0.5 ha.

2. To deliver updated crop coefficient (Kc) for reliable irrigation recommendation.

2. To map and assess water stress in order to present to the grower and to distribute efficient stressed irrigation recommendation.

4. To account for local environmental adjustments with climate factors and machine learning algorithms.

These goals were achieved by 1) Relying on imagery of Sentinel-2, Landsat-7 and Landsat-8 to enable a revisit-time of five days and sometimes even twice a week, globally; 2) Transforming spectral data from the above sensors to Kc. Transformation took place using equations that were found to be highly accurate versus flux towers data of different crops; 3) Assessing water stress based on spectral data of the above sensors in order to

allow mapping of small plots around the globe. Maps were validated according to ground measurements; 4) Adjusting irrigation recommendations according to site specific climate and soil characteristics as provided by the grower or by inputs of long-term time-series datasets processed by machine learning technics.

These topics will be addressed with examples at different scales such as pixel, plot and farm.

Advanced soil sampling strategy for precision agriculture

M. Iggy Litaor, Ofer Shir, Assaf Israeli and Shalev Malul

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The objective of precision agriculture (PA) is to increase crop production system efficiency, productivity, and profitability while reducing negative environmental impacts by employing inputs at variable rates. In the context of PA, crop yield directly reflects soil spatial variability, fertilization and irrigation. However, harvested yield data is only obtained after the season, whereas many agronomical difficulties such as nutrient deficiencies and water stress may occur during the growing season. Hence, the main impetus for this work is to develop an integrated system capable of quantifying soil spatiotemporal variations at the field level before and during the growing season in order to facilitate optimal fertilization. The final project product will be a web-enabled integrated decision support system that provides near real-time solutions to farmers such as variable rate nutrient applications across spatially variable fields. We hypothesize that soil spatial variability dictates optimal nutrient inputs for prime crop production; to test these hypothesis, Site-Specific Management Units (SSMUs) were delineated by collecting large ancillary datasets using proximal soil survey and multispectral imagery in order to facilitate cost-effective sampling. The study was conducted in Neve Yaar research station in support of the model farm initiative. There are hard theoretical questions concerning effective soil-sampling using a minimal set of points while aiming for maximal information. Such questions require rigorous mathematical modelling and involve the perspective of tradeoffs and multi-objective (Pareto) optimization. Several solutions were tested juggling between strictly pure mathematical representations of the SSMUs versus practical solutions of the number and spatial extent of the SSMUs as well as the number and spatial pattern of representative soil sampling locations.

The potential of the spectral 'water balance index' (WABI) for crop irrigation scheduling

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Physiological measurements for irrigation scheduling require intrusive equipment and proficient manpower, and are thus time- and cost-inefficient due to substantial variability in the field. A plausible solution to these issues is the implementation of visible (VIS)-to-shortwave infrared (SWIR) hyperspectral instruments (350-2500 nm), which are sensitive enough to detect slight variations in leaf bio-chemistry and may, thus, offer a faster, broader and non-destructive alternative to assess the physiology status of crops.

In this talk, I will demonstrate the inter-disciplinary potential of combining plant physiology with hyperspectral VIS-SWIR sensing through the introduction of a novel narrow-band model – the 'water balance index' (WABI). Relying on independent, rapid alterations in leaf water content and in the efficiency of the non-photochemical quenching (NPQ) photo-protective mechanism, WABI was recently shown to be sensitive to water status changes in various crops, and was even able to schedule the irrigation of a vineyard throughout a growing season.

Session II

Precision agriculture, advanced monitoring and modeling (part 2)

Chaired by Victor Alchanatis

Geophysical characterization and monitoring to support agriculture

Johan A. Huisman, C. Brogi, C. von Hebel, A. Klotzsche, F.H. Haegel, H. Vereecken, J. Vanderborght and J. van der Kruk

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In order to support a growing world population, there is a strong demand to increase agricultural production. At the same time, the environmental footprint of agricultural production needs to be reduced by a more sustainable use of the limited available resources while maintaining profitability. To achieve this, detailed high-resolution information on the shallow subsurface is indispensable. Geophysical measurements provide a unique opportunity to rapidly and inexpensively map spatially continuous variations in soil properties across agricultural fields, and allow monitoring of processes that are relevant for agricultural production (e.g. root water uptake, water and nutrient transport and storage). In this overview presentation, three case studies will be presented. In the first case study, multi-configuration electromagnetic induction (EMI) measurements were used to obtain a high-resolution soil map of a 1 km^2 agricultural area. Subsequently, this soil map was used to simulate the effect of subsurface heterogeneity on crop productivity in the presence of water stress by an agro-ecosystem model. A comparison with independent remote sensing observations showed the importance of quantitative and high-resolution soil information in capturing the patterns of reduced productivity caused by water stress (see Figure 1).

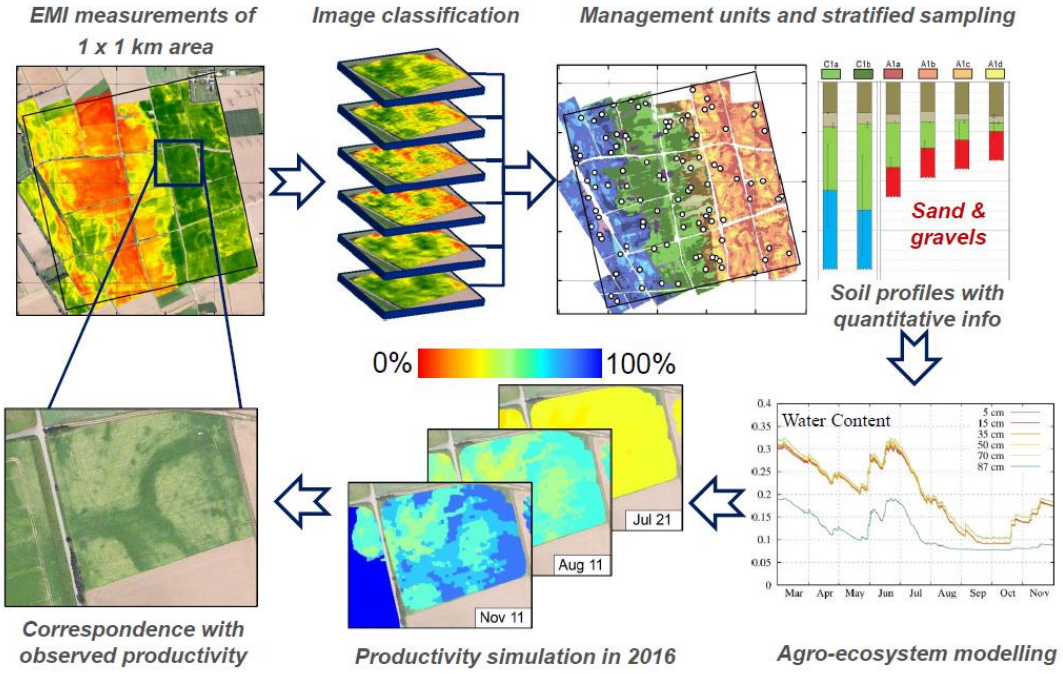

Figure 1. Illustration of workflow to obtain high-resolution soil information from multi-configuration EMI measurements and the subsequent use in agro-ecosystem models to predict crop productivity.

In the second case study, ground penetrating radar (GPR) measurements in horizontal boreholes were used to characterize soil water content variability in space and time in a unique facility that allows monitoring both crop and root development using mini-rhizotron tubes. The GPR measurements showed significant horizontal variability in water content that cannot be captured by point-scale water content sensors. In the third case study, spectral induced polarization (SIP) measurements were used to quantify the amount of biochar in soil. Biochar is considered as a soil amendment to improve the water holding capacity and soil fertility, but adequate methods for in-situ characterization were lacking so far. Overall, this presentation will highlight the potential of geophysical measurements in an agricultural context.

Below canopy radiation divergence in a vineyard – implications on inter-row surface energy balance

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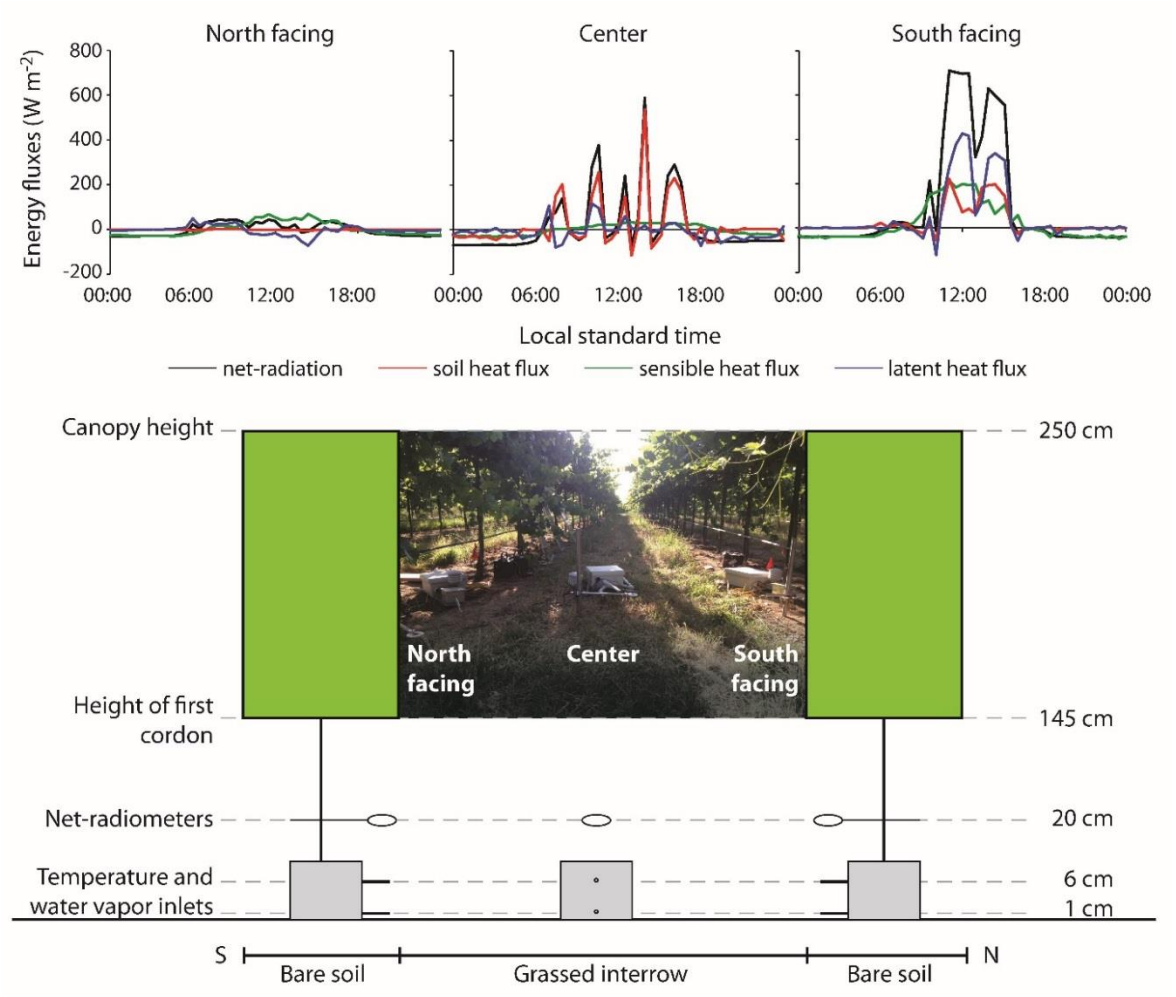
Vineyards canopy architecture and row structure pose unique challenges in modeling the radiation partitioning and energy exchange between the vine canopy and the interrow area. The vines are often pruned and manipulated to be strongly clumped while mechanical harvesting requires wide rows, often with vine height to vine spacing ratio >1. Here we aimed to estimate the intercepted radiation by the canopy, and the effect of this interception on the below-canopy surface energy balance and evapotranspiration (ET). Measurements were conducted in an east-west oriented vineyard in CA during Intensive Observation Periods (IOPs) as part of the Grape Remote sensing Atmospheric Profile and Evapotranspiration eXperiment (GRAPEX). Below-canopy incoming shortwave radiation was measured at multiple positions across the interrow, and the surface energy balance/evapotranspiration (ET) below the vine rows was measured for one growing season using three micro-Bowen ratio (MBR) systems one in the center of the interrow and one underneath a vine row south and the other north of the MBR in the center of the interrow. A significant spatial and temporal variability in radiation was observed due to the fact that the vines were not significantly pruned or manipulated so they were allowed to grow randomly into the interrow. However, when averaged over the sensor array, the values appeared to give reliable average radiation extinction conditions that agreed with model estimates. The variation in the surface energy fluxes were

dominated by the amount of transmitted radiation, while soil moisture was a 2nd order affect. Daily estimates of ET from the three micro-Bowen ratio systems, weighted by their respective representative sampling area, yielded estimates similar to values computed by the correlation-based flux partitioning method, which utilizes high frequency eddy covariance data.



Biogeochemical modeling for sustainability performance standards: Adapt-N and N balance in US corn production

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In the US, 78% of corn growers apply the bulk of N outside of the growing season when application is logistically easier and often incentivized by fertilizer retailers. In many cases this leads to low N use efficiency (NUE) and environmental N pollution with high societal costs. There is a growing interest from food companies and consumers to produce food with less environmental impact. This requires robust indices that give insights into the sustainability and the efficiency of the sourced food production environment. McLellan et al. (2018) recently suggested N balance as a simple input-output based sustainability metric, which is defined as the amount of N applied to a production unit minus the amount of N removed from the field at harvest. N balance is readily calculated across different scales and can be associated with potential N pollution. Several studies suggest a nonlinear increase in N losses and possible critical threshold values ranging from 0 to 50 kg/ha for different production environments. This characteristic makes N balance useful for policies that aim to reduce N losses or track progress toward sustainability goals.

Critical research gaps currently exist that hamper further advancement and implementation of the N balance approach for US crop production. First, there is a need to match designated performance standards for a specific location with realistic goals by farmers that are achievable without yield reduction. Second, once a goal has been identified, management practices need to be identified for farmers to reach the designated performance target. Here we will present how these research gaps can be addressed using biogeochemical modeling, as demonstrated by the Adapt-N modeling framework. Adapt-N was developed at Cornell University and has been licensed to Yara International ASA. It is a decision-support tool for corn cropping that utilizes near real-time (6h lag) weather

data to monitor soil N, crop N, N losses and other agronomic and environmental parameters based on continuous daily model simulations (Sela et al., 2016). The core of Adapt-N is a process-based biogeochemical model which is used to optimize N inputs needed to reach a yield target. N recommendations generated by Adapt-N were validated in 150+ replicated field trials in seven US states on a variety of soil textures and climates. On average, compared to the regular grower practice, the adaptive-dynamic approach of Adapt-N enabled a reduction of 34% in N inputs without reducing yield, thus increasing profitability by $65/ha. Furthermore, the reduction in N inputs led to a 36% reduction in N balance, and 38% reduction in N simulated N losses. Based on the extensive dataset of field trials, a 'hockey-stick' type curve was fitted between N losses and N balance, indicating a general threshold of ~48 kg/ ha of N balance for excessive N loss initiation (Sela et al., 2018a). Compared to the grower's regular practice, the adaptive-dynamic approach to N management enabled a threefold increase in the cases included within this N balance threshold.

To further explore optimal N balance values across the Midwest with variable soils and climate, we employed a systematic simulation approach (Sela et al., 2018b, under review). Specifically, we were interested in the pathways growers can take to reduce N balance, and explored two pragmatic options: changing the timing of N application, from prior of the growing season to closer to the timing of crop N uptake, or changing the form of the N applied (i.e., adding a nitrification inhibitor). The model was run for 7 years in 25 locations encompassing the five largest corn production states in the US. N deficiencies were prevented by adding in-season supplemental N as needed, when recommended by Adapt-N. Results indicate that the timing of application was a significant factor affecting N balance and NUE, with greater effects in more humid locations. In general, highest N balance and lowest NUE were found when the bulk of N was applied in fall, and best results were achieved with the bulk of N applied within-season, with early spring application being intermediate. Soil texture also had a large effect, with highest N balance values found for coarse soil textures. The use of a nitrification inhibitor allowed for greater efficiencies with fall and spring applications, but effects were less pronounced than changes in timing of application. Adapt-N simulations also indicated that seasonally-specific efficiency metrics may be affected by biotic and abiotic factors beyond a grower

control. Notably, unpredictable mid-season droughts may reduce grain yields and unfavorably increases in N balance, implying that N balance targets should be applied based on multi-season averages. The model simulations offered ranges of realistic N balance values that can now be used to inform policy discussions, and advance the development of performance standards in US corn production.

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Using simple RGB Camera to estimate Nitrogen Uptake, Nitrogen Nutrition Index (NNI) and critical Nitrogen: spring wheat case study

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Rational

Besides the economic importance for optimizing the nitrogen (N) use, the uncontrolled N supply may lead to severe environmental pollution of drinking water, aquifers, lakes and rivers. Especially in a rainfed agricultural area in a Mediterranean ecosystem where water resources are scarce and N supply is low. A reliable test for forecasting the potential availability of soil N to the plants is extremely important.

Objectives

1) To demonstrate the feasibility of digital camera; 2) To determine critical N (Nc) and Nitrogen nutrition Index (NNI); 3) Use N% and dry matter yield in order to calculate N uptake by wheat. This last is expected to be a tool to calculate the required amount of nitrogen to obtain maximum yield.

Critical Nc is defined as the minimum N concentration required for maximum crop growth. This term is a fundamental reference at any growth stage, which allows the determination of whether crop N nutrition is supra-optimal or sub-optimal. Following the decline of N concentration in wheat as a function of crop stage we developed a semi theoretical model which related Nc and NNI to the ratio of dry matter yield (DM) (Shlevin et al. 2018) Nc/Ncmax = 1/[1+(W/W50)^b], where W and W50 are DM biomass (kg/ha), and when W=W50 then Nc=0.5 Ncmax.

Materials and Methods

The model was tested experimentally in a lysimeter random split plots distribution with wheat. The main variable was nitrogen fertilization levels that was given via drip

irrigation. The fertilization treatments were: 0 – no N added; 6 units of N as pre-planting only; 12 units of N (6 unites pre-planting and the rest during growth period); 18 units of N (6 pre- planting and the rest during growth period).

This study can be described by four paragraphs: 1) a comparison between camera measure N uptake and standard laboratory analysis; 2) calculation of N uptake by wheat: Nuptake = %N*W/100; 3) Nc calculation; 4) NNI estimation.

Results

1) The correlation between Nitrogen uptake that was taken by a camera and in the laboratory are presented in Fig 1. The correlation between N uptake obtained by the two methods was very good (r^2>0.9 and a unit slope). It indicates the advantage of camera over the laboratory due to the fact that obtaining N uptake based on image analysis is less expensive and faster than results obtained from the lab.

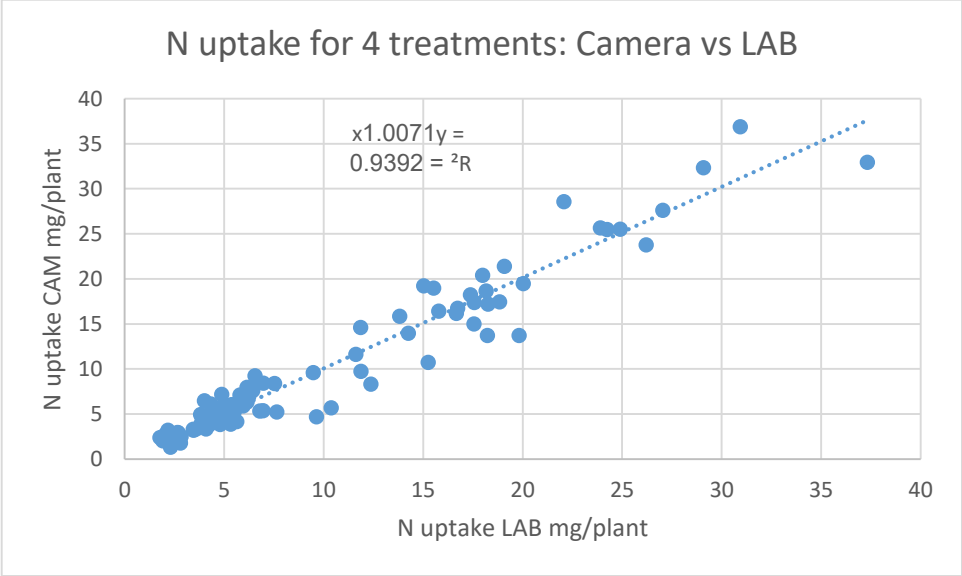

Fig 1. Nitrogen uptake by wheat. Comparisons between laboratory and camera of all data collected (120 data points).

2) N uptake: The smartphone camera was used in an irrigated wheat field during the growth stage of several varieties from early to to late ripening group. It was found that nitrogen units uptake at the spiking stage (about 75 DAE) ranged from 15 unites for the

optimal model to 20 N units for a late ripening variety. From 3 leaves to the flag leaf all varieties absorbed nirogen at the same rate (Fig. 2).

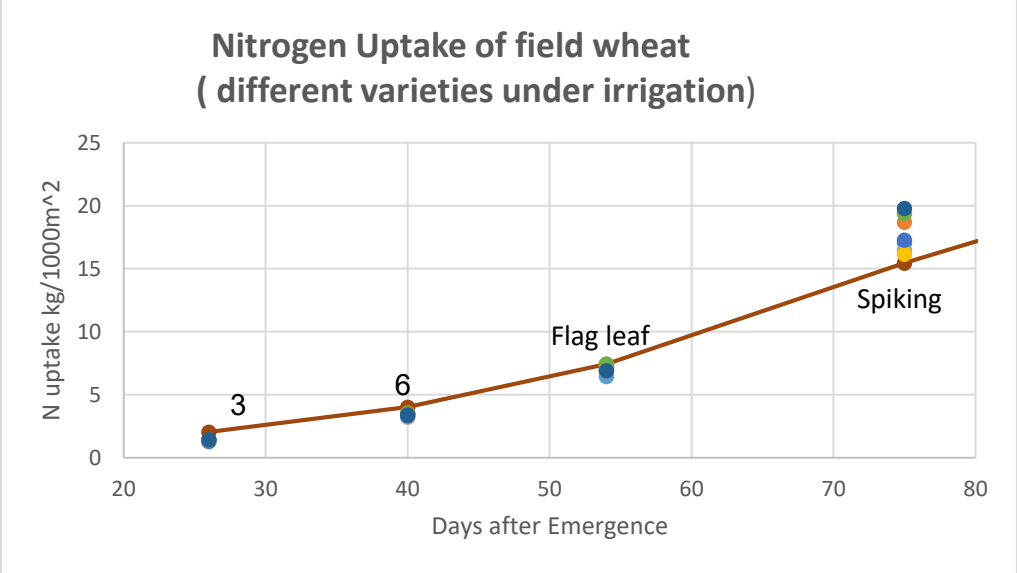

Fig 2. Camera measurements of N uptake in wheat field . The numbers next to the data are number of leaves in the measuring date; the points relate to 7 varieties.

3) Critical N: All previous models described the relationship between Nc and crop DM that could not reach Nc at zero because the model had a point of singularity. Our modified model resolves this problem as demonstrated in Fig 3. A realistic hypothesis that Nc level after base fertilization before planting is known. This value is the upper limit of Nc. In Fig 3 it is 6% that appear in W=100 corresponding to 3-4 leaves or/and 25-30 DAP. Fig.3. displays the %Nc measured in laboratory vs. dry matter biomass. The central line describes the change in % Nc measured in two wheat varieties (late and early ripening).

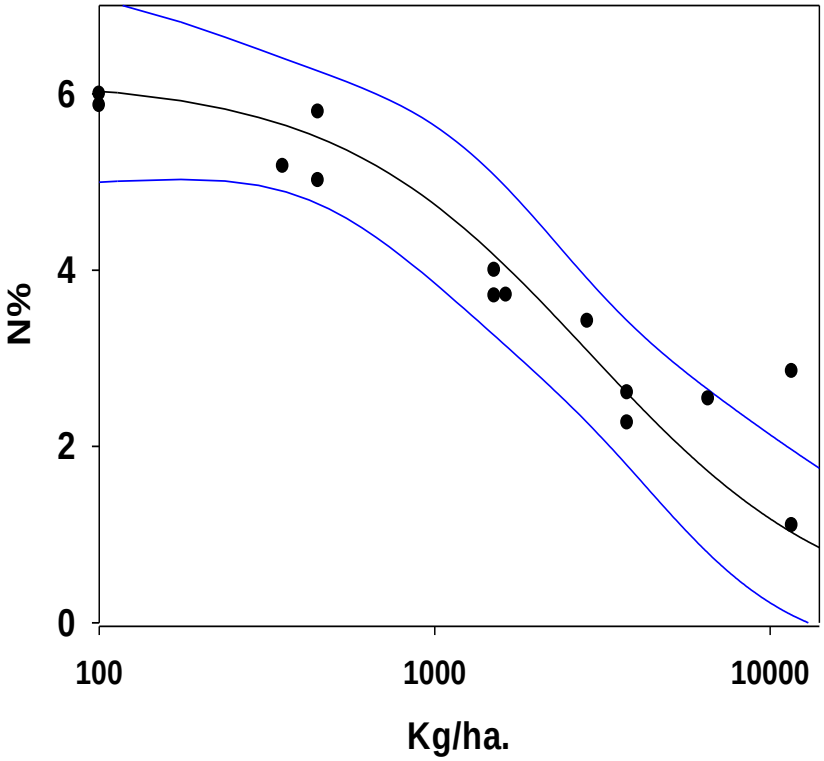

Fig 3. %Nc vs wheat dry matter biomass. The solid line in the center describes the theoretical model and the two external lines describe the confidence limits of the data at 95%.

4) NNI: the ratio of Nactual / Ncmax is defined as nitrogen nutrition index (NNI) (Gastal and Lemaire, 2002). If NNI = 1, N nutrition is considered optimal. If NNI >1, N nutrition considered supra-optimal. If NNI <1, it is suboptimal.

Figure 4 indicates that most of the days after emergence the NNI was lower than 1 index unit. Final conclusion can not be drown here for two reasons. First the experiment was conducted in the greenhouse and not in the field and second it was tested only once and in order to obtain conclusive results more experiments should be made. However, the test demonstrated again that we have developed a useful tool to conduct fertilization measurement in the field.

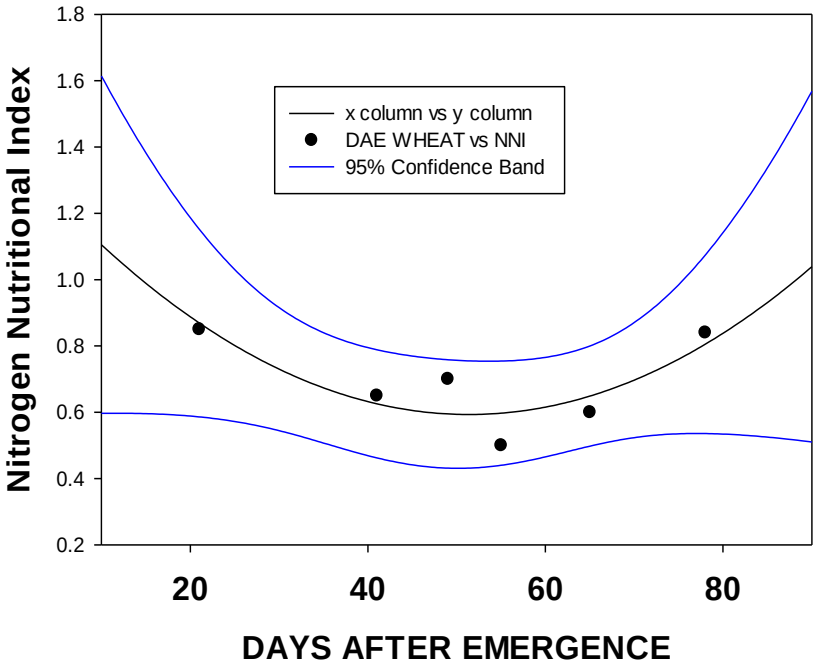

Fig 4. The course of NNI during the growing stages of spring wheat in the green house.

Summary

We examined the feasibility of smartphone to determine N% and its derivatives (NNI) as a tool for using in a farming management of nitrogen fertilization. The camera output was validated against laboratory tests for total N uptake. A greenhouse experiment with spring wheat resulted in r2>0.9 and a slope of a unit (see Fig.1). Using simple RGB camera for determination of N uptake by a crop is a rapid and cost effective. Regarding wheat fertilization management, final conclusions cannot be drown here for two reasons. First the experiment was conducted in a greenhouse and not in the field and second it was tested only during a single experiment. In order to obtain conclusive results more experiments should be made. However, the test demonstrated again that we have developed a useful tool to conduct fertilization management in the field.

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Biological and optical challenges to remote sensing: Implications and opportunities for plant stress detection

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Light absorption in the photosynthetically active (400 – 700 nm) spectral region is necessary for plant CO_2 fixation via photosynthesis. Over the past decade, observations of vegetation (soybean and maize) optical reflectance have produced indications of plant photoprotective behavior which can confound estimation of biophysical parameters and may provide detection of plant stress. Light absorption in excess of that which can be used for photosynthesis may result in photoinhibition and/or other processes detrimental to normal plant function. Under stressful conditions, plants have evolved several photoprotective mechanisms to either reduce light absorption (e.g., chloroplast movement, leaf movement) or dispose of the absorbed energy in benign ways (e.g., fluorescence emission, increased non-photochemical quenching). Our previous leaf-level observations of greenhouse-grown maize and soybean indicated an increase in reflectance and transmittance that can most likely be attributed to chloroplast movement, a photoprotective response, within leaf cells in response to water stress. This has implications for detecting (as a signal and noise) diurnal and stress-related changes in canopy reflectance in field-grown crops and estimation of leaf water content.

A new instrument configuration hosted on a large mobile field platform and operated by newly developed software allows simultaneous measurements of reflectance and solar induced fluorescence (SIF). Through the use of bifurcate fibers and optical switches, near-simultaneous upwelling and downwelling spectral measurements allow reflectance to be obtained under all sky conditions. Comparing data obtained from the new system to our

previous research reinforces our contention that plants cannot be treated as stable piles of chemicals, but rather as dynamic organisms capable of hiding pigments from incident light, and thereby from observation, in response to stress and incident light levels. Changes in canopy reflectance spectra measured in morning and afternoon correlate with changes in gross primary production. The reflectance changes are likely due to chloroplast movement as they have been shown not to result from physical changes in chlorophyll content. As analysis continues, it is expected that SIF estimation will provide an indication of changes in photosynthetic activity which correspond to photoprotective responses.

Session III

Soil Health

Chaired by Guy Levy

Development of multi-factorial soil health index for the Mediterranean agricultural systems

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Soil health is affected by a wide range of biotic and abiotic soil properties that maintain complex interactions. We consider the health of a soil as a function of its ability to provide ecosystem services, including agricultural production (provisional services); regulating natural cycles (regulation services) and as a habitat for plants (support services). The decline in soil health includes deterioration in its physical properties (e.g., degradation of soil structure, compaction and sealing, water-repellency, soil erosion by water and wind), chemical properties (e.g., salinization, depletion of nutrients and organic matter content, accumulation of pollutants) and biological properties (e.g., vulnerable populations of microflora, microfauna, and mesofauna, leading to a breach of ecological balance and

biodiversity and, as a result, destruction of beneficial populations and pathogen outbreaks). The relationships among soil health, soil conservation, food security, resilience, and functioning under a wide range of agricultural uses and different environmental systems, is the focus of many agro-ecological studies worldwide. A multi-factor index needs to be developed to enable the classification of a full spectrum of soils, including the examination of the effectiveness of reclamation management regimes for degraded agricultural soils. However, evaluation of soil-health status in the Mediterranean region is rather limited. Moreover, there is no objective test which is capable to evaluate and monitor conservation or reclamation activities in our region. This research and the index to be developed are aimed to provide an objective tool for soil health assessment in Israel and the Mediterranean region. Another benefit, which is expected to come out from this research, is the development of rapid and cost-effective methods for soil health characterization.

At the first stage of the current study, we tested the effect of long-term agriculture activities on more than 60 physical, chemical and biological soil attributes that have been quantified in the laboratory and in the field in two most important agricultural regions of Israel. We aimed to identify the most sensitive physical, chemical and biological indices (quantitative and semi-quantitative) for three different land uses (Orchard, Field crops and Uncultivated). Accordingly, three sites were chosen from each region, representing different soil textures. Three adjacent plots, with long-term history (>15 years) of the same given land use were chosen for each site: 1. Orchards. 2. Field crops. 3. Un-cultivated plots. At each site three replicate trenches were dag at each land use. Soil samples were taken in each trench from four different depths: 0-10 cm, 10-30 cm, 30-60 cm, 60-100 cm. A total of 432 soil samples were collected (2 regions * 3 sites * 3 land uses * 3 replicates * 4 depths * 2 sampling times [fall and spring]).

Assessment of soil health index comprises three main steps,: (1) selection, measurement and minimization of the set of relevant soil attributes; (2) scoring of the selected and measured soil attributes ; and (3) integration among the scored attributes to construct the final index, by providing criteria for defining the weight of each attribute or group of attributes. These steps usually include statistical and/or expert opinion-based approaches.

Accordingly, statistical models such as correlation matrix and ANOVA have been utilized to minimize the dataset (step 1) for identifying the most sensitive, available, accurate, cost-effective and relevant attributes extracted from the large dataset.

More work should be done, including statistical analyses and experts discussions in order to accomplish the establishment of the soil health index. In addition, another sampling campaign is planned in the near future in order to validate the obtained index and its effectiveness for evaluating soil health status under different reclamation and conservation practices.

Biochar on extracellular enzymes, microbes and organic matter dynamics in sediments

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Biochar addition to soils affects the dynamics of soil organic matter (SOM). In this study, sediments were amended with 0 (the Control), 0.5, 1.0 and 2.0% of biochar and incubated at 25 oC in laboratory incubator for 90 days. After the incubation, enzyme activities, including phenol oxidase (PHO), peroxidase (POD), β-glucosidase (GLU), N-acetyl-glucosaminidase (NAG) and acid phosphatase (ACP), microbial abundance (both bacteria and fungi), and the increased percentage of sediment organic C content were measured. Both increase (PHO and GLU) and decrease (NAG and ACP) of selective enzyme activities were observed after biochar treatments, but only POD activity showed a significant decrease ($p < 0.01$) comparing to the Control. Moreover, the activities of all enzymes tested were significantly related to the amounts of biochar addition ($p < 0.05$). On the other hand, the abundance of both bacteria and fungi under biochar treatments was significantly lower than the Control ($p < 0.001$), and a significantly negative relationship ($p < 0.05$) between the bacterial abundance and the amounts of biochar was established. Additionally, an increase of organic C gradually was associated with biochar addition rate, which provides a direct evidence for biochar application to mitigate climate change by emission of greenhouse gases. Given the importance of microorganisms and enzyme activities in cycling of organic matter, the increased C sequestration might be explained by the decrease of microbial abundance and POD activity after biochar amendment.

Soil free-living nematodes community as bioindicators of Soil Health

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In recent years great efforts are made in the study and use of soil biota components as bioindicators in order to evaluate soil health. Soil bioindicators are organisms that have the capacity to detect changes in natural environment and monitor soil health by being sensitive to changes in chemical, physiological or behavioral, correlated with soil use. The nematodes community are one of those groups that help in detecting the smallest footprint changes on the environment as they: abundant in soil, easy to sample, well classified into functional (feeding) groups and having the ability to respond readily to changes in the soil‘s physical and chemical properties. In the present study, soil free living nematode community composition, density and diversity were used as tool in order to evaluate alterations between different long term agricultural practices as part of soil health evaluation. Soil samples were collected during the autumn 2016 from two climate zone in the north (Jezreel Valley) and in the south (north- western Negev). The soil samples were collected under three long-term soil management as following: control (UC), field crops (FC), orchards (OR) and from three soil layer: 0-10 cm, 10-30 cm and 30-60 cm. Chemical analysis (soil moisture, organic matter) and biological analysis were conducted as follows: nematode communities were extracted (using the Bermann funnel procedure), counted using a compound microscope, following molecular analysis for species determination.

Soil moisture was found to be significantly ($p<0.05$) affected by study site, were the north site was higher in comparison the south site. Moreover, the sampling location at each site was as follow orchard > field crops > control significantly ($p <0.05$). They had been found as well affected by the soil layer and location. The soil free living nematodes had been

found to follow the changes in soil moisture and organic matter content which are correlated with the long-term management at each site. From all the four soil free living nematodes trophic groups the bacterial feeding (BF) trophic group was found to be the dominant reaching 80 individual /100g dry soil followed by the fungi feeders (FF) (32 individual /100g dry soil), and decrease to plant parasites (PP) (15 individual /100g dry soil) and omnivore predators.(OP) (12 individual /100g dry soil). Based on the above data the calculated indices that had found to explain the treatment effect. The FF / BF ratio was significantly higher ($p < 0.05$) in orchards, elucidating that a higher BF based food exhibits higher and faster decomposition rates in comparison to a fungi-based webs. Species diversity (H') was found to be significantly higher ($p<0.05$) in the north compared with the south. No differences were found in the ratio (FF + BF) / PP ,the ratio of bacterivores and fungivores to plant parasites

According to the size of the population, the species diversity and division into the trophic groups, the soil free living nematode community was found to a reliable bioindicator for soil health determination.

Session IV

Environmental and economical sustainability

Chaired by Klaus Butterbach-Bahl

Can farming be precise and sustainable? And how can we be sure?

Veerle Van linden

Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Technology and Food Sciences Unit, Belgium

The challenges to our agricultural production system are huge. The world population is continuously increasing and the worldwide demand for animal products is still growing. At the same time, our climate is changing and the circumstances to produce are becoming less favourable in many regions (EEA, 2017). The responsibility to face these challenges lies with the primary producers and consumers (Poore and Nemecek, 2018). Farming should be sustainable, or should not be.

Sustainable farming is reaching far beyond environmental issues. Sustainable agricultural systems produce adequate amounts of high-quality food with respect for the environment (regarding emissions caused, resources used, ecosystem services delivered, soil quality maintained, etc.), is financially viable and contributes to the wellbeing of farmers and their communities (Reganold and Wachter, 2016). Maybe the most important aspect of sustainable farming is showing a good balance of the multiple sustainability goals. These goals, set by Brundtland, are economic, societal, and environmental in nature and they all go hand in hand and are equally important (Brundtland et al., 1987).

This brings us back to our question, 'Can farming be precise and sustainable? And how can we be sure?' In the field of sustainability metrics, many efforts have been done in the past to combine the three goals and express sustainability in terms of one single score. It is a very difficult thing to do, and it might be wiser to include all three sustainability goals in one study but separately score them, as a lumped score may complicate and hide some of the issues. Especially the environmental challenges and the issue of food security in primary production are extremely important. Are we capable of producing sufficient, healthy, and safe food for the growing population and with respect for the environment and animal welfare? Can we produce within the planetary boundaries and not jeopardise

the chances of the future generations to produce their own food in the same secure, healthy, and sustainable way? We need to answer these very questions when we evaluate precision agriculture and agricultural practices in general.

Environmentally sustainable agriculture is not some privilege of one particular production system; it is something we have to aspire for all existing production systems. Although we can achieve sustainable production in intensive and extensive farming systems and in plant as well as in animal production systems, the way we organise it will be different. There are a lot of active management tools and strategies at hand that we can use to reduce emissions and resource use, and one of them is precision agriculture (PA) (JRC, 2015). According to the JRC of the European Commission, 'precision agriculture or precision farming is a whole-farm management approach using information technology, satellite positioning data, remote sensing and proximal data gathering, with the goal to increase the production efficiency whilst potentially reducing environmental impacts'. Precision agriculture is often associated with intensive production systems, as it involves technological solutions and advanced machinery or equipment. Precision farming technologies are: machine guidance systems, variable rate (nitrogen or pesticide) application, variable rate irrigation or seeding or planting, controlled traffic farming, and precision physical weeding (Barnes et al., 2019). In animal production systems, we speak about precision livestock farming (PLF). PLF aims to automatically monitor, model, and manage animal production. Examples of PLF techniques are precision feeding, early and automatic detection of health problems, and fertility management. (Tullo et al., 2019).

The key words in JCR's description of precision agriculture, is that it is 'potentially reducing environmental impacts'. So, can farming be precise and sustainable? And how can we be sure?' Precision technology is considered environmentally sustainable if there is a net environmental gain in case precision farming technologies are applied compared to the reference situation without PA. This net environmental gain should appear from a thorough sustainability assessment of the precision farming technology under study.

A thorough environmental sustainability assessment should reach beyond the direct resource use and emissions on farm and should include more than, say, greenhouse gas emissions. Several methods exist to evaluate the environmental impact of production

systems. One of them is life cycle assessment or LCA, a standardised methodology (ISO 2006a and 2006b) that provides a holistic approach, which includes all stages in the life cycle of the production and different environmental impact categories. LCA can detect and prevent problem shifting between impact categories and between stages of the life cycle.

When is the best time to perform an LCA? When you are intending to implement a precision technology, but even more when you are developing a precision technique, it is important to evaluate its sustainability potential. Two major aspects will determine the potential environmental impact intensity (i.e. impact expressed per unit output) of precision farming: the productivity and the used inputs. Precision agricultural technologies often optimise the yield (e.g. by preventing losses) and use less inputs, causing reduced emissions.

This brings us to a final remark. The environmental sustainability assessment and the performance assessment of a technology are two different things. A technology performance study will assess the direct impact to the environment: 'Do we cause less emissions to the environment or do we use less inputs by using this technology? And what about the yield?' It does not consider the impact of the manufacturing and use stages of the technology itself and for that reason, it cannot assess the net environmental impact of the technology. Performance assessments are always made, sustainability assessments not (yet). The latter can answer our question.

Agriculture and pollutants in the Hula Valley

Moshe Gophen

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Significant positive correlations that was found between TN, TP, NO_3, TDP, NH_4 and Dissolved Kjeldhal and Jordan River Water Yields (mcm/y) is an obvious hint that precipitation regime is a principle impact factor on pollutants flux from the Hula Valley into Lake Kinneret. Long Term (started mid 1980`s) decline of precipitation included 8 years of droughts with recent 5 years in a row. A reclamation project in the Hula Peat soil, the Lake Agmon System (LAS), was implemented during 1993 – 1997 included, elevation of under ground water table, the use of irrigation portable lines , adaptation cropping cycles to year around green cover, renewal 90 km of canals for irrigation water supply and drainage improvements. Recent monitored data evaluation indicates minor quantitative impact of the LAS on nutrient removal: TP-1.1t/y, TN-34.7 of which 16.0 t/y are due to Nitrates, and Ammonium- 5.4 t/y. Nitrogen drained from the Peat soil is fluxed into Lake Agmon mainly in winter whilst Phosphorus mostly during summer. The principle transporter of Nitrate are the winter precipitation. Most of the Phosphorus migration is in summer by irrigation waters.

The Organic Nitrogen loads from the Basin were significantly reduced mostly due to fishponds restrictions and sewage removal. Total Dissolved Phosphorus from these sources was also reduced but to a lesser extent. The Hula Reclamation Project (LAS) significantly improved agricultural management: Prevention of dust storm. slow down the rate of soil surface descent, reduce rodent outbreak and underground fires. Conclusively, nutrient export from the Hula Valley to Lake Kinneret was significantly affected by climate change (precipitation decline), sewage removal and fishponds restriction.

Future Perspectives: The Lake Kinneret ecosystem require a slow gradual increment of Epilimnetic Nitrogen which is presently a factor of limitation. Potential sources of available Nitrogen are the Peat –Organic soil in the Hula Valley. Water mediation is the best “transport service” for Nitrogen supply. Ground Water Table elevation combined

with soil moisture increase by irrigation is optimal for the agricultural maintenance. If precipitation decline continue, import of water from other sources (such as desalinization), to improve Hula Valley`s soil condition, are recommended. Recommended future Hydrological management is an integration between the two ecosystems , Lake Kinneret and the Hula Valley. The present increase of salinity and lack of Epilimnetic Nitrogen in Lake Kinneret are the most acute environmental difficulties. Hula Valley soil condition deterioration under dryness is a major concern for agricultural development. A combined proposition is suggested: Import desalinated waters to Lake Kinneret and export (pumping) partly saline lake water to the Hula Valley and enrichment of Kinneret Epilimnetic Nitrogen stock by Hula Valley sources.

Best management strategies for sustainable rice production with minimum water requirement

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Food security is one of the grand challenges of our society and is a global priority. At present, about 800 million people globally go to bed hungry every day. To feed the future increased population by 2050s, food production will need to be increased by 60-100% (GFFA, 2015). Rice is a staple food for nearly half of the world's population; it is the primary food for 3.5 billion people worldwide (IRRI, 2013). In Asia, 137 million hectares of farmland are used for rice cultivation, which is about 89% of the total land utilized for agricultural production on the continent (FAO, 2017). However, rice is one of the most water demanding crops for its production. With water scarcity as our society's utmost challenge at present, it is essential that we develop alternative strategies to sustain and increase rice production with minimum water requirement. Additionally, climate change would have a significant effect on crop yield and the environment; therefore, we investigated several management strategies – conservation agriculture, direct seeding, postharvest loss reduction, supplemental irrigation requirement, and rice cultivation practices, and predicted rice yield and water requirement up to 2050s.

The CERES-Rice model in DSSAT (Hunt et al., 1989) was used for this study in order to estimate water stress impact on rice production, and to develop best management strategies to increase rice yield, followed by calibration and validation with collected field experimental data. Our study focused on Bihar, one of the poorest states in India, where rice is a predominant crop, and farmers per capita income is less than $1.25 per day. The livelihood of 80% of the population in Bihar depends mainly on agriculture. Analysis of the climate data for the state provides insights of the use of data for crop production, water

requirement and farmers' livelihood. To study the climate change impact on rice yield and water requirement, four GCMs were used (IPCC, 2014) for all the four climate change scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5). The projected changes in climatic variables showed the change in future climate during 2020-2059 from baseline period (1980-2004). The results showed that the precipitation amount increased from 2020 to 2059, and hence, the irrigation requirement would not to be as much higher as one would expect for a 60% increase in crop yield. Yield increase by the year of 2059 also partly accounted for by an increase in CO_2 concentration as predicted by all climate change scenarios. We investigated several strategies, such as conservation agriculture, direct seeding, and reduction of post-harvest losses to produce 60% more rice and reduce water requirement by 2059.

Results of this study indicate that irrigation requirement is 28 % for rice production with current condition (5580 kg/ha) in Bihar, where transplanting technique is used for cultivation (Fig 1).

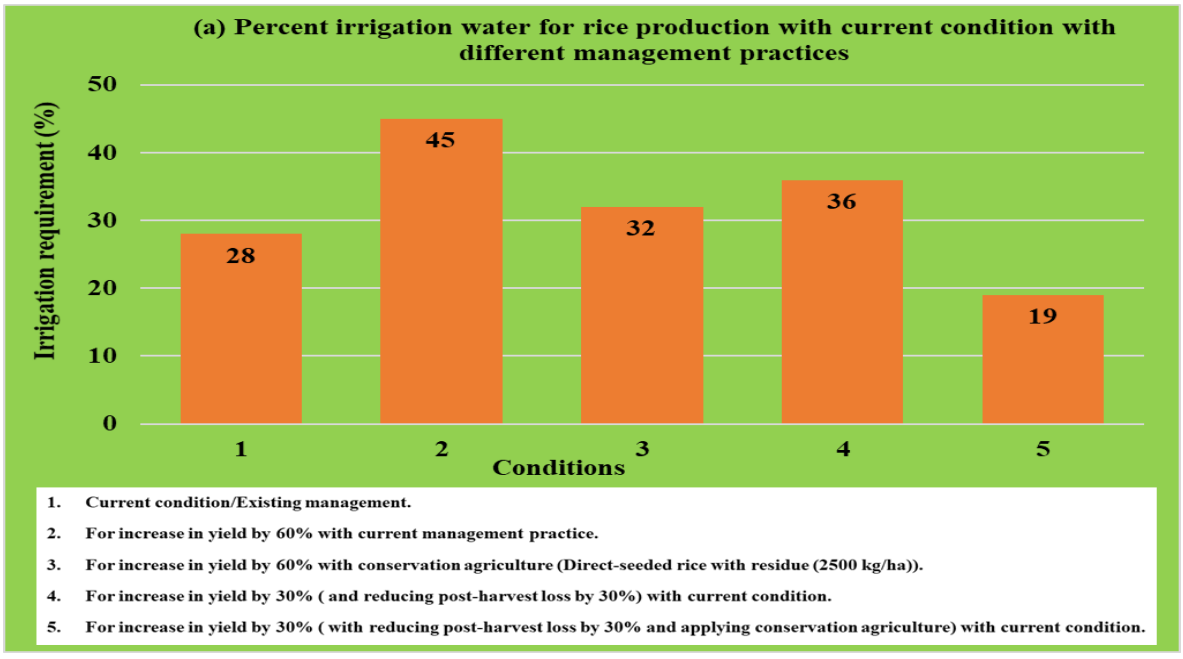

Fig. 1. Irrigation water requirement for 60% increase in rice yield with the current conditions

The yield obtained with climate change scenarios, RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5, were 5306 kg/ha, 5255 kg/ha, 5247 kg/ha and 5148 kg/ha, respectively, for 2050s,

and requires 27%, 26%, 23% and 24% irrigation water, respectively (not shown in Fig 1). Increase in yield by 60% by 2050s with current agronomic conditions, RCP 2.6 (shown in Fig. 1), RCP 4.5, RCP 6.0 and RCP 8.5 needs 45%, 44%, 43%, 39% and 41% irrigation water, respectively. These results show that on an average, irrigation water demand will increase by 17% for a 60% increase in yield, although precipitation might increase by 2050s.

With conservation agriculture, irrigation requirement for a 60% increase in yield would be 32%, 31%, 28%, 26% and 25% with current condition, RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5, respectively. These results show an increase of 60% yield is possible with conservation agriculture by only a 1-4% increase in irrigation requirement. Increase in rice yield by 60% with best management strategies will need 19%, 24%, 22%, 17% and 21% irrigation water with current condition, RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 (Fig. 2), respectively. This indicates that a 60% yield increase (reducing post-harvest losses by 30%, increasing crop yield by 30%,) may be possible by actually decreasing irrigation water requirement by 3-9% by 2050s. This is a desirable condition to implement strategies to increase food production and reduce water demand.

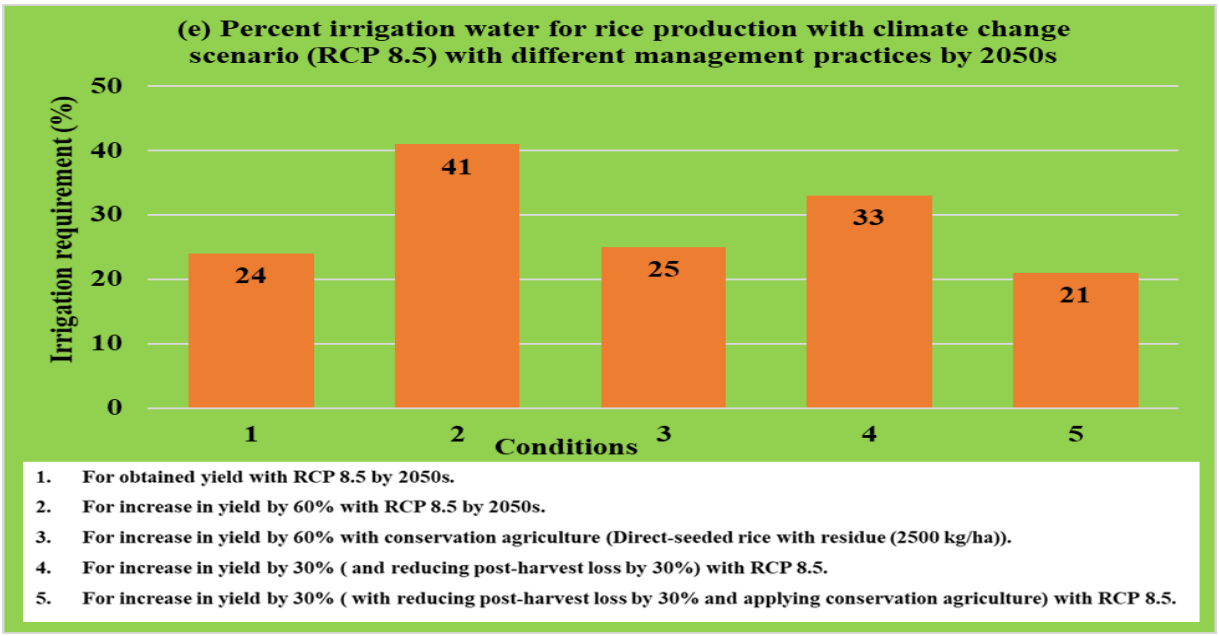

Fig. 2. Irrigation water requirement for 60% increase in rice yield with RCP 8.5 for 2059

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Carbon debt of field-scale Conservation Reserve Program grasslands converted to annual and perennial bioenergy crops

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Over 5 million ha of US Conservation Reserve Program (CRP) grasslands have been converted to annual crops since 2000, driven mainly by demand for corn grain ethanol. Much of the soil carbon sequestered under CRP is lost upon conversion, creating a "carbon debt" that is presumed to be repaid by future greenhouse gas (GHG) savings from ethanol's substitution for petroleum. Model simulations, extrapolations, and national statistics rather than direct measurements have been used thus far to estimate the long-term global warming impact (GWI) of such conversions. Here we report measured GWIs for three 22 year-old CRP grassland fields and three conventionally tilled agricultural (AGR) fields (11–17 ha) converted to either annual no-till corn or perennial cellulosic (switchgrass or restored prairie) bioenergy crops. We assessed GWIs for each field over eight years using whole-system life cycle analysis (LCA) by measuring: a) greenhouse

gas fluxes via eddy covariance and static chamber methodologies, b) farming operations and agronomic inputs, and c) the fossil fuel offset by ethanol use. Payback times were much longer than those estimated by prior modeling efforts. After 8 years, cumulative GWIs of switchgrass, restored prairie, and corn at the CRP grasslands were, respectively, -2.6±4.0, 6.9±3.6 and 85.2±5.1 Mg CO_2-equivalent ha^{-1}. The switchgrass system had repaid its carbon debt by year eight and the restored prairie will have likely repaid by year ten; however, the no-till corn system appears likely to require >300 years. The same bioenergy crops grown on former agricultural lands, with no sequestered carbon lost on conversion, repaid their carbon debts within two years. Results indicate that GWI estimates and carbon debt payback times due to conversion of CRP lands to annual bioenergy crops have been substantially underestimated by current models.

Economy-Wide Long-Run water management under salinity: Lessons from the Case of Israel

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This paper incorporates the agronomic detrimental effects of irrigation-water salinity into a large-scale dynamic hydro-economic model for studying the salinity implication on long-run water-infrastructure plans. Application to the case of Israel points at economic viability of large-scale delivery of desalinated water for agricultural irrigation. This result is explained by the large share of salinity-sensitive crops in the total irrigation-water consumption and production value of the Israeli vegetative-agriculture sector. The damage caused by the presence of salts in Israel's water sources is evaluated at nearly 5,600$ per hectare of arable land; this estimate encompasses implications on both the water and agriculture economies. Overlooking the salinity agronomic effects in the design of water infrastructures entails a welfare loss of 1,000$/ hectare, and leads to redistribution of incomes, where the profits of water suppliers significantly increase at the expense of the economic surpluses of urban-water users, farmers, and consumers of agricultural products.

Session V

Advanced technology and climatic monitoring for environmental sustainability

Chaired by Gil Eshel

Hydrothermal treatment of agricultural and food waste: a circular economy approach to improve energy recovery, nutrients and bioactive compounds

Roy Posmanik

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Population growth leads to high production of agricultural and food waste that challenges the sustainability food production systems. Uncontrolled disposal of these waste streams is an environmental hazard, as they contain high concentrations of organic carbon, nutrients and microbe-inhibiting substances. On the other hand, via appropriate chemical conversion, the value of these feedstocks can be enhanced and valuable resources can be recovered. Hydrothermal liquefaction (HTL) is an attractive thermochemical process to generate energy and bio-based chemicals from wet waste biomass such as sewage sludge, animal manure, food wastes, etc. The technology is based on accelerated hydrolysis and condensation reactions that are favorably influenced by the substantial changes in the properties of water that occur near its critical point (Tc=374°C; Pc=22 MPa). The primary product of HTL is crude-oil, a non-polar liquid with low oxygen content that can be upgraded to liquid fuels by standard refinery processes. In addition, HTL produces some amounts of solids (hydro-char) that can also be directed to renewable energy applications and an aqueous co-product that can be directed to agriculture applications.

To date, the technology efficiency was evaluated using batch experiments operated at 200–350°C, 5–20 MPa for 5–60 min. Experimental data demonstrates the capacity of the HTL process to generate valuable products (crude oil, hydro-char and water-soluble product) from various feedstocks such as manure, waste activated sludge, food waste and more. Our experimental data demonstrates how energy recovery is highly influenced by the feedstock chemistry and by the operating temperatures and times. For example, energy recovery of crude- oil from food waste (52–70%) was higher than from waste activated sludge (22–33%). This can be attributed to the natural acidity of food waste, which accelerates dehydration processes and converts monosaccharides into cyclic furan

compounds. On the other hand, the energy recovery of hydro-char from waste activated sludge (17–30%) was higher than from food waste (10–16%). This was probably due to higher lignin content in the sludge while the tested food waste was rich in pectin. For bio-crude oil production, high temperatures (300–350°C) found beneficial for all tested feedstockes in terms of the total energy recovery for all time tested. Low temperatures (200–250°C) and long reaction times (60 min) favored the production of hydro-char.

In addition, HTL produces a water-soluble product that can be utilized. One of the options to utilize the water-soluble carbon is to convert it into bio-methane via anaerobic digestion (AD). The feasibility of coupling HTL and AD for the conversion of food waste into energy products was experimentally tested through conducting biochemical methane potential (BMP) assays. The results demonstrate that the anaerobic biodegradability of water-soluble hydrothermal product was lower when the process temperature increased and vise versa. Combining HTL and AD may, therefore, yield a higher energetic return by converting the raw feedstock into crude-oil and bio-methane. Another options to utilize water-soluble hydrothermal product is by membrane distillation (MD) of the aqueous effluents to concentrate a nutrient-rich stream that can be used as fertilizer. This process integration uses the residual heat from the HTL process to drive the distillation process, which would improve the efficiency and reduce the cost of the general process. Our data demonstrates how the MD system can recover 75% of the water. The MD retentate had very high ammonium and phosphate concentrations, making it suitable as a fertilizer.

Another research direction is to test the activity of water-soluble hydrothermal product in plant protection applications. Since this phase derived primarily from depolymerization and fragmentation reactions of the raw biomass, compounds can be classified into five broad categories: (1) aldehydes; (2) ketones; (3) sugars and dehydrosugars; (4) carboxylic acids; and (5) phenolic compounds. In-vitro antifungal activity assays suggest that addition of diluted aqueous product from HTL of manure to a growth medium of the pathogenic fungus Botrytis cinerea inhibits the colony expansion. Furthermore, In-vivo bio-stimulant activity assay suggest an induced residence phenomena, as shown by the effect on the gray mold disease in tomato, caused by the pathogenic fungus.

To summarize, this talk will present the HTL technology as a new opportunity to bring the circular economy into agriculture and food production systems. Valuable products will be identified to demonstrate their implementation opportunities. Specifically, the talk will focus on the capacity of HTL to generate high value products for renewable energy, plant nutrition and plant protection.

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A general framework for optimal crop selection and water allocation using dynamic crop models

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We propose a general model-based optimization framework for selecting crops and/or allocating water. The main novelty of the approach is that it does not rely on predefined water productivity functions but rather the water productivity function of each crop at each location (i.e. for each soil) is estimated within the procedure itself by solving a separate multi-objective optimization problem. The basic requirements of the procedure are: (1) a dynamic model (such as AquaCrop, DSSAT or SWAP) for each crop, (2) yield value ($/kg) for each crop, (3) characteristics of the soil(s) in the relevant areas, (4) water quota(s) and (5) historical weather data or weather forecasts. The first step of the procedure consists of estimating the water productivity function for each crop/soil combination. This is done by solving a separate (independent) multi-objective optimization problem for each crop/soil combination, using a procedure which we have developed in previous works (Linker and Sylaios, 2016; Linker and Kisekka, 2017; Linker et al., 2018). After computing all the relevant water productivity functions, the problem of crop selection and/or water allocation is formulated as a convex optimization problem. Before planting/sowing, the proposed formulation enables solving simultaneously the problem of crop selection (or land allocation), i.e. which crops should be planted where, and water allocation, i.e. how much water should be provided to each crop. During the growing period, the same formulation can be used to re-optimize periodically water allocation, taking into account the actual weather and applied irrigation, and changes in factors such as water quotas and crop value.

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Gallic Acid Interactions with Iron coated Smectites

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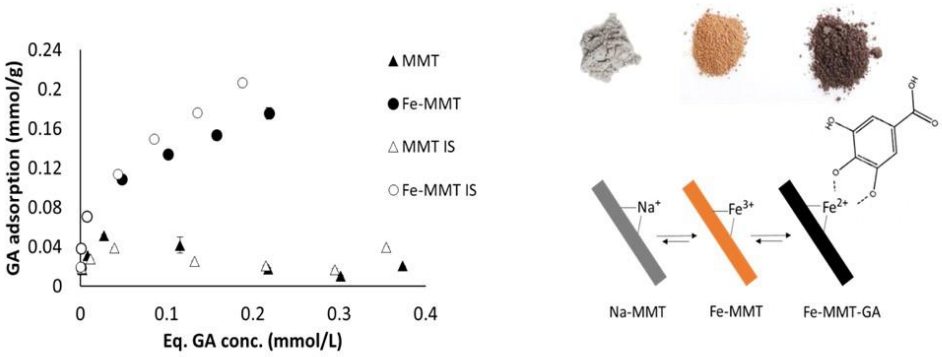
The occurrence of organic matter significantly effects pollutant fate in soils and aquifers and impacts efficiency of soil and water treatment processes. In that respect, a fundamental study was performed on the interactions between a prevalent quinone moiety in dissolved and solid organic matter, gallic acid (GA), and a smectite coated with amorphous iron oxides. Adsorption/desorption experiments revealed an increased affinity of GA to the Fe-MMT over the raw MMT. The adsorption was irreversible and only slightly affected by salinity indicating a strong inner-sphere complexation mechanism.

This Fe-MMT-GA complex was then characterized by UV-Vis, XRD, FTIR, LC-MS and XPS. The results showed further transformation reactions such as polymerization of the GA and reduction of the surface iron. The resulting complex also had increased adsorptive affinity towards PAHs and BTEX compounds due to increased hydrophobicity. Lastly, increased catalytic and conductive properties were shown and quantified using cyclic voltammetry and peroxide titration experiments.



Gallic acid adsorption to raw and iron-rich montmorillonite: **A**. Adsorption isotherms and **B**. Illustration of adsorption process and the respective picture of the clay at each step.

These interesting and complex interactions can occur in soils and sediments under ambient conditions and can in turn significantly effect pollutant sequestration and transformation. Consequently, the findings are relevant not only in terms of predicting the fate of pollutants in the environment, but also for the evaluation of in-situ soil and sediment treatment processes such as chemical oxidation and reduction.

Nature-sourced desalinization using halophyte-zeolite wetlands

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We present an integrated nature-based treatment system designed to treat agro-industrial wastewater to irrigation standards. At a dairy shed (case study), water is used as a spray to cool the animals, to wash them before being milked, and with sodium hydroxide to clean the floors of the milking platform between rounds. The mixed slurry from these activities is concentrated with organic matter, solids, nutrients and salinity. In the pilot system organic load and solids content is reduced by 50% and 99% respectively with a nanocomposite clay-polymer system in a footprint of 5 m2 in around 15 min. After solids removal the clarified sewage is transferred to secondary treatment consisting of aerated bioreactors, which removes 90% of remaining organic matter, 50% of nitrogen and 99% of P in a footprint of 40 m2. The treated water is then transferred to constructed wetlands (CW) containing zeolites and halophytes with the purpose of removing sodium chloride and replacement of monovalent ions (K+, Na+) with divalent Ca2+ and Mg2+ leading to an overall reduction in sodium adsorption ratio. In the constructed wetlands, sodium concentration declined from around 300 mg/L to around 100 mg/L. Concurrently, sodium accumulated in some of the halophyte plants, most notably in Sesuvium portulacastrum (50-90 mg NaCl/g dry weight). The pilot system is achieving the target of treating 1000 L raw dairy farm wastewater/day for all regulated levels suitable for release to the regional sewage system and in the case of sodium, phosphorus and solids, also for onsite irrigation. However, in order to reuse the water onsite (and not as part of a regional water reclamation project) it will be necessary to remove 150 mg/l chloride. We are currently investigating approaches to bring those remaining contaminants down without increasing the overall footprint or complexity of the system. Additionally we are investigating the contribution of competing sodium removal mechanisms (ion exchange and plant uptake). A significant advantage of the proposed system is inclusion of a cash-crop halophyte

Sesuvium portulacastrum that can be used as fodder and as a source of essential oils. Finally, the excess phosphorous in the wastewater is captured and reused as fertilizer (P-mining). Hence the project is contributing to circular economy. This work is funded by BRIGAID, a 4-year project (2016-2020) under EU Horizon-2020 aimed to effectively bridge the gap between innovators and end-users in resilience to floods, droughts and extreme weather.

Microclimate, evapotranspiration and water use efficiency of pepper in high-tunnel greenhouses and screenhouses in semi-arid regions

Daniel Hadad, Victor Lukyanov, Shabtai Cohen, Ziva Gilad, Ephraim Zipilevitz, Achiam Meir, David Silverman, Uri Adler, Yitzhak Esquira and Josef Tanny

Institute of Soil, Water and Environmental Sciences, ARO, Volcani Center, Israel

The area of crops grown in protected environments, like greenhouses and screenhouses, is constantly increasing worldwide. However, in the agricultural practice, most growers do not consider the difference in cover type in their irrigation management. The objective was to study the effect of roof cover type, either plastic or porous screen, on microclimate, Penman-Monteith evapotranspiration (ET) models, and water use efficiency, to improve irrigation management. A field study was carried out during the growing season 2016-2017 in two otherwise identical structures in which a pepper crop was grown (Fig. 1). One roof was a plastic sheet (hereafter denoted as the greenhouse) and the other an insect-proof 17-mesh screen (screenhouse). In both houses, microclimate was measured simultaneously above the canopy.

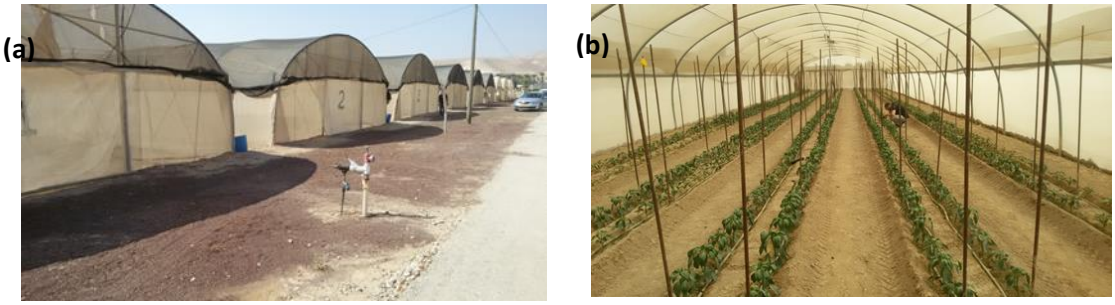

Fig. 1. (a) general view of the tunnel houses covered with black shading screens (15.9.2016). (b) internal view of a tunnel screenhouse with pepper plants shortly after plantation.

Evapotranspiration was estimated using 8 different versions of the Penman-Monteith model. Transpiration was measured using the heat-pulse technique. In 4 neighbouring houses, an irrigation trial was conducted with 3 treatments. Linear regressions were derived between internal and external meteorological conditions, with R^2 values between 0.08 and 0.99. Higher R^2 values were obtained for the screenhouse. Linear regressions between measured and modelled ET were derived with R^2 between 0.48 and 0.84. Transpiration measurements were in high agreement with a PM model based on internal meteorological conditions and a boundary-layer resistance. Water use efficiency for the irrigation treatment based on this model was larger by 31% (screenhouse) and 38% (greenhouse) than that obtained using regional recommended irrigation.

Exploiting dynamic changes in internal screenhouse climate to inform irrigation in bananas

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In the hot and dry Jordan Valley of Northern Israel banana irrigation under screens is reduced below rates for open stands by 25%, following research in the past 15 years on average climate and banana response to irrigation rates under screens. In the Western Galilee and Carmel coastal regions reductions are about 10%. The ratio of evaporation inside to that outside decreases during the season due to the accumulation of dust on the screen which reduces transmission of solar radiation and atmospheric evaporative demand.

We are exploiting these dynamic changes to inform irrigation management by monitoring climate under the screens and computing reference evapotranspiration (ET0) daily. Irrigation is adjusted according to ET0 from the previous day. The experiment focuses on 3 plots: reference unscreened, 10% 'crystal' and 20% 'pearl' screens. Significant reductions in irrigation have been obtained and after the first 3 years (and two yields) yields are best under the 10% screen and slightly reduced under the 20% screen. The reduced irrigation has not significantly affected soil salinity although at the end of the dry season a trend of increased salinity for the reduced irrigation was observed. No other detrimental results were found.

Dust accumulation reduced solar radiation transmission by an additional 10% at the end of the dry season. While for unscreened plots irrigation averaged 2250 mm a^{-1} for the two years of fully grown plants, below the 10% screen rates were 1775 for non-dynamic and 1465 mm for dynamic irrigation, respectively. Savings under the 20% screen were greater, but slight reductions of yield were found in that case.

Measurements included sap flow, leaf temperatures and horticultural data. The presentation will show and discuss these data and their implications for crop water relations and irrigation management under screens.

Session VI

Soil and plant biology

Chaired by Asher Bar-Tal

The rhizosphere microbiome - Key for plant health and growth

Doreen Babin[1], Namis Eltlbany[1], Tarek Elsayed[1], Nina Bziuk[1], Adam Schikora[1], Rita Grosch[2] and Kornelia Smalla[1]

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[2]Leibniz Institute of Vegetable and Ornamental Crops, Germany

Plant -microbe interactions play a key function in plant growth and health. They influence also the soil properties and various ecosystem features (Berg et al., 2017). Recent research of our and other groups focused on the effects of the agricultural management practice on soil microbiome, soil properties and plants' health and growth. The rhizosphere microbiome of lettuce or barley grown in soils from the same long-term experimental field site in either growth chamber or field, respectively, showed a distinct composition. Based on sequencing of the 16S rRNA gene fragments amplified from total community DNA, the differences were dependent on the respective management practice: plough vs cultivator or organic vs mineral fertilization. Most importantly though, the plant growth and expression of defense related genes was very likely affected by the management related differences in the soil microbiome. Improving plant's growth and health by managing the soil microbiome through a better understanding of how agricultural practices influence the soil microbiome and soil properties is will pave the way for a more sustainable agriculture. A more extensive, environmental-friendly management of soils can also be achieved by organic amendments or microbial inoculants. In this talk we present two studies on the use of microbial inoculants. The remarkably enhanced growth of tomato or maize achieved through microbial inoculants (Trichoderma, Pseudomonas, Bacillus) in soil with reduced P-supply was correlated to the rhizocompetence of the inoculants. Direct effects of the inoculants on the plants' growth as well as the observed microbiome shifts will be discussed. Furthermore, inoculants offer a potential for sustainable control of soil-borne diseases. Efficient control of the bacterial wilt caused by Ralstonia solanacearum through inoculants (Pseudomonas, Bacillus) was tested under

greenhouse conditions. In contrast to the non-inoculated tomato plants, significantly reduced wilting symptoms were observed for two of the five tested in vitro antagonists. In addition, the abundance of R. solanacearum was reduced in the rhizosphere up to four orders of magnitude as demonstrated by selective plating, qPCR (fliC) and amplicon sequencing (16S rRNA gene) techniques. Amplicon sequencing revealed strong shifts of the rhizosphere microbiome in response to the inoculants and the pathogen.

The last decade brought about remarkable methodological progress in the study of e.g., the microbiomes, chemistry and spatio-temporal structure of the rhizosphere. However, our present understanding of the factors that modulate the rhizosphere (microbiome, water availability, nutrient cycling, soil properties) is still very fragmented and limited. Therefore, a new DFG-funded Priority Program (SPP2089) was launched aiming at unraveling the spatio-temporal organization in the rhizosphere. Hence, this program will bring together the different aspects, processes and scales of the rhizosphere research under a common framework. The use of this knowledge shall improve our understanding of the resilience of agricultural soils and belowground plant-microbe interactions to support sustainable farming.

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Agricultural practices from the microbiome's point of view

Dror Minz[1], Judith Cohen[1], Avihai Zolti[1,2], Alla Usyskin-Tonne1[1], Eli Argaman[3], Yitzhak Hadar[2]

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[3]Soil Erosion Research Station, Ministry of Agriculture and Rural Development, Israel

Proper microbiomes are essential for soil health and fertility. Here we will describe how common agricultural practices such as organic farming, tilling, fertilization and irrigation with treated wastewater affect the structure and function of soil and root microbial communities. We will demonstrate how shifts in microbiome may serve as an indicator for the anthropogenic impact of these practices as well as how we can interfere with the microbiome structure to improve its function.

Screening for biostimulants effect on yield and drought tolerance using an innovative high-throughput physiological functional-phenotyping system

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In recent decades, the implementation of biostimulants has been reported as an alternative approach to improve crop productivity under normal as well as stress conditions. However, the identification and characterization of a new active biostimulant is a time-consuming and expensive process, as it requires expensive yield-related field experiments. In this study, we hypothesized that detailed physiological characteristic of 4-8 weeks seedlings in response to biostimulants treatment can be used to predict their yield. To test this, we used our high-throughput functional-phenotyping system (PlantArray) and facilitated high-resolution physiological phenotyping of *Capsicum sp*. in response to two different commercial biostimulants (ICL Specialty Fertilizers, Israel- seaweed extract - 'ICL-SW' and a metabolite formula - 'ICL-NewFo1') compared to untreated control. The experiment included well-irrigation period, controlled drought and recovery, and was continued till yield, enabling us to correlate between the physiological traits measured during the experiment and the fruit yield.

Our results revealed that under well-irrigated condition ICL-SW increased the plant-growth rate and consequently its transpiration rate compared to both ICL-NewFo1 treated and control plants. On the other hand, under the water-deprived condition, ICL-SW plants had significantly lower transpiration-rate compared to that of ICL-NewFo1 and control

plants. This led to 52% and 18% increase in fruit number of ICL-SW and ICL-NewFo1 plants, respectively, compared to the control plants under well irrigation. Yet while droughted ICL-SW reduced fruit by 44%, ICL-NewFo1 reduced only by 16% compared to their respective well-irrigated condition. We also found that ICL-NewFo1 improved the plant resilience better than ICL-SW, in particular, due to improved maintenance of its water-content. We conclude that the "physiological-boost" mechanism of ICL-SW was beneficial under well irrigation but injurious under drought, while ICL-NewFo1 revealed "physiological-protective" mechanism which did not improve the plant productivity under normal conditions yet prevented the injurious effect of the drought. We conclude that, using this approach large number of plants can be simultaneously phenotyped for different physiological traits under various treatment combinations, thus ensuring characterization of the treatment impact at an early stage.

Spatial dynamics of carbohydrate content in trees in tree across diurnal and seasonal time scales

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Nonstructural carbohydrates (NSC; soluble carbohydrates and starch) fulfill distinct pivotal functions in plants such as transport, energy metabolism, stress defense, osmosis, and serving as the building blocks for growth and structure. NSC allocation toward these functions has to be balanced with storage in order to buffer supply and demand asynchronies on different temporal scales. Indeed, during periods of low to no photosynthetic activity, such as dormancy, night and severe water stress, plants are entirely dependent on NSC storage (Stitt & Zeeman, 2012; Hartmann & Trumbore, 2016). Because of their key role in resilience to stress, the predicted rise in temperatures, increase in the frequency of drought events, and shifts in trees phenology resulting from climate change has led to increased research interest in NSC storage (Hoch & Körner, 2012; Sperling et al., 2017). The perennial habit of trees and full reliance of spring growth resumption on nonstructural carbohydrates (NSC) reserves necessitates that trees accumulate NSC prior to dormancy (Martínez-Vilalta et al., 2016; Tixier et al., 2017). Hence, NSC storage has been shown to have seasonal fluctuations notably marked by the alternation between favorable season with positive net photosynthetic activity and dormancy season relying solely on stored NSC in temperate climates (Hoch et al., 2003; Hoch & Körner, 2012). One the over hand, diurnal starch turnover in herbaceous leaves has been intensively studied, but remains overlooked with the complex architecture of perennial woody plants (Graf & Smith, 2011; Tixier et al., 2018). Detailed analyses of diurnal NSC dynamics within mature trees that include high spatial (specific tissue, canopy location, and age) and temporal (hours) resolution are necessary for the study of

NSC mixing and redistribution processes between dispersed storage sites within the complex architecture of trees. Indeed, our limited understanding of NSC diurnal and seasonal dynamics requires massive amount of data to decipher importance of organs, environmental conditions, endogenous regulations and their intra and interspecific variability in order to build robust mechanistic models.

Here we present first study of diurnal NSC dynamics in almond trees (Prunus dulcis) in combination with short-term temporal dynamics of newly assimilated carbon using isotope labeling. We show that both components of NSC (i.e. soluble carbohydrates and starch) are highly dynamic at the diurnal time scale and that these trends are influenced by tissue type, age, and/or position within the canopy. NSC diurnal fluctuations within the tree's structure in combination with dispersed carbon allocation patterns provide evidence for the presence of vertical mixing and suggest that the xylem acts as a secondary NSC redistribution pathway.

This study is combined with a comparative analysis of the seasonal dynamics of NSC in relation to the aboveground phenology and growth temporal patterns of 3 deciduous Mediterranean species: almond (Prunus dulcis), walnut (Juglans regia) and pistachio (Pistacia vera) commercially grown in the same location. We show that phenology had a strong influence on NSC seasonal dynamics and that NSC mobilization and accumulation among wood tissues from the different parts of canopy bares high level of synchronism. Seasonal patterns of growth did not present strong relationship with phenology nor strong trade-off with NSC storage, but seemed to be highly responsive to temperature and photoperiod in non-water-limiting environment. However, our results suggest that species with late phenology might exhibit trade-off between growth and storage after the end of the growing season when reproductive growth cease. Finally, these high temporal and spatial resolution seasonal dynamics of NSC concentrations are complemented by a "citizen science approach" where NSC levels are tracked in orchards at the whole California state level. This approach allows us to collect massive amount of data and assess effect of climate on NSC dynamics, such as chilling hours and drought.

Modeling spring phenology of deciduous trees by temperature mediated kinetics of carbohydrate metabolism

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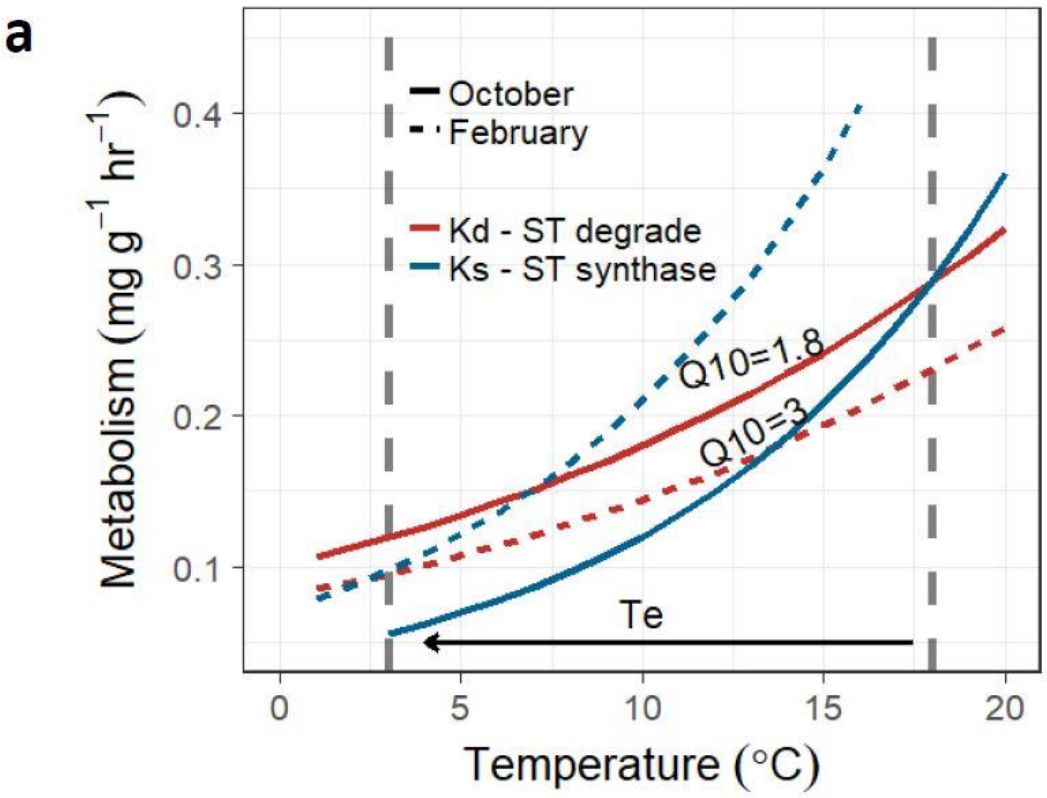
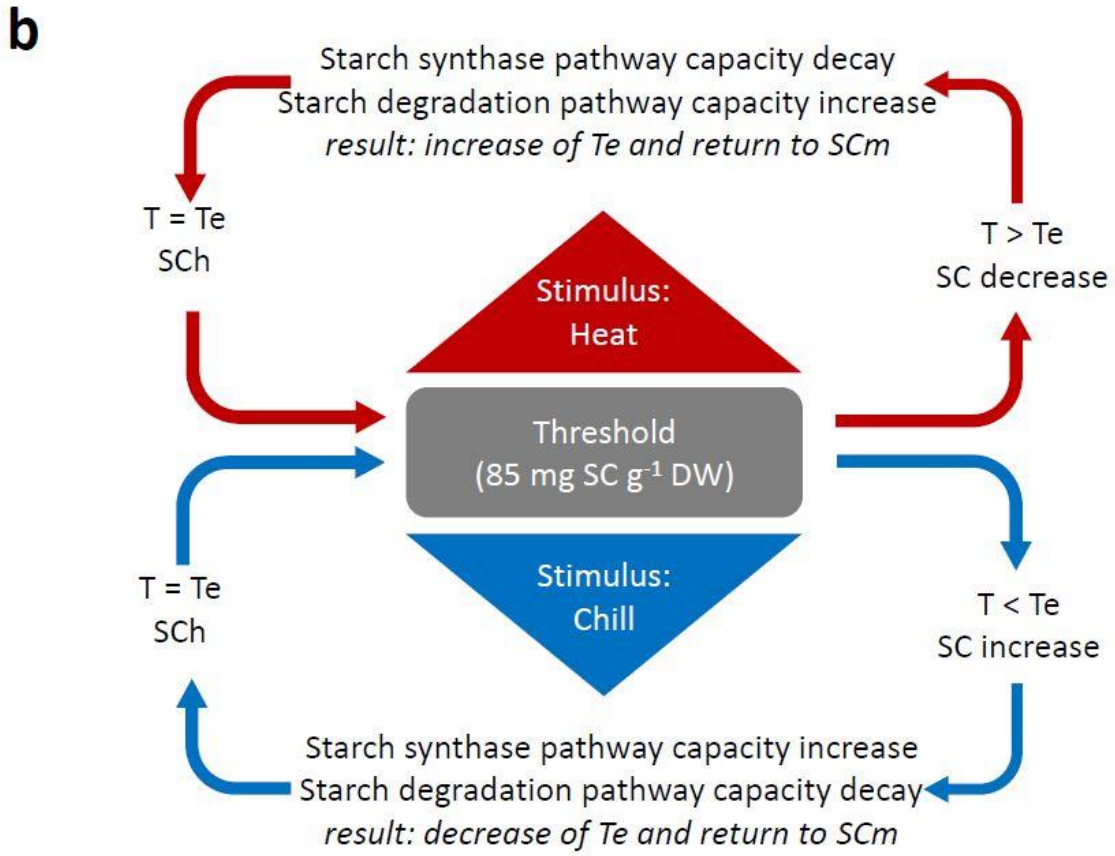
Trees in seasonal climates gauge winter progression to assure vital and synchronized blooming. Yet the physiology behind this mechanism remains obscure and we postulated that it involves the energy reserves that ensure sufficient resources for bloom.

We quantified non-structural carbohydrates throughout winter in almond, peach, and pistachio trees in California and Israel and characterized winter metabolism. We constructed a carbohydrate-temperature (C-T) model that projects changes in starch synthesis and degradation by temperature mediated kinetics. We tested the C-T model against bloom times under various climatic conditions using 20 years of temperature and bloom records for California's Central Valley.

The C-T model attributes carbohydrate regulation in dormant trees during winter to continuous updates of metabolic pathways. The model projects a surge in starch synthesis at the end of winter, and critically low levels of soluble carbohydrates, that trigger bloom. This is supported by field measurements of starch accumulation at the end of winter (10 to 50 mg g^{-1} DW in almonds) that preceded bloom by ~10 days.

The C-T model provides a physiological framework for forecasting bloom in deciduous orchards. It integrates contrasting notions of chill and heat and elucidates why abnormal winter temperatures may compromise bloom in deciduous orchards.


a
October
February
Kd - ST degrade
Ks - ST synthase
Q10=1.8
Q10=3
Te
Metabolism (mg g^{-1} hr^{-1})
0.1
0.2
0.3
0.4
0
5
10
15
20
Temperature (°C)


b
Starch synthase pathway capacity decay
Starch degradation pathway capacity increase
result: increase of Te and return to SCm
T = Te
SCh
T > Te
SC decrease
Stimulus:
Heat
Threshold
(85 mg SC g^{-1} DW)
Stimulus:
Chill
T = Te
SCh
T < Te
SC increase
Starch synthase pathway capacity increase
Starch degradation pathway capacity decay
result: decrease of Te and return to SCm

Session VII

Plant nutrition and related soil processes

Chaired by Patricia Imas

Maximizing the nitrogen use efficiency in long term high yielding soilless grown tomato

Wim Voogt

Greenhouse Horticulture, Wageningen University and Research, the Netherlands

One of the major differences between soil and soilless is the available rooting volume for plants, which is in soilless approximately 50 (stonewool) to 150 (hydroponics) times smaller than it commonly is in soil ((Sonneveld and Voogt, 2009). This obviously has consequences for the buffering and the availability of moisture and nutrients. This low volume in soilless enables almost full control over plant nutrition, however, for nitrogen (N) which is taken up rapidly and in large quantities, depletion can be a serious thread. The choice of the right nutrient solution for a certain situation (crop /stage/growing media/water quality), with ample NH_4 and NO_3 is a crucial factor for successful cropping. As a result of culture practices, such as over-irrigation (free draining systems), discharge (nutrient solutions from hydroponics or closed systems), a lot of N can be lost to the environment. In the last decade efforts were made to reduce these N-losses, which will be discussed in this presentation.

Recirculation is of course the obvious solution for the reduction of the nutrient emission via the leachate. The rate of success depends largely on the quality of the source water and to a less extent to the purity of the fertilisers and growing media used. Recirculation of solution is constrained by accumulation of undesired ions such as Na and Cl, which highly determine the discharge rate of the recirculating solution (Voogt and van Os, 2012). Other issues playing a role in decisions to flush and discharge the running nutrient solution are associated with accumulations and circulation of undesired substances, like metabolites or root exudates (Beerling et al., 2017). Despite of the advantages of saving water and nutrients by using closed systems, it is common practice to discharge nutrient solution once and again to minimize alleged risks. Given those practices, some strategies have been developed to minimize the N-losses. A key factor for nutrient management in soilless systems is the EC level, targeting at the recommended optimum EC (ECrec). Keeping this target EC is very important as it is assumed to give the best results for yield

and fruit quality. However, the concentrations of individual nutrient ions at ECrec are much higher than evidently needed for the optimal nutrition of the crop, as could be derived from mineral balances. As a result, the virtual EC made up by all nutrients to be sufficient for the nutrient demand (ECnutr) is lower than ECrec, thus creating space between the two and opens the possibility of filling up the difference by non-nutrient ions. Likewise the anions Cl or SO_4 can be used to made up the ECrec and consequently reduce the NO_3 concentration (Sonneveld and Voogt, 2009). Experiments have shown that using Cl to replace up to 50 % of the NO_3 concentration in the recommended nutrient solution in the root environment, did not compromise growth or yield (Voogt and Sonneveld, 2004). Some trials even showed advantage of this shifted NO_3:Cl ratios, favouring a higher Ca uptake and less BER. Obviously the reduced NO_3 concentration in the root environment reduce the potential N-losses strongly. The strategy of adapted NO_3:Cl ratio have been tested in Dutch commercial practice to test the applicability of this approach as well as a way to convince growers of its potential. Crop performance, yield, fruit quality, the water- and mineral balances as well as plant uptake were monitored at two commercial greenhouses with intensive, high yielding and long season (11 months) tomato cropping in a common stonewool-recirculating solution system. The yield nor fruit quality were affected, where the average input N (NO_3) concentration was reduced by 13-18 %, and the resulting concentration in the root environment (drainage) was decreased by 40 – 55 %, compared to the standard. Surprisingly, the total crop N-uptake was only slightly decreased by less than 10 %, compared to the standard NO_3:Cl ratio, which confirms the high efficient uptake mechanism for N of a tomato crop. Since there was actually no discharge of drainage water at the crops under investigation, model calculations have been used to estimate the potential gain in the reduction of N-losses. It worked out that, compared to the standard NO_3:Cl ratios the N-loss could be reduced by 55% to 85 %, depending on the chosen strategies, which is a net reduction of N-emissions of 80 and 120 kg N/ha/year respectively.

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Sonneveld, C. and Voogt, W. ,2009. Plant Nutrition of Greenhouse Crops. Springer, pp. 431.

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Fluorescence spectroscopy: a sensitive tool for detecting changes in composition of water-extractable soil organic matter and predicting nitrogen mineralization rates

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Soil solutions contain a variety of organic compounds that play an active role in soil biogeochemical cycling and may be important indicators of microbial processes (Osterholz et al. 2017). Excitation-emission matrix (EEM) of fluorescence coupled with parallel factor analysis (PARAFAC) is a relatively simple method that combines a large datasets with advanced chemometrics and may be used for characterization of soil water-extractable organic matter (WEOM) in terms of fluorescent components. Albeit the continued interest in use of fluorescence spectroscopy in soil science, there is still a need for improved characterization of the spectral components and their sources. To fill this gap, three types of the experimental setups were examined including 1) EEM analysis of specific pools of soluble OM, 2) monitoring relative changes in the PARAFAC

components over time, or 3) examining correlations between the PARAFAC components and other soil attributes or processes.

In the 1st experiment fluorescence spectroscopy coupled with PARAFAC was employed for the characterization of chloroform fumigation-extractable soil organic matter commonly used to quantify soil microbial biomass. This study allowed, for the first time, to discriminate between contributions from humic (i.e., non-cellular) and microbial tryptophan-like, fumigation-extractable soil organic matter. Tryptophan-like fluorescence appeared almost solely in the fumigated soil extracts and was negligible in the non-fumigated control, making up 81% of the total fluorescence of fumigation-extractable material under the classic 0.5 M K_2SO_4 extraction.

The 2nd study examined a set of soil incubations across a diverse set of soils and fertility managements to measure net N mineralization rates and explain variation in the rates with EEM-PARAFAC analyses. Sequential cold (20°C) and hot (80°C) water extractions were conducted during the incubations. The relative changes of the derived PARAFAC components during incubations were utilized to identify specific components that can be related to biodegradation (mineralization) processes and / or to N losses through immobilization and denitrification. Therefore, a EEM-PARAFAC based examination of WEOM may provide effective tools to investigate potential effects of fertility management practices on C and N processes thus contributing to better understanding of soil N dynamics and factors affecting its availability.

The 3rd experiment was designed to couple EEM characterizations of soluble OM pools with advanced chemometric techniques to improve prediction of potential and gross nitrogen (N) mineralization rates (Rinot et al. 2018). We analyzed soil water extracts spanning over a broad range of OM contents from Midwest United States (MUS) and Israeli (ISL) agroecosystems under organic- and mineral-based N management strategies. PARAFAC components were used to detect changes in labile soil OM pools and to predict N mineralization rates. N-way partial least squares regression (NPLS) was used to analyze EEM data to obtain spectral factors correlated to total organic carbon concentration and potential and gross N mineralization rates. This NPLS analysis led to a reliable estimation of all three tested properties for the ISL and MUS soils.

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Rinot, O., Osterholz, W.R., Castellano, M.J., Linker, R., Liebman, M., Shaviv, A., 2018. Excitation-emission-matrix fluorescence spectroscopy of soil water extracts to predict nitrogen mineralization rates. Soil Science Society of America Journal, 82, 126–135.

Nutritional and chemical implications of long-term irrigation with recycled wastewater in olive (*Olea europaea* L.) orchard

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The demand for water is rapidly rising along with the global growth of population and standard of living. Fresh water (FW) scarcity in arid and semiarid regions promotes utilization of marginal water sources. Utilization of recycled wastewater (RWW) significantly increases the available volume of water for irrigation of agricultural crops while presenting an environmentally agreeable solution for the disposal of sewage water.

Typically, RWW contains considerable amounts of valuable plant nutrients and hence, can reduce farmer's expenses and conserve valuable resources. These 'recycled' nutrients often have large annual variations depending on the source of sewage water, treatment and precipitation. In spite of the agronomic and environmental benefits of RWW utilization, it is not free of hazards. RWW is typically characterized by high salt content, which can impair agricultural yields and have environmental repercussions. In the long-term, irresponsible use of RWW may lead to soil sodicity and subsequently, to impair soil physical and chemical properties. The objective of this study was to determine the effect of long-term utilization of RWW and accompanied fertilization practice on soil properties and plant performance. We evaluated irrigation and nutrient management of olives with RWW versus FW in a long-term field experiment. Two olive cultivars (Barnea and Leccino) were subjected to irrigation with RWW, either with standard or reduced fertilization, and irrigation with FW with standard fertilization.

Our results reaffirm the need to consider nutrients provided with the RWW in fertilization management. During the eight years of the experiment, considerable amounts of N, P and

K were delivered with the RWW. Under our specific experimental environmental conditions, tree requirements for nutrients were successfully supplied by the minerals present in the RWW, without need for additional fertilization. Fruit yield was higher in RWW treatments compared to the FW, probably due to the presence of P in the RWW and the lack of P fertilization as commonly practiced in standard olive cultivation. We arrive at two main deductions regarding nutrition management: i) Common fertilization practice typically leads to N over-fertilization, and ii) P nutrition is underestimated. These conclusions are well in agreement with former studies on olive responses to fertilization. When N level in the irrigation water was not considered, we consistently observed large buildup of nitrates in the soil profile, which were later leached down by winter rains. In addition to the environmental impact caused by significant NO_3^- transport to groundwater, N over-fertilization may lead to impaired product quality and reduced yield, while balanced N management minimizes N losses with no negative impact on yield.

By the end of the irrigation season each year, soil salinity was higher in the RWW compared to the fresh water treatment, but this did not lead to accumulation of Na or Cl in leaves or to reduced tree productivity. From an agronomic point of view, the lack of response to salinity implies that irrigation of olive with RWW is sustainable as long as precipitation ensures sufficient seasonal leaching of salts. However, sodium absorption ratio of the soil solution slowly and steadily increased in the RWW treatments resulting in a high exchangeable sodium percentage (14%), nearly double that of the FW treatment. The latter observations highlight the likelihood for deterioration of soil physical and chemical properties subsequent to long-term irrigation with RWW. These long-term hazards were not manifested in the duration of the current study, but the trend is alarming. We therefore conclude that utilization of RWW should be accompanied with routine close monitoring of soil sodicity to avoid soil degradation and allow consideration of soil remediation practices.

Studying the effect of plant nutrition and variety on the nutritional value of teff grown in Israel

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Teff (Eragrostis tef) is an annual cereal, a staple food in Ethiopia. Teff is rich in nutritionally important minerals, and is also a gluten free, high in polyphenols and dietary fiber, with a low glycemic index. Recently there is a growing interest in teff, owing to its nutritional values and being gluten free. In Israel there is a large demand for teff by the local Ethiopian community, and lately it has been commercially grown in the Golan Heights and in the Negev area. Our aim was to study the effect of nitrogen (N), phosphorus (P) and potassium (K) fertilization and variety on the nutritional value of teff grown in Israel. For this, red and white teff seeds from commercial varieties were grown in pots, in a greenhouse located at the Gilat Center. Plants were exposed to 5 N levels in an irrigation solution (10,20,40,80, 120 ppm), 4 P levels (1,3,6, 12 ppm) and 4 K levels (10,20,40, 80 ppm), grown to full maturity and harvested manually. Mineral concentration, total phenolic content and fatty acid composition were measured. Results showed that for increasing N, P and K levels fertilization, a significant decrease in zinc contents was observed, mainly in the red variety. In addition, N and P fertilization resulted in a significant decrease in manganese contents, in both red and white cultivars. In addition, polyphenol contents increased with increasing N fertilization in both white and red varieties. Fatty acid analysis showed that N fertilization resulted in an increase in polyunsaturated fatty acids (PUFA), accompanied by a decrease in saturated fatty acids (SFA), with no significant changes in monounsaturated fatty acid (MUFA) levels. Today's costumers are aware of the health benefits of food, and are willing to pay higher prices for healthier foods. We showed that plant nutrition regime greatly affects teff's nutritional composition, indicating that fertilization should be a delicate balance between physiological needs, yield outputs and nutritional outcomes.

High fertilization decreases blueberry yields and fruit quality in China

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Blueberries have been commercially grown for 18 years in China and the plantation area is expanding rapidly due to their high antioxidant activity properties and high profits. Until 2016, planting area of blueberries in China has accounted to 16.3% of the world (Brazelton et al., 2017). However, there is lack of knowledge on the required fertilization for blueberry in China; therefore the current fertilization recommendations for blueberry are based on protocols of other fruit trees. The objectives of the presented studies were to investigate the effects of macro-nutrients (N, P and K) rates on blueberry fruit yield and quality. For this purpose a fertilization field experiment was setup in 2017, in a commercial orchard of 6-year-old blueberry ('Brightwell' Cv.) located in Huangmei county, Hubei province, China. The treatments included four levels of the N, P and K (15-15-15) fertilizer: 0, 300, 450 or 600 g/plant/year (the customary dose is 600 g /plant/year), fertilizer was split applied in three times (in the beginning of March, April and August) and banded on each side of the plant. Each treatment consisted of one row with five plants and was replicated three times. The fruit yields of the blueberry in 2017 and 2018 were 14.8～17.4 kg/bush and 13.9～16.2 kg/bush, respectively. The lowest yield was obtained at the customary dose, whereas the yield of the 300 g treatment in 2017 and 2018 was higher by 17.6% and 16.5% than 600 g treatment, respectively. The treatments had no significant effect on fruit setting rate and average berry weight. In 2017 and 2018, the titratable acid content of blueberry under 600 g treatments was the highest. Total soluble solid content of blueberry under 300 g treatments was significantly higher than other treatments in 2017, but there was no significant difference among treatments in 2018.

Another experiment was carried out to investigate the correlation between macronutrients concentration and anthocyanin content of blueberry. Fruits and leaves were sampled from blueberry ('Brightwell' Cv.) in 10 commercial orchards from east to west of China. Nine bushes were sampled in each orchard as 9 replicates. The results showed that leaves nitrogen and phosphorus concentration has no correlation with total soluble sugar in berries, while leaves potassium concentration showed a significant positive correlation with it. Besides, leaves phosphorus and potassium concentration had no correlation with berry anthocyanin content. However, there was a significant negative correlation between leaves nitrogen concentration and berry anthocyanin content. The results suggested that high potassium concentration in leaves could increase blueberry sugar content, while high nitrogen concentration could decrease blueberry anthocyanin content.

Therefore, it could be concluded that high fertilization application decreases blueberry yields and fruit quality, and high nitrogen application leads to low anthocyanin content; while high potassium application is good for sugar accumulation in blueberry.

Brazelton C, Young K, Bauer N. Global blueberry statistics and intelligence report. International Blueberry Organization, 2017: 1-84

Session IIX

Plant nutrition and related soil processes (part 2)

Chaired by Avi Shaviv

The influence of chloride on plants response to nitrogen level

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Chloride (Cl) is the dominant ion in natural water in arid areas and it is considered as a major limiting factor of plants biomass and yield production. Chloride and nitrate are univalent ions that compete on uptake by plants. Therefore, it has been assumed that higher nitrogen level is required by plants irrigated with water containing high chloride concentration, whereas low N level is required when desalinated water are applied. Consequently, the downward leaching of N below the roots zone can be minimized under irrigation with desalinated water. The overall objective of the presented study was to evaluate the need to adjust N level to the concentration of Cl in the irrigating water. The specific objectives of the research were to study the interaction effects of N with Cl concentrations in the irrigation water on: 1. the performance and yield of different crops 2. The uptake and concentrations of Cl, nitrate and N in plants' organs and 3. The downward leaching of nitrogen below the roots. The response of three different crops, maize, lettuce and potato to a range of different concentrations of N and Cl concentrations were evaluated in lysimeters filled with coarse sand. The three plants yield increased with N up to optimal value (defined as the lowest concentration with the highest yield) and decreased with Cl. The uptake of nitrogen and chloride increased as functions of their respective concentrations. Increasing Cl in the irrigation water decreased nitrate concentration in the measured plants organs, however, no effect of Cl level on total N concentrations in the organs of the three studied crops was obtained. Increasing N level reduced Cl in most analysed tissues of the plants used in this study. Although N significantly reduced Cl concentrations in leaves of potatoes and lettuce and cobs of maize it did not compensate for the negative effects of increasing Cl. Consequently, there was

no advantages to higher N level under high salinity for plant performance and it increased the downward leaching of nitrogen. Opposite to the expectations, the optimal N concentrations in all the studied crops increased as the Cl concentration decreased. These results indicate that nitrogen fertilization under low salinity can be more efficient and with less negative impact on the environment.

Are micronutrient deficiencies the sole obstacle to blueberry growth in neutral-alkaline pH soils?

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Blueberry growth is extremely retarded in soils with pH above 5.5. Under such conditions, it has been widely suggested that uptake of micronutrients, mainly iron, manganese and zinc become the limiting factor for plant's growth. In a previous pots experiment, we found that fresh biomass production of blueberry declined as a function of the dose of calcite amendment of soil and/or the ratio of NO_3/NH_4. This reduction in biomass production correlated with Ca concentration in the canes. For the best of our knowledge, there is no information in the available literature on Ca uptake and accumulation in blueberry organs and the effects of Ca accumulation on biomass production. The objectives of this study were to investigate the effect of calcite and Ca concentrations in plant organs on biomass production and mineral uptake of blueberry plants. Ochlockonee Cv. plantlets were grown in tissue culture medium at pH=7 with and without 1% $CaCO_3$. Another set of plants were grown in hydroponically system at two pH values, 4.5 or 7.0 combined with four concentrations of Ca (0, 10, 20 and 40 mg/l). The dry biomass production of plants grown in tissue culture medium in the CaCO3 treatment was 50% of that without $CaCO_3$. The concentrations of the minerals were higher in the shoots of plants grown in tissue culture medium with than without $CaCO_3$. Calcium concentrations were higher in the roots of plants grown in tissue culture medium with $CaCO_3$ treatment than without. The maximum biomass production in the hydroponic system for the two pH values was obtained in 10 mg Ca/l. The Ca and Mn concentrations in the roots were higher in pH 4.5 than in 7.0, except of the treatments of 0 mg Ca/l in which the concentrations of both elements were very low in both pH values. SEM analysis

showed that Ca accumulated on the surface and inside the roots tissue under alkaline-neutral pH conditions. These results and the results of the previous study in pots experiment, suggest that excess Ca uptake plays a major role in the negative response of blueberry to alkaline-neutral pH conditions and to high $CaCO_3$ content in soil.

Polyhalite - a new multi nutrient fertilizer with sulphur, potassium, magnesium

Patricia Imas

ICL Fertilizers, Israel

Polyhalite is a new multi-nutrient fertilizer, available in its natural state, and mined in the UK. It has four nutrients: sulphur (48% SO_3 as sulphate), potassium (14% K_2O as sulphate of potassium) magnesium (6% MgO as magnesium sulphate) and calcium (17% CaO as calcium sulphate). It is a soluble material therefore its nutrients are readily available for plant uptake.

Polysulphate comes from the polyhalite layer of rock, over 1000m below the North Sea off the North Yorkshire coast in the UK. Polysulphate is the trade mark of the mineral 'Polyhalite', which is one of a number of evaporate minerals containing potassium. Polyhalite (dehydrate) is a single crystal complex with 2 molecules of water of crystallization. It is not a mixture of salts. The chemical formula is $K_2Ca_2Mg(SO_4)_4 \cdot 2(H_2O)$.

Polyhalite is natural and has a low carbon footprint. It has low environmental impact and is certified for organic use in many countries. Its chloride content is very low, thus can be applied also to sensitive crops.

Being a natural crystal, it has a very unique dissolution pattern, which releases its nutrients gradually after being applied to the soil. The extended release period of the nutrients in polyhalite, particularly the sulphate, offers considerable advantage in practical farm conditions. Polyhalite has been shown to release S over a long enough period to meet the crop's requirements for sulphur over the major growth period and is also unaffected by pH. This special solubility characteristic of Polyhalite provides prolonged availability to plants of sulphur whilst reducing the risk of its leaching in sandy soils and under high precipitation.

Independent trials have shown Polyhalite to be an effective source of S, K, Mg and Ca. Polyhalite trials have focused on establishing that its nutrients are readily available to the plant. Crops were grown and given standard sources of pure potassium and magnesium sulphates, or polyhalite. Uptake of the polyhalite nutrients by the plants was found to be as good as the standard equivalent fertilizers already used in the field. These trials have been repeated many times over the last ten years, both in pots and in the field. Polyhalite has performed equally well or better than the best standard alternatives.

Field and greenhouse trials in five continents tested the response and behavior of polyhalite in 40 crops and in more than 20 countries. Some of the results are presented here.

Concentration dependence – a new understanding regarding the validity of redox measurements in the soil environment

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The soil redox state has great effect on the availability of nutrients and toxic elements. Direct potentiometric measurements using redox electrodes (most commonly using a Pt electrode) yields the oxidation reduction potential (ORP) which is the most straightforward parameter to describe the redox state of a system. Many scientists oppose the use of redox electrodes as a quantitative method because in many studies the measured ORP did not correlate with the speciation of the measured electroactive species according to Nernst-based calculations. Despite this opposition, redox electrodes are increasingly employed in environmental and agricultural studies because they remain the only means of measuring the redox state continuously and because they provide in-situ measurements. Many of the environmental studies where more than one redox electrode was used reported great variability, which was attributed to spatial causes, calibration loss and to degradation of the reference electrode – all leading to the ambiguity of the ORP meaning and validity. To date, no investigations have attempted to estimate the factors affecting this variability. We investigated the variability between eight Pt electrodes set in stirred soil slurries (1:10) aimed at eliminating spatial differences in redox state. Calibration was performed before and after the incubation period, and the reference electrodes' reading were compared periodically to a robust external reference electrode. We found that throughout oxic and anoxic alterations the variability in ORP ranged between 50 and 100 mV and this was attributed primarily to the Pt electrodes. The variability remained steady even when the system was left in a steady redox state for one week. We further investigated this phenomenon in a similar system with defined solutions containing only Fe^{+2}/Fe^{+3} as the electroactive species at differing ratios, pHs and ionic

strengths. In the Fe solutions significantly less variability was measured, ranging between 4-20 mV. More importantly, the variability in the Fe system showed great dependence on the molar activity of the Fe species, with variability increasing dramatically when Fe^{+3} activity was lower than 10nM. Based on these findings we argue that there is a limit of concentration of the electroactive species, above which redox electrodes give a more accurate representation of the redox state of the system. We shall discuss previously reported data measured in aquatic and soil environments, in light of this new perception and suggest mechanisms responsible for the phenomenon.

Modeling nitrogen transport, uptake and transformation in the root zone with HYDRUS (2D/3D)

Thomas Groenveld[1,2], Yair Y. Kohn[2], Amir Argaman[2] and Naftali Lazarovitch[1]

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[2]Central and Northern Arava R&D, Israel

The potential uptake of water and nutrients are time-variable boundary conditions required by all models describing these fluxes. These potentials can be either given as predefined values based on measurements done on crops grown under optimal conditions, or can be calculated by a plant growth model combined with a climactic model. A mechanistic description of plant growth and the resulting potential uptake is an important goal in plant modeling, but the large amount of plant specific information required currently limits the application of such models. Reducing a known potential uptake is a common feature in models describing the transpiration response to water or salinity stress, but the permanent reduction in potential due to limited plant growth is usually not specifically taken into consideration. Including this effect in a system-dependent manner makes it possible to model water flow and solute transport, uptake and transformations in a more mechanistic fashion.

A modified version of the HYDRUS (2D/3D) model was used to model the effect of limited nitrogen fertigation on the transport, uptake and transformation of nitrogen in the root zone. The uptake by plant roots was considered by means of passive, active and compensated uptake, and the transformation of nitrate to a gaseous form of nitrogen was modeled with a first order decay reaction. The potential transpiration was reduced due to limited nitrogen uptake. The model was calibrated and validated with a data set of cucumber plants grown in perlite and fertigated at three nitrate concentrations and six irrigation/transpiration ratios for a 40 day growing period.

The modeled data fit the measured data well, both in terms of the season total water and nitrogen fluxes for all treatments, and the daily fluxes per individual treatment. The model could be used to determine the contribution of active uptake to the total uptake, demonstrating that at lower nitrogen fertigation more of the uptake was active. Understanding the spatial and temporal distribution of nitrogen in the root zone can be used to optimize irrigation frequency and nitrogen concentration. This model also has the potential to be an important tool in interpreting measurements of gaseous forms of nitrogen emitted from the root zone.

Session IX

Irrigation and Irrigation Technology

Chaired by Ami Gips

Drip fertigation for staple food crops: can we do it?

Naftali Lazarovitch

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With the increase in world population and the reality of limited water and land resources there is a growing need for supplying more food per drop of water in irrigated agriculture. Remarkably, most farmers today still irrigate their crops using surface irrigation methods with very limited water and fertilizer use efficiency. Irrigated agriculture is practiced on only 17% of the cultivated land worldwide but yields about 40% of the world's food.

The use of drip irrigation (DI) is increasing in agriculture because of growing recognition of its advantages compared to other irrigation methods. DI has been shown to successfully increase water and nutrient use efficiency and to increase yield for many crops. Expanded use of DI is desirable due to the potential contributions to water conservation and environmental sustainability.

Although many farmers have adopted micro-irrigation techniques mainly for high-value crops that can promise profitability, the extensive adoption of DI for staple foods growers still remains a challenge. These crops supply a large fraction of energy and nutrient needs, particularly in regions which are poor in resources.

The presentation will explore various staple food crops (rice, potato and cassava) irrigated with DI. Water and nutrient use efficiency will be given for various system designs and fertigation amounts. These results could support a DI system that is less costly to purchase, install and sustain.

Controlling variability in vineyard with variable rate drip irrigation

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Many vineyards worldwide are subjected to spatial variability, exhibits in areas with lower yield than the rest of the plot. In addition, there is also variability in the grapes quality and thus for the produced wine. The common cause for variability is different water holding capacity across the fields due to different soil types or sloped plots. The new VRDI (Variable Rate Drip Irrigation) irrigation concept we developed gives an answer to the variability found in vineyards. The VRDI system divides the vineyard into 30 by 30-meter irrigation zones where each zone can be irrigated separately using NDVI maps and stem water potential (SWP). The first VDRI system was installed in Israel in a 2006 Syrah variety on a 1.2-hectare plot. The experiment was conducted during 4-years where in 2014 the plot was irrigated according to the farmer best practice with only one irrigation zone (control), on 2016 and 2017 the plot was irrigated with the VRDI system (12 irrigation zones), and in 2018 it was irrigated again by the farmer (control). During each season, several physiological parameters such as: LAI, SWP, yield quantity and quality, were measured to quantify the spatial variability in the vineyard. During the 'control year' (2014) we found a trend of reduced yield, LAI and canopy size along the rows from south to north while at the same time increasing water potential values. During the two years of operating the VRDI system (2016-17), the trends of LAI, SWP and yield found in previous year were vanished. The yield, LAI, canopy size, water potential and primary juice chemical analysis were very similar across the plot from south to north in contrast to the variability found in the control year. The elimination of the spatial variability was attributed to different irrigations and timing applied for each zone. In 2018 the vineyard was irrigated only by the farmer with the old irrigation system (one zone) to evaluate if the variability would appear again. The results from 2018 indicated that the same trends of reduced LAI, yield and SWP found in 2014, where shown again in the plot as a result of irrigating with one zone. This research shows that spatial variability can be

addressed by variable rate irrigation but once back to one zone irrigation, the variability returns as before.

The effects of treated wastewater irrigation on the spatial distribution of water and solutes in the root zone and their availability to the plants

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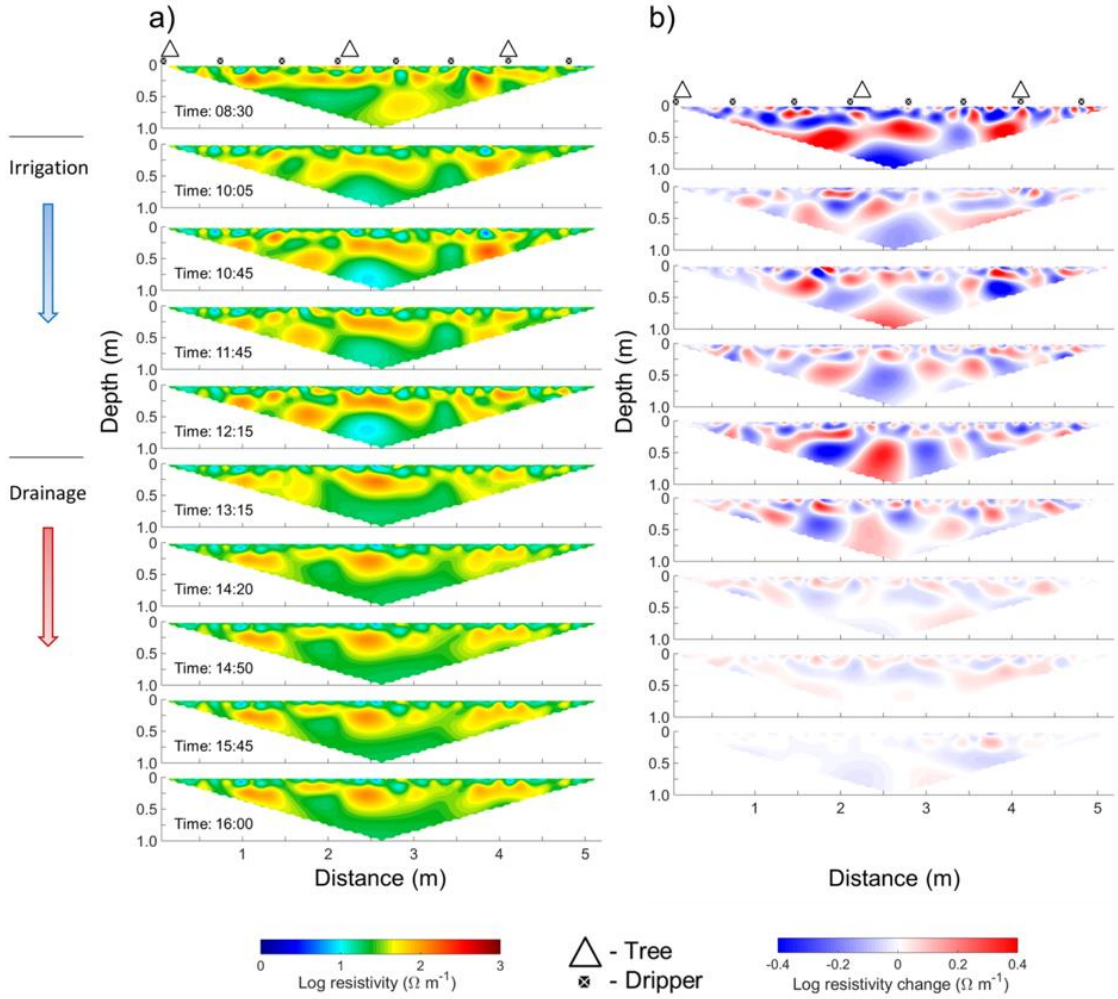
Treated wastewater ('TWW') gradually replaces freshwater (FW) for irrigation, as water shortage is gradually growing. Today, most orchards in Israel are irrigated with TWW. While the benefits of TWW irrigation are apparent, there has been an increasing amount of evidence regarding its negative effects on soil, trees and yield. This study, performed in a TWW irrigated commercial citrus orchard in central Israel, intended to study used on 1) the effect of soil wettability decrease by prolonged TWW irritation on the spatial and temporal unevenness of water content and associated chemical distribution in the root zone, 2) the replacement of TWW by FW as a mean for soil reclamation. Electrical resistivity tomography surveys at TWW and FW plots revealed that water flow in the root zone of both plots takes place in preferential flow paths leaving behind a considerable nonunifrom water content distribution. This was in spite of the independently measured gradual relief in soil water repellency in the TW plots. The four soil sampling campaigns (spring and fall at two consecutive years) were performed for the 0-20 and 20-40 cm layers of the TWW and FW plots revealed that the gravimetrically-measured water content distribution was bi-modal; The average salinity, SAR, and nutrient concentrations that were initially high in both plots gradually dispersed, as concentrations in the FW plots diminished; The preferential flow rendered the elemental concentrations distribution uneven, with high concentration, that reach toxic value, at the dry spots and vice a versa for the wet spots.



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DIDAS - a user-friendly software package for assisting drip irrigation design and scheduling

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The DIDAS software package, based on analytical solutions of linearized water flow and uptake problems, assists in drip-irrigation system design and irrigation scheduling. Water flow is described by superposition of solutions for positive sources (on-surface or subsurface emitters) and negative sinks (root systems). Steady water flow is assumed in the design module and unsteady flow in the irrigation scheduling module. The design tool, based on relative water uptake rate (RWUR) criterion, assesses the effects on water use efficiency of geometrical attributes: distances between emitters along drip lines; separation between drip lines; depth of subsurface emitters; and size and depth of root systems. Evaluation of the maximum possible RWUR assumes no plant-atmosphere resistance to water uptake, i.e., the roots are assumed to apply maximum suction and the water uptake rate depends only on the soil capability to conduct water from sources to sinks. The RWUR computations require only three parameters describing the soil texture, the root zone size, and the potential evaporation, in accounting also for evaporation from the soil surface. The optimizing tool for irrigation scheduling is based on a relative water uptake volume (RWUV) criterion. The computations of diurnal variations of water uptake rates and RWUV for a given irrigation scenario require additional information on the diurnal pattern of plant resistance to water uptake and on the soil hydraulic conductivity. DIDAS also contains a diurnal pattern module for evaluating diurnal water-uptake patterns; it assumes quasi-steady flow and accounts for the diurnal variations of plant-atmosphere resistance and evaporation in fine-tuning the design and in preliminary evaluation of scheduling scenarios. DIDAS was programmed in Delphi, runs on a PC under the Windows operating system, and requires no further software. The drip irrigation scenario is constructed via a few GUI windows, which contain also a library of the required soil input parameters, and a best-fitting procedure for determining them. The

computed RWURs and RWUVs are displayed graphically and the tabulated output results can be exported to, e.g., Microsoft Excel for further processing. An updated DIDAS version can be downloaded freely from https://app.agri.gov.il/didas. The present, second public release of DIDAS meets the major demands dictated by its development objectives. Recent developments include addition of new drip irrigation configurations, addition of a module for evaluating water uptake from drip irrigation in the presence of shallow groundwater, a module for soil salinity management and extension to sprinkler irrigation. 1450 people from 125 countries downloaded either the first or the second DIDAS versions 1.0.1 (and 1.1.1) from March 2014 through October 2018.

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Session X

Irrigation and Irrigation Technology (part 2)

Chaired by Anat Lowengart-Aycicegi

Aerating the subsurface by micro-nano-bubble infused irrigation water

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Long-term irrigation of clay soils with treated wastewater (TWW) has led to structural damage and periodic lack of oxygen in the root zone. A lysimeter study was conducted to promote oxygen availability in the root zone of TWW degraded clay soil through surface drip irrigation with nanobubbles (<200 nm in diameter) infused TWW. Nanobubbles have several unique properties such as long lifetime in liquid owing to its negatively charged surface, and its high gas solubility into the liquid due to its high internal pressure. Lettuce plants were irrigated for 40 days with oxygen nanobubbles infused TWW. Oxygen-nanobubbles significantly increased the dissolved oxygen concentration in the TWW (18 vs. ~8 mg L-1; P,0.05) and in the root zone of the irrigated plants (19.7 vs. 15.6 mg L^{-1}; P,0.05). Irrigation with nanobubbles infused TWW reduced N2O emission from the soil by almost 50% but did not affect N losses through deep leaching. Our results demonstrated that irrigation with nanobubbles infused TWW may be potentially effective tool for alleviating anaerobic conditions in clay soils degraded by prolonged irrigation with TWW while reducing N leakiness from agricultural activity.

Management practice can mitigate ill effect of treated wastewater on soil and tree sap flow

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Treated wastewater is an important source of irrigation water in water scarce areas world-wide. However, recent findings have shown significant ill effects of long term irrigation with treated wastewater on soil physico-chemical properties and plant response in clay soils. This study is being conducted to evaluate the effects of management practices on prevention and mitigation of damage to soil and avocado orchard after long-term irrigation with treated wastewater. Five treatments with six replications were applied: irrigation with treated wastewater (TWW), freshwater (FW), low-frequency irrigation with TWW (LFI), TWW mixed with FW in a 1:1 ratio (MIX), and tuff trenches irrigated with TWW (TUF). TUF trenches, 30 cm deep and 30 cm wide, about 30 cm away from the stem on both sides of the tree rows were dug and filled with volcanic tuff. Soil solution chemical properties and tree sap flow response were monitored on periodic and continual bases, respectively. Soil samples were collected to a depth of 90 cm (at 30 cm intervals) annually in the Autumn at the end of the irrigation season in all plots. Tree sap flow was monitored continuously with automated thermal dissipation probes (TDP) installed in 10 trees for each treatment. Soil solution analyses (1:2 soil:water extracts) showed that, compared with the TWW control, electrical conductivity (EC), sodium adsorption ratio (SAR), Na^+, K^+, and Cl^- concentrations were significantly lower in all treatments at 0-60 cm depth, whereas significant increase in Ca^{2+}, and Mg^{2+} occurred at a depth of 0-30 cm in FW. Use of FW significantly reduced EC and SAR compared with all treatments at all depths sampled. The seasonal and daily courses of sap flow were significantly higher in TUF, FW and MIX compared to control (TWW). The results observed are indications that FW, MIX and TUF enhance the leaching of sodium at different magnitudes leading

to reduced SAR that probably prevented and mitigated damage to soil structure. The leaching of salt from the top soil may have contributed to better availability of water for the avocado tree as revealed by the sap flow and other physiological attributes. Even though further analysis of soil physico-chemical changes and plant responses are ongoing, there is tangible evidence that FW, MIX and TUF are reliable candidate treatments for prevention and mitigation of TWW adverse effects on soil physico-chemical properties and trees response.

Salt crusting over evaporating soils - Three-Dimensional Insights

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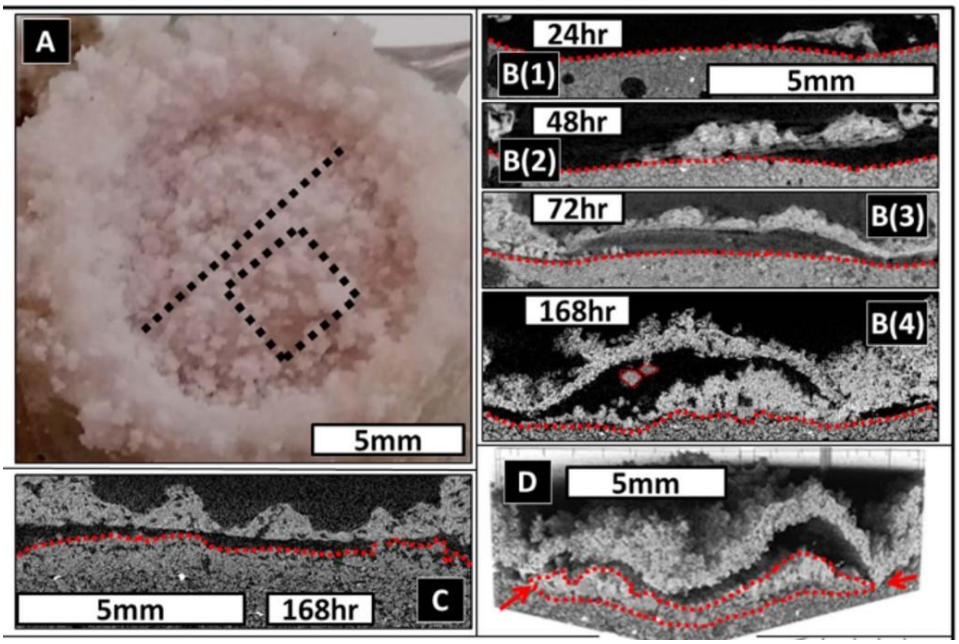
Department of Environmental Hydrology and Microbiology, Zuckerberg Institute for Water Research, The Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Israel

Salt precipitation over porous media due to evaporation is known to affect various important processes, including evaporation itself. Several studies have shown that salt crust precipitation reduces evaporation rate, and it has been explained by the fact that the crust constitutes a barrier to vapor flow. Nevertheless, it remains unclear how the salt crust - which is a porous medium, does not enable upward liquid water transfer by capillary flow. In this work, we show by various imaging methods that the salt crust grows out of specific nucleation centers, to generate an elevated crust approximately one mm above the soil surface, most of which is disconnected from the matrix. This indicates that evaporation from a porous medium that is covered by NaCl efflorescence salt crust may occur below the crust, at the soil surface.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Posters

(Alphabetic order of the first presenter)

Algal indicators Database in the quality of surface waters assessment

Sophia Barinova

Institute of Evolution, University of Haifa

Last years, we, in the Institute of Evolution, University of Haifa, are collected large references and own experience data about algal ecology that used for bioindication of water quality. These data were compiled in a database for indicator species from fresh and brackish aquatic habitats (Barinova and Fahima, 2017) Information about aquatic species ecology was collected from international guides, our own research during the last 40 years, as well as from monographs and electronic resources describing the ecology of diverse taxonomic groups of organisms. Most of the species represented in the database belong to algae and cyanobacteria taxa, but the ecology of some other aquatic organisms, such as higher plants, moss, and bacteria is also documented. Altogether, 8475 algal, cyanobacteria, plants, and other aquatic inhabitants from 36 taxonomical divisions are represented in the database. Ecological information is given according to 12 indication methods for the following parameters: confinement to the substrate, temperature, oxygen, and the mobility of the water mass, preferences to water pH, water salinity, saprobity according to Watanabe, saprobity according to Sládeček, saprobity index (SI) according to Sládeček, trophic states, nutrition types and several others. This comprehensive database is used for the water quality indication by algae in the rivers and other diverse water bodies in Israel and close region (Barinova, 2011). It can be used by a wide spectrum of ecologists for the purpose of aquatic ecosystem assessment and monitoring of water quality based on bioindication methods.

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Investigation of the role of operational dynamics on biochemical efficiency of a soil aquifer treatment system - A long-column experiment

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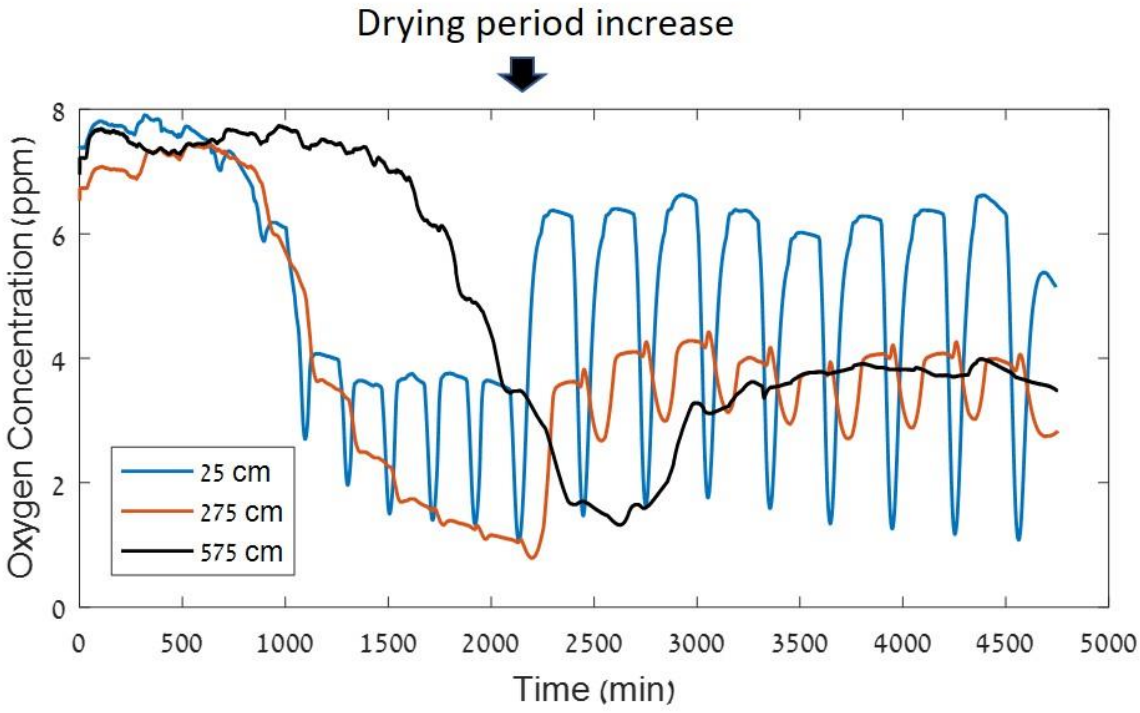
Soil Aquifer Treatment (SAT) systems are used around the world as tertiary treatment for waste water reclamation. In SAT systems, waste water are infiltrated through infiltration ponds into the aquifer, in cycles of flooding and drying. SAT systems are able to enhance water quality using natural traits of the soil environment (such as its microbial community, which plays an important role in organic compound degradation), combined with site-specific hydraulic operation. In the SHAFDAN site, treated waste water meet regulatory standards and are approved for unlimited irrigation. As population grows, the amount of waste water directed to SAT sites increases every year, causing a strain on existing sites that in some cases results in untreated water flown directly to the sea or local steams. The long-term existence and sustainability of SAT sites depends heavily on the ability to control the hydraulic operation in a way that maximizes infiltration while maintaining the highest possible reclaimed water quality. In this work, we present a series of column experiments, designed to examine the effect of different drying periods and influent composition on oxygen content and redox potential in a 6-meter sand column. Our experimental set up included four main experiments, in which three different influent solution-types were infiltrated through the column in varying cycles of wetting and drying. Water content, surface head, dissolved oxygen concentrations and redox potential

were continuously tracked using specific sensors. We hypothesize that the hydraulic operation of the column during the experiments (i.e. different wetting-drying ratios and durations) and the different influent composition will result in different bio-geo-chemical conditions in the soil profile. We expect the oxygen content and redox potential in the upper vadose zone to be greatly affected by the length of the drying periods and the deeper parts to be affected to a much lesser extent due to the limitations of advective oxygen - flow mechanisms. Our results confirm that the deeper parts of the column are indeed aerated less effectively during the drying periods compared to the upper parts, the oscillation patterns of the oxygen concentrations throughout the wetting-drying cycles indicate that advective fluxes are significant in almost all parts of the column and become increasingly more dominant as depth increases. The longer (240 minutes) drying periods had an advantage over the shorter (150 minutes) periods in terms of oxygen concentrations in the upper parts of the column as well as in the deeper parts. Chemical analysis confirmed that nitrogen species, as well as orgamic carbon were found in smaller concentrations in the experiment with longer drying times. In a subsequent experiment, drying periods were increased after several cycles of shorter periods (see figure), We found that upon the increase in drying times, oxygen concentrations increased immediately and dramatically in the upper part of the profile, while in the deeper parts it displayed a delayed, moderate yet significant response to the increase in drying periods, which is explained by our hypothesized oxygen delivery mechanism.



The data we gathered show that the duration of the drying periods is detrimental for the bio-geo-chemical state of the soil profile. Short drying periods might be beneficial for the aeration of the upper vadose zone but may not be substantial enough to allow oxygen recovery in the deeper parts and thus inflow quality will be compromised. The quick oxygen recovery after an increase in the drying periods suggests that combining short and long drying periods in the same infiltration campaign might be beneficial for both the amount of influent infiltrated and reclaimed water quality. To examine this, however, additional research is needed.

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Early warning detection of water contamination in the Kinneret watershed's streams using advanced spectral devices

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Streams and rivers are susceptible to various contaminations, such as, agricultural lands leachates (pesticides and fertilizers), cowsheds, chicken coops, fish ponds, and partially treated wastewater overflows. Hence, rapid detection of pollution events in Lake Kinneret watershed, may reduce, or even prevent health risks to water consumers and bathers, damage to ecosystems, and financial costs of treating the contaminated water.

This study examined the suitability of two innovative commercial UV/Vis spectrophotometers for online detection and warning of stream contamination in selected monitoring stations in Lake Kinneret watershed. The instruments measure the light absorbance of stream water in the UV/Vis range. The scope of the research project included field experiments for examination of the alarm parameters sensitivity and response time of each of the two instruments for varying concentrations of organic simulants (such as potassium hydrogen phthalate and ascorbic acid) and representative herbicides. The results of these experiments will allow the assimilation of in-situ submersed spectrophotometer measurements in an online warning system which is based on an innovative index that expresses the quality of the stream water at each monitoring station.

Field Crop Irrigation - Multi-Objective Optimization and Sensitivity to Weather Forecast Accuracy

Theodor Bughici, Eran Tas and Naftali Lazarovitch

The French Associates Institute for Agriculture and Biotechnology of Drylands, The Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Israel

Accurate irrigation and fertigation of field crops are crucial for maximizing crop yield while avoiding overuse of water and fertilizer. Irrigation management takes into account many plant and environment variables such as soil physical properties, root depth and salinity stress tolerance. In addition, the key environmental factor controlling crop development is the weather—i.e., precipitation and evapotranspiration (ET0). Numerical weather forecasts that can predict precipitation and ET0have advanced rapidly in recent years but are still far from perfect. Moreover, the definition of what is an accurate forecast for crop irrigation is still absent as the definition of adequate accuracy may vary between crops, irrigation regimes, seasons and climates. We used a case study of sprinkler irrigated spring potato in coastal Israel as a test case to define a minimal accuracy level of ET0 predictions for irrigation. First, by using a numerical model that simulates water flow, solute transport and root water and solute uptake (HYDRUS 1D) we ran a genetic algorithm (NSGAii) to optimize irrigation management based on multi annual mean ET0 with the objectives of minimizing excess solute and water leaching and maximizing yield. Next, we used the optimal irrigation management for simulating the spring irrigation season of 2016 to perform a Global sensitivity analysis. By modelling crop irrigation based on varying forecasted ET0 bias ranges as well as crop and soil parameters we were able to rank the parameters by contribution to crop-model output variance. This procedure of optimization and sensitivity analysis can be extended to a wide range of case studies and help define what is an adequate weather forecast accuracy suitable to base crop irrigation upon.

The Effect of Amyloid Fibers on E. *coli*-Clay interactions

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The fate of bacteria in the environment has a significant impact on soil fertility, quality and health. Clay minerals and oxides are key players in the physico-chemical interactions between bacteria and their environment and can impact their growth, activity and ability to form biofilm. Many have explored the role of bacterial membranes and extracellular materials in soil-bacteria interactions, however, to date and despite their prevalence in environmental biofilm, the role of microbial amyloids in bacterial adhesion to clay surfaces hasn't been properly addressed.

Microbial amyloid fibers are strong, insoluble membrane appendages, ranging from 0.1 to10 µm in length and 4–12 nm in width. Presented here is a systematic study on the effect of curli (amyloid fibers formed by E. *coli*) on bacteria-clay interactions. The aggregation and adsorption of the curli-producing bacteria to clay minerals was followed using zeta potential measurements, optical density measurements, fluorescent spectroscopy and electron microscopy. We found that curli production and biofilm formation were both enhanced when E. coli were grown in the presence of montmorillonite but not with kaolinite or iron oxides. In terms of interactions, bacteria aggregation and sedimentation tests (without clay) showed that curli-producing E. coli sedimented within hours as opposed to days for curli-deficient E. coli. In the presence of clays, large flocs were formed, and sedimentation time was reduced to minutes when curli was produced. The interactions of curli-producing E. *coli* alone and with clay did not follow the extended DLVO theory - sedimentation was fast even at low ionic strength and pH values. This was probably due to non-DLVO forces such as polymer bridging; the fibers effectively pierce through the energy barrier posed by the electrostatic forces.

The results of this study suggest that natural surfaces can enhance microbial curli production, enhance clay-bacteria interactions and consequently biofilm formation. These findings will help shed light on important microscale processes at the aqueous-solid soil interfaces, such as biofilm formation, nutrient-cycling, pollutant and pathogen fate in the environment.

Multi-phase Nitrogen tracking in plant, soil, drainage and gaseous emissions for evaluating Nitrogen use efficiency and loss mitigation in greenhouse experiment with enhanced efficiency eertilizers

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Nitrogen-based fertilizers are essential for coping with global changes and increasing food demand. In spite of their undoubtable importance, nitrogen losses and low recovery by the plant severely induce environmental pollution. Urea ($(NH_2)_2CO$), the most widely used N-fertilizer, dissolves rapidly and decomposes to $(NH_4)_2CO_3$ by enzymatic hydrolysis within 1-2 days. Such hydrolysis affects the soil chemical properties favoring high NH_3(g) emissions and toxic NO_2^- accumulation. Furthermore, high N-fertilizer loads relative to plant uptake capability result in NO_3^- leaching and N_2O(g) emissions. Enhanced Efficiency Fertilizers (EEFs) offer slow-pace and improved matching of nitrogen supply throughout the growing cycle, reducing losses and improving Nitrogen Use Efficiency (NUE).

The objective of this work was to evaluate the NUE of urea-based EEFs in comparison to common split application of granulated urea, at greenhouse scale. 2-months controlled release polymer coated urea (CRF-2M), 4-months controlled release polymer coated urea (CRF-4M), urea with a mixture of NPPT and NBPT Urease Inhibitors (UI) and regular granulated urea (UREA) were applied in a custom tables greenhouse experiment with basil speedlings planted in containers filled with sandy-loam soil. The regular urea and the urease inhibitors amended urea were surface split-applied in three portions during the experiment and the CRFs were applied pre-planting. Environmental and agricultural response was examined according to comprehensive multi-phase nitrogen sampling and

monitoring. The experiment included three growing cycles. At the end of each cycle, plants were harvested and weighted, and nitrogen content was analyzed. soil was sampled directly from the containers and drainage was collected via a special set up after leaching events. In both, Nitrogen species were analyzed (NH_4^+, NO_3^-, NO_2^-). Gaseous emissions (NH_3(g) and N_2O(g)) were collected into air sampling bags from, specially constructed, closed static gas accumulation chambers and analyzed in a laboratory FTIR spectrometer combined with Long Path IR gas cell.

UREA treatment had the lowest NUE and highest gaseous emissions. NH_3 emissions increased during the first days after fertilization and peaked to 10-30 times higher than the EEF treatments. The nitrogen released from CRF-4M was best matching plant uptake capability, leading to a 60% increase in fresh crop yield relative to UREA treatment, and about 20%-30% compared to CRF-2M and UI. Moreover, in the CRF-4M treatment nitrogen content in soil was kept lowest throughout the experiment, hence reducing N losses via drainage and gaseous emissions. The NUE of CRF-4M (based on shoot N-uptake) was 45.5%, representing an increase of 50% in comparison to UREA. CRF-2M and UI also performed better than UREA, increasing NUE by 7% and 30%, respectively. Although improving NUE and yields, N loses were measured in those treatments, including nitrite accumulation, gaseous emissions and leached nitrogen. According to the release pattern of CRF-2M, 20%-30% of the nitrogen was released during the first two weeks, corresponding to the losses measured especially at the first month of the experiment. The UI treatment mitigated the NH_3 and N_2O emissions and retained the nitrogen available within the soil, and consequently enhanced nitrogen leaching.

The experiment approved the known disadvantages of the regular urea surface application commonly used in cropping systems, and approved EEFs potential to reduce environmental impact along with improving agricultural and economic benefits. A preliminary larger scale greenhouse experiment was conducted in order to combine Open-Path FTIR system for on-line and continuous measurement of gaseous emissions.

The Open-Path FTIR system provided significant evidence to the EEFs in reducing NH_3 emissions. The Greenhouse scale experiment can provide a more realistic and improved mass-balancing tool of N resources (inputs, outputs and losses) for evaluating further

EEFs at different soil types, climate conditions and agricultural crops, and thus improving NUE in various systems.

Effect of irrigation with aquaculture drainage water on hydraulic properties of Arava soils along 3 growing cycles of Basil

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Aquaculture has expanded over the years to keep up with an ever-increasing food and nutrition demands from the growing world population. Consequently , huge drainage water volumes containing concentrated dissolved organic and inorganic compounds are discharged from the culture ponds. Parallely, the increasing demand for finite water resources in agricultural production presents a challenge to sustainable global food security. In this study, the temporal dynamics in hydraulic properties of two local agricultural soils in the Arava Valley of Israel, as well as biomass production and nutrient contents in basil, were investigated following regular irrigation with effluent from Barramundi fish Aquaculture (AC) in comparison with Tap Water (TW) mixed with commercial fertilizer. A system comprised of drainage lysimeters was designed for measuring drainage rate and Evapotranspiration. Near-saturated hydraulic conductivity under a tension of -6 cm of water (K-6) was measured by tension infiltrometer, soil water retention curve (SWRC) was determined from the hanging water column method and post-season evaporation rate was determined with TDR probes. Results showed that irrigation with AC effluent reduced K-6 of the sandy soil by 0.6 from initial conductivity and TW irrigated soil. On the other hand, in the loamy sandy soil K-6 was 4 times higher after 3 growing cycles than irrigation with TW. Interestingly, SWRC indices of Arava sandy soil irrigated with AC water quality were improved compared to soils irrigated with TW. Similarly, rates of deep percolation and evaporation in lysimeters irrigated with AC drainage water was higher than the measured rates in TW. In both soils, water quality did not affect fresh and dry biomass. The research results indicate that irrigation with an

organic nutrient-rich AC drainage water can improve the hydraulic behaviour of Arava soil. Thus, application of AC drainage water for agricultural practices in the region has the potential to increase water use efficiency.

Monitoring of pasture net primary production and water stress using remote sensing in a holm oak savanna rangeland

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Dehesas are Mediterranean oak savanna woodlands, which provide important ecosystem services such as the prevention of forest fires, the protection of soils or the conservation of key habitats for biodiversity. The management of these large areas (more than 3 million ha in the Iberian Peninsula) requires effective tools providing regular and accurate data to assist decision-making at different levels. The information at regional scales and aggregated time-steps (season/year), may be used to support planning decisions, such as the designing of agrarian policy instruments, or environmental and rural development aids. Local information at field level and at higher frequencies (week/month) is needed to assist farmers' management decisions to minimize livestock feed costs in extensive grazing systems and prevent overexploitation. Similar data sources and model schemes can be used to meet the requirements of these applications when considering the heterogeneity in time and space of factors affecting grasslands production.

This work has addressed the estimation of net primary production (NPP) of oak savanna grasslands using an adaptation of the Light Use Efficiency (LUE) model proposed by Monteith (1972), and the analysis of factors limiting this production. At regional scale, the model has been applied using MODIS data (MOD09Q1 product) to calculate the fraction of absorbed photosynthetically active radiation (APAR). This is combined with interpolated meteorological data to obtain NPP estimations, validated with field biomass measurements from the years 2014 and 2015. This is a water-controlled ecosystem, with its productivity directly dependent on water availability. For that reason, at a local scale, two approaches have been tested to account for its impact on primary production using

Sentinel-2 images: i) reducing the LUE as a function of vapor pressure deficit and minimum daily temperature (Running et al. 2000) and, ii) using a water stress coefficient, the ratio of real to reference evapotranspiration (ET/ETr), as limiting factor. At both scales, multiple applications have been dealt with: the spatial and temporal interpolation of meteorological variables; the presence of a tree layer as part of the ecosystem that contributes to the spectral response and needs to be accounted for and subtracted accordingly; the estimation of the fraction of photosynthetically active radiation absorbed by the pasture (fPAR) using different satellite sensors; and the empirical estimation of the light use efficiency for natural grasslands using biomass field measurements.

The results show that the general approach produces admissible errors, around 13% and 16% at regional and field scale respectively, supporting its use as a multi-purpose tool to monitor pastures. The method proposed to remove the contribution of oak trees appeared to be useful under the conditions of the area studied. However, the density of trees of these areas was low (<50%) so the performance of this approach over areas with higher coverage of trees or scrub requires further examination. On the other hand, the light use efficiency parameter also requires more attention: aspects such as considering the influence of soil properties and the evaluation of the model in extreme situations of high and low production should be addressed in the future to reduce current errors.

At the local scale, both water stress parametrizations have been validated using gross primary production measurements obtained with an eddy covariance tower during 2017 and 2018. The model fit well with the observations for both approaches ($r>0.8$ y $p<0.001$), with a better correlation at the daily scale using the water stress coefficient and the opposite result when using aggregating time scales.

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The role of nitrogen in photosynthetic acclimation to elevated [CO_2] in tomatoes

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Background

Although elevated [CO_2] causes an increase of photosynthesis in the short-term, this increase is often attenuated over time due to decreased photosynthetic capacity of the leaf in a process called photosynthetic acclimation to elevated CO_2 (PAC). PAC is often accompanied by N deficiency and sink:source imbalance. The aim of this study is to investigate mechanisms that lead to PAC, N deficiency and sink:source imbalance in tomato plants grown in elevated [CO_2] and how they are affected by different levels of N treatments.

Methods

Two long-term experiment and two short-term experiments were conducted in which tomato plants were grown in chambers with ambient [CO_2] and elevated [CO_2] combined with different levels of N nutrition. The following parameters were measured: 1) Biomass 2)Leaf N, P and K concentrations, 3) leaf NO_3^- concentration, 4) Gas exchange 5) Rubisco expression and 6) Leaf starch concentration.

Results

Plants grown at e[CO_2] had increased biomass and starch, and decreased gas exchange, stomatal conductivity, Rubisco expression, Vcmax, NPK and leaf NO_3^- Increasing N fertilization counteracted many of the effects of elevated [CO_2].

Conclusions

PAC was caused by decreased N uptake or transport coupled with increased growth which leads to N deficiency and a sink:source imbalance. Increased N fertilization counteracted the effect of e[CO_2] on photosynthesis, N status, and sink:source imbalance. Furthermore, elevated [CO_2] caused stomata to partially close, which accounted for some of the PAC observed.

Effects of variable fetch and footprint on surface renewal measurements of sensible and latent heat fluxes in cotton

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Understanding crop evapotranspiration (ET) is important for efficient irrigation management. The eddy covariance (EC) technique is useful in measuring whole canopy latent heat flux from field crops. However, it requires expensive equipment and complex data analysis; hence, is relevant for research only. With the aim of developing a low-cost and simple method, we investigated here the surface-renewal (SR) method. This method estimates sensible heat flux from high frequency temperature measurements by using a fine wire thermocouple (TC). Next, latent heat flux is derived from the energy balance closure. Since fine wire thermocouple measurements of air temperature can be performed near the canopy top, it was hypothesized (Castellví, 2012) that fetch requirements can be relaxed relatively to those for EC, and a relatively small fetch is sufficient for reliable flux measurements by SR. In the present study, the SR technique was examined in a cotton field in southern Israel. Seven fine wire thermocouples were installed at various distances from field edges and at different heights above the ground, providing variable fetch from 50 to 200 m, depending on field geometry and wind direction. An EC system was installed within the field at a position that provided sufficient fetch (400 m) for reliable reference values of sensible and latent heat fluxes. Excellent energy balance closure of 0.96 (R2 = 0.95) was obtained from a non-continuous period of 31 days of measurements. SR data from fine-wire thermocouples at all heights were classified by either available fetch or by 90% flux footprint. Only cases in which footprint was smaller than the available fetch were included in the analysis. Two footprint models were examined, KJ (Kljun et al., 2015) and HS (Hsieh et al., 2000). Results of fetch classification showed that the SR weighting factor varied between 0.67 and 1.34 and was independent of fetch. Footprint classification provided weighting factors between 0.46

and 1.18 for the KJ model and between 0.8 and 1.26 for the HS model. LE derived from SR sensible heat flux and energy balance closure, was regressed against LE reference values measured by the eddy covariance. Results showed deviations of up to 15% and 30% between SR and EC, for the KJ and HS model data, respectively. We conclude that in the cotton field under study the SR technique was reliable in estimating sensible and latent heat fluxes and the weighting factor was essentially independent of the geometrical fetch and the flux footprint of the sensors.

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Hyperspectral monitoring of salt sensitivity in grafted tomatoes

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Water salinity is a widespread agricultural hazard that affects approximately 20% of irrigated land, causing a significant yield reduction in agricultural crops. Stress coping mechanisms by plants have been examined thoroughly, but real understanding of the plant adaptation and acclimation is still lacking and is specific for different species and even varieties within species. Hence, there is a worldwide demand for agro-techniques or breeding solutions to enhance crop productivity. Tomato (Solanum lycopersicum L.) is one of the world's major fruit and is a moderately salt tolerant plant which is typically cultivated in salinization exposed environments. The most accurate methods nowadays to assess plants state of stress are physiological measurements that many times may be costly, intrusive and time consuming. An alternative emerging method for plant stress detection is spectroscopy, which has demonstrated potential in ability to monitor and predict physiological state of plants under stress. The objective of this work is to build a spectral-based model that will detect plants under salt stress in order to optimise plant-status monitoring in a non-destructive manner. In this study, five different tomato graft combinations were examined under four different saline treatments in greenhouse conditions. Hyper-spectral measurements were conducted in the range of 400-2500 nm, and chemometrics were used for data analysis. Salt treatments were found to affect the morphological and physiological performance of plants, although environmental conditions had an influence on the temporal trends. Chemometric models that are independent of the environmental conditions were the main findings of this study for the prediction of salt accumulation in plants in order to monitor stress with spectral data acquisition. Accuracy of the established partial least squares prediction models varied according to the diversity of the samples (leaf location, temporal changes). Hyper-spectral

decision-supporting classification model was established for detection of plants under salt stress.

A novel inflation method for Ensemble Kalman filter-based data assimilation in a crop model used for irrigation scheduling

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To improve the accuracy of crop growth estimation, field measurements are assimilated into crop simulation models with data assimilation algorithms. Data assimilation can improve the estimations of state variables. Among the most popular algorithms are Kalman filter and its extension to Monte Carlo algorithm, including Ensemble Kalman filer (EnKF). Small ensemble size can cause underestimation of the ensemble covariance. One way to alleviate this phenomenon is so-called covariance inflation. Covariance inflation is conducted by multiplying the ensemble members by a factor to increase the state covariance. Various methods of inflation have been used. One way is multiplying the ensemble by a pre-determined constant factor. Other methods are determining the inflation factor by treating this factor as an additional state variable and using data assimilation algorithms such as Kalman filter. However, this approach relies on some assumptions which in practice are not satisfied. In this work we present a novel way of estimating the inflation factor based on confidence interval. This method does not rely on any strongly restrictive assumptions and does not include any tuning parameters. The method was tested successfully with an example of water infiltration in a three-layer soil.

In situ geo-electrical measurements to estimate water content in agricultural contexts

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Water is the most valuable resource for any living organism on Earth and understanding the complex water system and the interaction between water and its environment is vital in order to manage that resource in a viable way. Understanding and managing plant water uptake is essential in precision agriculture. An accurate estimation of the in-situ water content in agricultural context is vital for sustainable food production. Traditional hydrological methods involve point scale water and soil sampling that are time, labor and money consuming. Another widespread method is time domain reflectometry (TDR) that allows measuring time-lapse water content variations through the estimation of the dielectric permittivity of the medium. Nevertheless, TDR measurements are still point measurements. Geophysical methods, such as electrical resistivity tomography (ERT) and electromagnetic (EM) methods, represent an interesting alternative to estimate water content in agricultural context. I present two examples of applications of the geophysical methods that show the potential of the geophysical method to estimate water content contrasts. In the first example, a new medium frequency electromagnetic instrument is used to estimate soil water content contrasts in the first meter of soil and thus estimate the plant water uptake of crops in a clayey soil. The second example shows the application of ERT on estimating water content contrasts in a date palm tree trunk. This new method can be particularly interesting because it allows to image the 3D water contrast over the entire tree trunk, help understand the palm tree water uptake and thus design appropriate irrigation schemes.

Nitrogen fertilization of plants in the desalinated-water era - A study of interactions of nitrogen with chloride

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The growing demand for fresh water led to increase in desalination of saline water. Chloride (Cl) is a dominant anion in natural water in arid areas and it is a major limiting factor for plants biomass and yield production. Several past investigations suggested that the chloride (Cl) ion competes with nitrate uptake by plants, therefore high application of N fertilizer is required to reduce Cl uptake by plants and to ensure high yields.

We assumed that the required N concentration for highest yield is lower in desalinated water than in natural water containing high Cl concentration; which in turn will decrease Cl and nitrate downward leaching below the root zone. To study this, the response of two different crops, lettuce and potato to a range of different concentrations of N and Cl concentrations were evaluated using a controlled irrigation lyzimeter growing system. Coarse sand was used as a growth media in lysimeters to allow high aeration and easy drainage of irrigating solution.

The yields of both crops increased with N up to optimal N concentration of the irrigating solution and decreased as the Cl concentration increased. N uptake by potato and lettuce increased significantly with increased N concentration in irrigating solution and the highest uptake was at low Cl. Cl concentration in plant tissues increased with increase in the chloride concentration of the irrigation solution. N fertilization significantly suppressed Cl accumulation in plant tissues, however it did not compensate for the negative effects of increasing Cl. Drainage N and Cl increased with increase in their

concentration in the irrigating solution and N fertilization above optimal N point resulted in steep rise in N concentration and total mass in the drainage. The evapotranspiration of potato decreased in the highest Cl treatments, whereas no significant effect was found in lettuce in the studied range of Cl concentrations. Therefore, the volume of drainage and amount of leached nitrogen and chloride in the potato experiment increased with the solution Cl concentration. In contradiction to our hypothesis, optimal N concentrations in both crops were higher in the water with the lowest Cl concentrations.

Exploring the possibility of obtaining remotely sensed evapotranspiration and transpiration: performance of the two-source energy balance model in a vineyard

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Remote sensing of evapotranspiration (ET) and partitioning into transpiration (T) and soil water evaporation (E), has the potential to help determine irrigation requirements based on water status across large surface areas. Estimation of T in addition to ET gives insight into irrigation efficiency as well as plant growth and associated carbon exchange. The two source energy balance (TSEB) model estimates ET from remotely sensed surface temperature based on separate energy balances for canopy and soil. However, while ET estimates have been successfully validated over a variety of crop types, the partitioning into E and T has not been fully assessed. This study evaluates TSEB for independent E and T estimates in an isolated drip-irrigated wine vineyard in the arid Negev desert. A canopy temperature adjustment is proposed to better account for the vertical structure of vineyard canopies. Modeled soil heat flux was poorly correlated with measured values. However, with adjusted canopy temperatures and measured soil heat flux, T and ET were within 11% of measured values. Model capability to detect plant stress was also evaluated.

Degradation and Reclamation: A simplified model for salinity and sodicity

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Soil salinity and sodicity present major challenges to agriculture, affecting soil conditions and plant growth. These concerns are especially high in arid and semi-arid areas. Existing models of salinity and sodicity are primarily numerical and often require lengthy calculations. This obscures analysis of interactions between variables and the model's output. Our model introduces a simplified system of reduced dimensions. This allows for more extensive exploration of the parameter space and clearer understanding of the results. Our minimalistic model considers salinity (electrolyte concentration) and sodicity (exchangeable sodium fraction) in the root zone, explicitly considering variations in soil water content resulting from irrigation and seasonal stochastic rainfall. The system considers feedbacks between all three state variables, including the effects of changes in salinity and sodicity on the hydraulic properties of the soil. Whereas existing models consider changes in soil hydraulic conductivity resulting from input water salinity and sodicity to be a reversible process, we explicitly consider the potential for hysteresis. Our model compares well to both experimental work and field observations. We use the tools of dynamical systems to explore the model. Preliminary analysis considers how steady-state salinity and sodicity levels are linked to irrigation water quality and seasonal rainfall patterns. Changes in soil water content move on a comparatively fast time scale, with changes in soil sodicity moving slower than those in salinity. We examine how changes in rainfall (intensity and number of events) affect statistical steady state values over long-term periods. More frequent rain events contribute to a reduction in soil salinity, but high intensity rain followed by longer dry periods has the potential to exacerbate problems with soil degradation. Our results can inform decisions regarding sustainable irrigation practices.

Understanding the role of herbaceous vegetation cover on soil structure in vineyards

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The increasing demand for food production in a world challenged by exponential population growth and unstable soil management has led to soil health degradation. This soil degradation implies a biological simplification with a loss in biodiversity, which in turn weakens the ability to sustain ecosystem services, such as nutrient recycling, pest regulation and local hydrological processes. Thus, agricultural systems have become more vulnerable and subsequently require constant human interventions, at a high cost. This is due to a reduction of basic regulating functional components, which reduces the capacity of the ecosystem to support its own needs. Another tendency of modern agriculture is to maintain bare soils in order to avoid potential competition with the local flora on shared resources required. . Such soil management decreases soil cover thus increasing its vulnerability to degradation processes. Additionally, this affects soil structure that plays a key role in soil health and function by creating conditions above and below the ground that allows retention and transmission of fluids and substances throughout the soil profile.

Grape (*Vitis vinifera*) is an important cultural, economic and ecological cultivar in the Mediterranean basin, but also a cosmopolitan crop with the largest acreage and the highest economic value among fruit crops globally. However, viticulture (grape production) results in one of the most erosion-prone land uses, due to common practices of leaving unprotected bare soils for a substantial part of the year, cultivation on steep slopes, and vineyard site preparation activities. Cover crops provide an alternative soil management, which was developed in order to overcome the negative outcomes of conventional

practices in vineyards. In Israel, due to Kosher regulations, it is forbidden to plant agricultural cover crops in vineyard. The only possible alternative practice is to allow the establishment of native vegetation in the vineyard. This religious restriction allows us to investigate a new practice that has not yet been studied. Most research that has been conducted so far on cover crops focused on the influence of a single or a mixture of a few cultivated species in short term trials.

The aim of the present study is to understand the effects of soil cover with native herbaceous vegetation (1) on water stable aggregates (WSA) and (2) on soil pore distribution (SPD); (3) to estimate the effects of shallow tillage and (4) herbicide application on WSA and on SPD. The study was conducted in three different commercial vineyards in the upper Galilee, representing two different types of vineyard management; (1) vineyards managed under conservation agriculture practice [certified organic (O) vineyard and sustainable agriculture vineyard management (SA)] and (2) the conventional vineyard management(C) .

Our results showed reduction tendency in soil structure stability due to differences in soil surface management by the treatments. In most cases, the slacking test results showed a decline trend in WSA percentage between plots covered with herbaceous vegetation (N) compared to those which were treated with shallow tillage (T) or herbicide application (S). Until now, there is no significant difference between T and S treatment effects on WSA. The only significant difference between the treatments was seen in the 12 year-old Organic site (O12), where 80% of aggregates were larger than 2mm under treatment N, while only 48% of aggregates were larger than 2mm under treatment T. SA10 showed the highest percentage of WSA >2mm (83.5). Duration time of cover crop management had a significant effect on WAS, where the older site (> 10 years) having herbaceous vegetation management had significantly higher percentage of WSA (71.8%+) than younger site with herbaceous vegetation (58.6%) or without herbaceous vegetation site (28.4%). There is also decreasing trend in dissolved organic carbon (DOC) when comparing between plots with N, T and S management, resulting in significant differences between treatments, and the following results: O13 (N – 0.26mg/gr soil T – 0.16 mg/gr soil), O12(N – 0.23mg/gr soil T – 0.17 mg/gr soil) and SA10 (N – 0.37mg/gr soil T – 0.24 mg/gr soil, S – 0.27mg/gr soil). S. O13 had the highest species richness (SR)

(8.97 species) and highest species diversity (SD), as measured by the Shannon Index (1.38), while SR showed SA11 (3.39 species) and SA10 had the lowest SD (0.62).

To conclude, reduction in soil cover weakens the soil structure stability by reducing the herbaceous vegetation root activity, which promotes stabilization and modification of the soil structure. This is accompanied by a decrease in soil organic matter, affecting multiple roles in soil structure functioning. Therefore, this research demonstrates that the presence of herbaceous vegetation cover helps to sustain soil structure and prevent soil degradation on erosion prone lands.

Row orientation affects the momentum flux in wine grapevines

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The momentum flux affects the energy exchange processes and thus may indirectly affect the water balance of agricultural fields. In wine vineyards, a high momentum flux between the vine rows may augment the evaporation and transpiration fluxes, and therefore decrease the water use efficiency. On the other hand, at night, high momentum fluxes may reduce (or even prevent) the formation of dew on the vine canopy, thus decrease the potential development of fungi and related diseases. We hypothesized that the wind direction relative to the row orientation in largely-spaced narrow hedge-rows characterizing wine vineyards greatly affects the momentum flux. This, in turn affects the vineyard microclimate, and ultimately, the grape quality. The objective of our research was to assess the effect of row orientation on the momentum fluxes in wine grapevines.

The research was conducted in two adjacent vineyards in the Judean foothills in Israel (31°48'38.6"N 34°50'43.6"E and 31°48'37.1"N 34°50'24.0"E) having row orientations of NE-SW and SE-NW, respectively. With a NW prevailing wind direction, the wind is typically flowing perpendicularly to the former and in parallel to the latter vineyards. In each vineyard, 10 self-made type -T fine-wire thermocouples (0.08 mm diameter) were set on a pole places in the middle of the inter row, at heights above the ground of 5, 10, 20, 40, 80, 140, 220, 250, 300, and 400 cm. In addition, 4 fast-response 2D sonic anemometers (ATMOS 22, METER group, Inc. Washington, USA) were set at 10, 40, 140, and 250 cm above the ground. The measurements were conducted at 20 Hz, using a high-frequency data-logger (CR6, Campbell Scientific) connected to a high-frequency multiplexer (AM25T, Campbell Scientific). Power-spectra analysis revealed significant differences in the size of eddies penetrating the two vineyards, and a different structure of wind and temperature profiles. The co-spectra analysis indicates a significant difference in sensible heat flux between the two vineyards. This implies that there is a

potential difference between the vineyards in the latent heat flux, and thus in the vineyards water use efficiency.

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eGreenhouse: a mobile sensor package for real-time greenhouse monitoring

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Increased demand for precision agriculture is reflected by a global rise in greenhouse food production. To maximize crop efficiency and yield, commercial greenhouses require live monitoring of growth conditions. Recent advances in open-source hardware allow for environmental sensing with the potential to rival lab-grade equipment at a fraction of the cost. This study introduces a high-resolution sensor package that costs less than $300. Consisting of microcontrollers and small open-source hardware, the sensor package can be deployed on the HyperRail, a modular conveyance system developed in Oregon State University's OPEnS Lab. The system can then provide data from multiple sensing locations at the cost of a single package. Sensor data, including CO_2, temperature, relative humidity, luminosity and dust/pollen, is saved to a microSD card as the HyperRail-mounted package travels throughout the greenhouse. A wireless nRF connection to a network hub allows the broadcast of a live stream of environmental conditions online. CO_2 monitoring efforts are especially relevant to greenhouse management as artificially elevated levels can significantly increase plant growth. Results from calibration in the lab show that the K30 CO_2 sensor (85$) can be calibrated to be accurate within <10 ppm of industry standard equipment costing thousands of dollars. Our sensor package's instructions, code, wiring, and 3D-printed enclosures are openly-published on the web (GitHub).

Numerical modelling of nitrogen transformation and transport response to dynamic environment in capillary fringe

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Nitrogen widely exists in domestic wastewater and has been a serious contamination problem in the world. The surplus nitrogen can percolate toward groundwater, affect the water quality and threaten public health. Capillary fringe is considered as the last barrier to protect groundwater from being contaminated due to the complex redox environment. Thus, research related to nitrogen transformation and transport in capillary fringe is increasingly significantly. The aim of this paper is to establish a mathematical model to study nitrogen accumulation, transformation and leaching when treated wastewater across capillary fringe in different discharge frequencies.

In the model, water flow, solute transport, biochemical reaction, gas flow and adsorption are considered. The water flow is governed by the Richards equation. Multiple solute transport is modelled by the advection-dispersion equation, involving biochemical reaction, gas transfer and adsorption (where applicable) as the sink/source items. Biochemical reactions are solved by Multiple-Monod kinetics reactions, considering suppressing and supporting environmental conditions. The gas flow is described by advection-diffusion equation, considering Henry's equilibrium law to address the equilibrium between aqueous and gas phases. The linear kinetic adsorption model is considered for ammonium adsorption.

The results show that the ammonium and nitrate concentration show different fluctuation trends from 0.2 to 5 times/day discharge frequencies due to the distinct alternative aerobic and anaerobic environment. Nitrate and dinitrogen gas transformation rates present relatively increase trend with treated water discharge frequencies. Ammonium and nitrate

leaching rates generally show decrease trend with water discharge frequencies. The research can be a theoretical method to instruct treated wastewater discharge in practice.

Optimizing fertilizer management for improved pomegranate productivity and quality

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Pomegranate has been grown as an orchard crop for thousands of years and has a long history in the mythology of many cultures. Pomegranate juice currently is receiving commercial popularity because of its human health benefits. Pomegranate fruit has been found to contain bioactive components and to be a potent anticancer agent. The increased demand for pomegranate drove efforts increase commercial orchard fruit yield. However, previous studies focused more on variety selection or post-harvest, and there has been little research concerning improvement of fruit yield and quality by optimal fertilization management. The aim of the current study was to evaluate the response of pomegranate yield and fruit/juice quality to different application levels of nitrogen (N), phosphorus (P) and potassium (K).

The experiment was located at the Gilat Research Center, Negev, Israel. Two-year-old pomegranate (cv. Wonderful and cv. Emek) seedlings were planted on July 2015 in 500-L containers filled with perlite growing media. Pomegranate trees were irrigated excessively via a drip system with different levels of N (5 to 200 mg L^{-1}), P (1 to 20 mg L^{-1}) and K (20 to 200 mg L^{-1}) concentrations in nutrient solution.

In general, pomegranate growth was more sensitive to nitrogen concentration changes in the irrigation solution compared with phosphorus and potassium. In the first harvest year 2017, Wonderful had significant lower yield in N and P deficient treatments, and its yield was also reduced when N was oversupplied. Tree scale productivity of Emek was relatively low compared with Wonderful, and its yield was decreased at high K treatment. Yield responses to the different nutrient applications in 2018 were same as in 2017, but average yields were tremendously increased. The average yield of Wonderful and Emek in 2018 was enhanced by 118% (36.5 to 79.4 kg $tree^{-1}$) and 53% (22.7 to 34.8 kg $tree^{-1}$) compared to 2017, respectively.

Pomegranate fruit weight and size, quantity of fruits, and number of arils all decreased significantly in low nitrogen application treatments. Nitrogen deficiency had more effect on aril number than on aril size. Aril color was lighter when nitrogen treatment was low. Decay inside the fruit decreased with reduced N but peel sunburn increased. Nitrogen deficiency significantly decreased the total soluble solids in the pomegranate juice, but no effect was measured on titratable acid or the ratio between these two parameters. Different N application levels did not have any influence on anthocyanins in juice. Both total phenols and flavonoids in juice were enhanced by N-deficiency.

A similar response was found in P treatments. Phosphorus deficiency lowered weight and quantity of fruit and arils per fruit in both varieties. The acid concentration of Emek and total soluble solids of Wonderful juice were also reduced under low P. In contrast, different K application levels had no significant influence on fruit and juice quality parameters, except aril quantity and total weight in each fruit. Higher K application decreased the total weight of arils by reducing their number per fruit in both varieties.

The result showed that appropriate fertigation management (moderate N and P, low K), not only increased the productivity of pomegranate fruit (up to 97.34 kg tree^{-1} in 2018), but also improved the fruit and juice quality (less proportion of decayed fruits and higher concentration of antioxidant compounds), and therefore enhanced benefits for both growers and customers.

Disinfected (chlorinated) water: what affects the correlations between formation of byproducts and organic matter descriptors?

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Disinfected water is not necessarily freely recommended for any application, including, for example, irrigation, use in hydroponics farms or any agricultural recirculating/reusing systems intended to address water shortage. It is because natural organic matter (OM) present in source water acts often as a precursor for the further formation of toxic disinfection byproducts (DBPs). Depending on water source, DBPs may appear during various disinfection treatments but distinctly it has a potential to occur upon water chlorination. Owing to the unique UV absorbance and fluorescence properties of OM, the concentrations of newly formed DBPs are correlated frequently with OM descriptors used as DBP predictors. These OM descriptors may include UV absorbance (or its derivative, specific UV absorbance, SUVA), fluorescence (examined by means of parallel factor analysis (PARAFAC), peak picking (PP), and regional integration (RI)), and organic carbon (OC) concentrations. Those correlations gained much attention due to the interest in understanding the formation of toxic DBPs in waters undergone chlorination and in the whole OM reactivity towards disinfection mechanism. This study was proposed to understand how the strengths of correlations between DBP concentrations and their predictors are affected by specific types of DBP, source water used for treatment, disinfection agents and type of DBP predictors. Total of 59 research studies covering the literature for the last two decades (1997-2018) reporting the correlations between DBP concentrations in chlorinated water and OM descriptors were collected. Set of 491 correlation coefficients describing variable associations between DBP concentrations and the predictors were converted to Z scores using variance-stabilizing Fisher transformation and analyzed by main effects ANOVA, both weighed and non-weighed. The statistical results indicated that the water type and DBP predictors are the most significant factors

affecting the strengths of correlations, followed by disinfection agents, whereas DBPs nature was relatively less important parameter, if at all. Among the water types, wastewater potentially rich in OM was associated with strongest correlations with DBP formation. UV absorbance and OC concentrations predominated as DBP predictors over SUVA and fluorescence, which highlights that non-fluorescent OM present in water has a high reactivity towards chlorination reactions and a potential to form DBPs. When considering fluorescence-based methods, RI and PARAFAC showed stronger correlations with DBP concentrations as compared to PP. The obtained results suggest that the scientific community should not overlook the role of non-fluorescent OM when evaluating the organic matter potential to produce toxic DBPs.

Fluorescent dissolved organic matter in leachates generated from flushing soil columns with water extracts of composts

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Dissolved organic matter (DOM), due to its high mobility and reactivity, is one of the most important factors controlling soil quality and management. DOM in soil originates from soil organic matter dissolution and leaching, decomposition of litter and plant residues and is also contributed by exogenous DOM as a result of treated wastewater irrigation and application of organic amendments (i.e., fresh or composted manure) to agricultural soils. Adding exogenous organic matter to soil may affect the concentration of DOM and its composition. A significant fraction of DOM is colored and absorbs light. Moreover, an important part of this colored DOM includes humic substances and proteinaceous material, which are capable of emitting light upon excitation, i.e. they are fluorescent. Fluorescence spectroscopy is considered as a fast, sensitive and non-destructive method to study DOM composition, without needing any complicated and time-consuming pre-treatment. Measuring emission spectra of DOM in a range of excitation wavelengths allows determining excitation-emission matrices (EEMs) which may be successfully analyzed with parallel factor analysis (PARAFAC). The outcome of this analysis is a chemically meaningful model that proposes a number of fluorescent components present in the studied DOM samples and allows estimating their fluorescencies and quantifying relative changes in their concentrations. Since composition of DOM, in general, and of the fluorescent fraction, in particular, have a recognized impact on DOM activity in soils, the EEM+PARAFAC analysis may help understanding DOM impact on multiple processes that occur in soils.

The composition of DOM in soil, especially in soils amended with exogenous organic matter, may change with depth, due to DOM leaching, fractionation and chemical/biological processes. Therefore, the main objectives of this research were to (i) characterize, by means of EEM+PARAFAC methodology, the changes in the composition of fluorescent DOM in leachates obtained from flushing soil columns with water enriched by compost-originating DOM, and (ii) compare the changes in the fluorescent components to those observed in attributes commonly used to characterize DOM (i.e., dissolved organic C [DOC] concentration, absorbance at 254 nm, Abs254).

We examined leaching with four types of DOM. Three DOM solutions were obtained from aqueous extraction of composts based on cattle and poultry manure ("Sde Eliyahu", SE) differing by composting duration (i.e., 1, 3 and 6 months). The fourth type of DOM was extracted from a compost made of human excretion mixed with pine sawdust ("Sherutei Compost", SC). Aqueous extracts of composts, containing variable concentrations of DOM (from 60 to 160 mg C/L) were then used as a flushing solution of saturated soil columns. Two Israeli soils with different textures (loess, 17% clay, and grumusol, 71% clay), sampled from a subsoil horizon (60-90 cm) containing low total organic C content (0.12% and 0.35%, respectively), were used. The leachates obtained by passing 4-6 pore volumes through the soil columns were filtered and analyzed for Abs254, DOC concentrations, electric conductivity, pH, and EEMs. Altogether, a total of 1450 EEMs were collected and modeled by PARAFAC.

PARAFAC modeling identified three dominant fluorescent components present in the analyzed samples. Components 1 and 2 represent two types of humic-like substances while component 3 demonstrated a tryptophan-like fluorescence that most probably is a proteinaceous component. Based on the fluorescence data, it was possible to monitor the dynamics in concentrations of fluorescent components and in their proportions thus revealing some quantitative and qualitative differences depending both on the DOM and soil types.

For example, DOM obtained from the SE compost led to significant changes in composition of humic-like substances in grumusol as compared with the soil-born DOM composition. However, specific composting duration, changing from one to 6 months,

had little impact on subsequent changes in soil DOM composition. When the loess was flushed with DOM obtained from the SC source, concentrations of DOM components increased, as compared with those in loess-born DOM; however, surprisingly, DOM composition (i.e., the relative fractions of the 3 components) changed little, if at all. While the fluorescent component concentrations in native loess-born DOM showed leaching trends similar to those of Abs254, the fluorescent components in leachates from the loess columns flushed with SE extracts showed trends opposite to those of the Abs254. In grumusol flushed either with water or SE extracts, the leaching of fluorescent components differed from those of both DOC and Abs254 . Thus, the results of our work suggest that the EEM-PARAFAC methodology is useful for better understanding of possible effects of compost extracts on soil DOM composition, which may be of significance for improved compost management and selection.

Validation of the protocol of the fumigation method for determining carbon and nitrogen in the microbial biomass of soils

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Microbial biomass (MB) in the soil is considered sensitive and useful indicator of the effects of human activity and environmental conditions on soil fertility. The widely used method for determining MB is the fumigation of chloroform-extraction (CFE). In which carbon and / or nitrogen content is measured in the water extraction of soil sample that has been fumigated with chloroform vapor (a process that destroys the cell wall and enables extraction of its contents), while deducting values obtained for a non-fumigated audit sample that reflects non cellulose extracts. The objectives of the study were 1. Quantification of residual chloroform levels in fumigated soils, in soils with different clay and soil organic matter (SOM) content. 2. Verification of the accuracy of the CFE method for MB under the influence of residual chloroform concentrations and examination of the effect of clay and SOM content in the soil on this effect. 3. Examination of the effect of soil moisture level on the chloroform residue and its relationship to the adsorption mechanism and the dissolution of the chloroform residue. 4. Quantification of residual chloroform levels along the soil profile of soils with different textures. For objectives 1 to 3, we used soil samples from a long-term study on the effects of compost dose on soil fertility and for objective 4 we used soil samples from soil profiles of non-cultivated soils from 3 sites from southern Israel (sandy soils) and 3 sites from northern Israel (clay soils). Microbial carbon and nitrogen as well as residual chloroform were determined using CFE. Main outcomes were: 1.Soil moisture in the CFE should be maintained at moisture content levels of ~ 30-50% of Water Holding Capacity (WHC). 2. High level of soil water content can be used without soil drying.3. Microbial carbon determined by the CFE

decreases exponentially with soil depth and there was no increase of the overestimation with depth. 4. Residual chloroform increased with SOM, but it was not affected by soil texture. Chloroform may contribute ~ 2.0% to over-estimate biomass (carbon) regardless of soil type or depth. The results strengthened the credibility of the CFE process for evaluation of MB in agricultural soils.

Site Specific nitrogen management in citrus orchard to minimize nitrogen pollution

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Permanent crops agriculture covers 1.2% of the global land area. Such agricultural land requires the addition of the essential nutrients (nitrogen (N), phosphorous (P) and potassium (K)) to the soil in order to sustain commercial viability. In the agricultural context, N is often regarded as the most critical nutrient, and the soil-related growth limiting factor. The relatively low cost of N fertilizers compared to the possible loss of crop yield has led to its over-application and increased losses of different N-forms into the environment. Nowadays, efforts are being directed toward: (1) optimizing and reducing N application rates, while maintaining crop productivity, and (2) enhance N use efficiency (NUE), thus decreasing N losses. Precision agriculture aims at sustainably optimizing the management of cultivated fields by addressing the spatial variability found in crops and their environment with Site-Specific Management (SSM). Therefore, the overall objective of the proposed project is to develop tree based optimal nitrogen (N) for SSM application to citrus orchard. Derived from this are the following sub-objectives: (1)Identify the spatial and temporal variability in N status across the orchard, (2) Correlate between the temporal (monthly) leaf N status, the "standard" leaf N status and the fruit yield per tree, (3) toping fertigation with tree-based application of controlled release N fertilizer to account for tree N status and needs and (4) correlate spatial and temporal variation pattern in N status to N leaching and NUE using remote sensing applications. There are several ways to estimate NUE including (a) yield produced per unit of fertilizer, (b) biomass production per unit of fertilizer, (c) biomass divided by amount of N absorbed

and (d) mass balance ratio between the N taken up by the plant and the applied N. Enhancement of the NUE can be achieved via knowledge of the optimal N nutrient uptake curve, and adjustment of the plant N nutrient status throughout the growing season to fit that curve. The research is conducted in four citrus plots at Kfar-Monash – Hefer Valley. These four plots, which include 270 trees, are fertigated by sprinklers. Analysis of the existing heterogeneity was used to choose 12 representative trees that were sampled at regular intervals. The data will be used to build a fertigation model, which will then be used to develop a site-specific fustigation strategy. The preliminary result shows N variance in soil (NO_3 0 - 8.84 mg/Kg DM, NH_4 0 - 5.57 mg/Kg DM) and leaves (1.91-3.25%) at each plot for the chosen trees' position. Thermal Image shows temperature differences which relate to variation in leaf temperatures and water uptake. The research has begun at November 18 and will focus in the first two years (2018-2020) on data gathering for the fertigation model to be built, while at the next two years (2020-2022) will focus on survey of fertigation making the needed adjustments.

Noninvasive measurements of plant roots using spectral induced polarization

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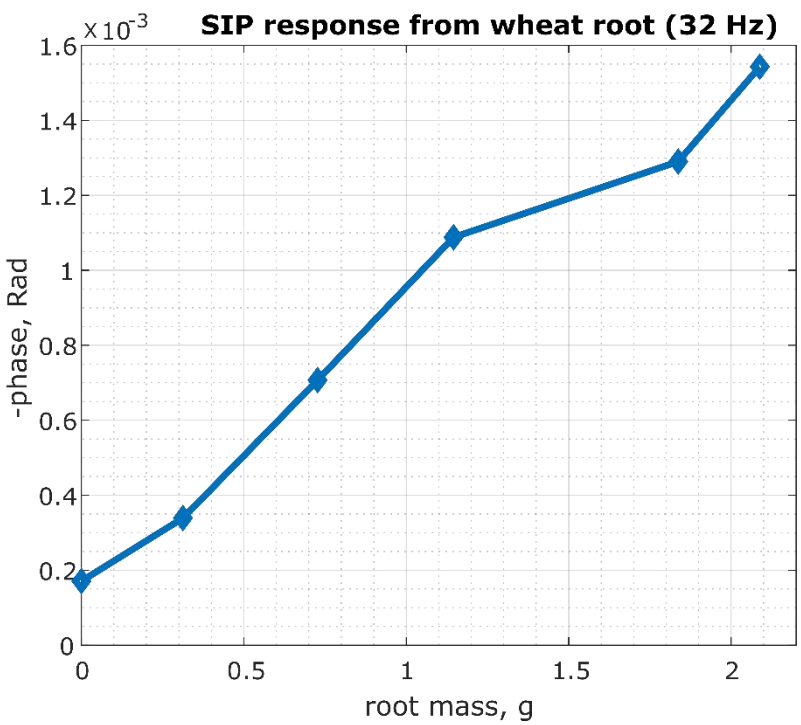
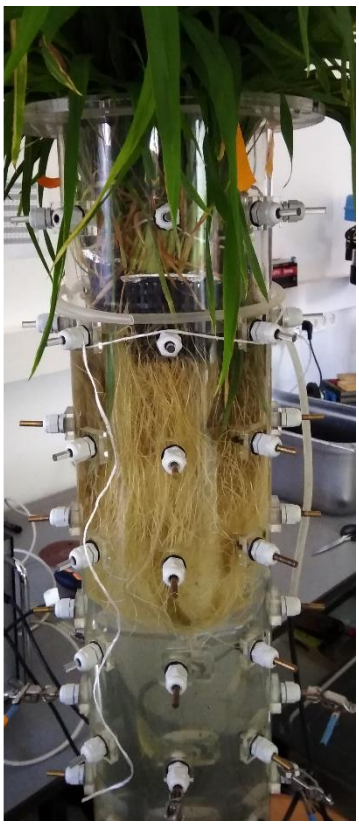
Exploration of root systems is challenging, as there is no direct access to the root. Recently, the spectral induced polarization (SIP) method is proposed to monitor roots in a noninvasive fashion. The SIP method is sensitive to polarization processes at relatively low-frequency range (mHz to kHz). To monitor roots, the relationship between root properties and its electrical signature needs to be established, and this is the main objective of this work.

We conducted a series of experiment to reveal the dependency between SIP signal and root's physical properties such as root mass, total surface area, etc. SIP response was measured for the different part of the root (from the beginning of the stem to the tip of the root) such that the distribution of the SIP signal along the root length was obtained. A linear relationship between root surface area and the magnitude of polarization was observed. A positive relationship between root biomass and polarization was also observed. In addition, and in order to shed light on the mechanism governing the SIP response of root, we conduct an experiment in which we add cyanide (Carbonylcyanide 3-chlorophenylhydrazone) to the growing medium. Following the addition of 2 mg/l of cyanide, a steep decrease in polarization was observed. The decrease in polarization is associated with the changes in root membrane potential caused by the cyanide.

To better understand the experimental results, we simulate single root polarization using the Poisson-Nernst-Planck equations in the frequency domain. Using the model, we demonstrated relationships between cell properties and cell polarization. We showed that the relaxation time increases with increasing cell diameter and that the polarization increases with increases of the cell membrane potential.

In accordance with the model, the decrease in the polarization of the root under the impact of cyanide supports the hypothesis that the cell membrane electrical double layer is the source of the plant root polarization. The relationships between the physical properties of plant root grown in hydroponics and SIP signal demonstrates the potential to phenotype plant roots using the SIP method.





Left: correlation between magnitude of polarization and root mass. Right: SIP measurement of wheat root.

A cheap, simple method for mapping available phosphorus in undisturbed soils

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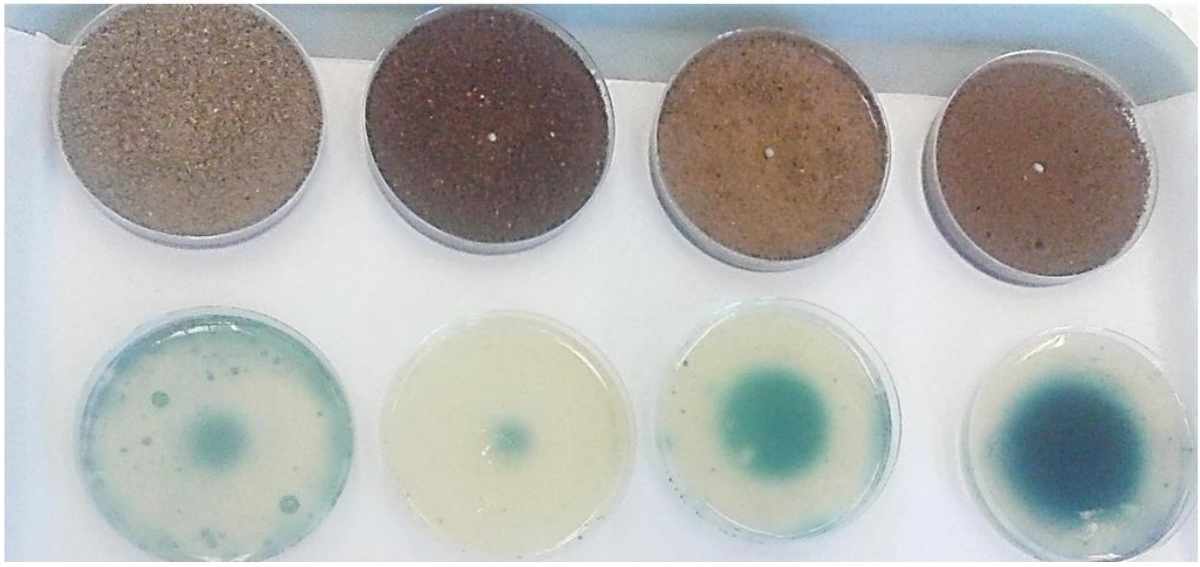
The low mobility of Phosphorus (P) in soils imposes a major constraint on the effectivity of P fertilizers. Investigations of P mobility in soils have commonly utilized column experiments, which represent the mobility of phosphorus in conditions of bulk flow. This may largely mask the diffusion-dependent movement of P, which is considered the dominant actual movement mechanisms towards roots in the soil environment. Methods used to investigate P diffusive movement in soils are either laborious (such as manual detailed separation of subsamples) or expensive (such as Energy-dispersive X-ray spectroscopy). In contrast, we propose a simple and cheap method to map the distribution of available-P in soil using agar gel and an ammonium-molybdate reagent for staining and mapping the labile P. To eliminate the extraction of non-labile P from the soil by the strongly acidic reagent, a two-step test is proposed here. The applicability of the method was demonstrated to compare P diffusion in diverse soils differing in texture and carbonate content. To this end, a series of petri dishes was prepared containing a thin layer of agar gel (2mm) over which a thin layer (2mm) of the tested soils was spread evenly and wetted so that no loose water was present. The series of dishes was incubated for either 1, 3, 5 or 7 days with a grain of mono-calcium phosphate fertilizer on top of the soil at the center of each dish. Following the incubation period, the soil was washed off and staining with ammonium-molybdate was performed. The blue staining showed visually distinct patterns around the previous location of the fertilizer. The radii of the stains differed in accord with the incubation time and soil properties (e.g., P adsorption capacity and pH) of the soil. Measuring the P concentration in representative agar subsamples by melting them enables P concentrations to be quantified according to the color intensity. Future prospects include using the method to map P distribution and

diffusion rates around plant roots and around novel P fertilizers. Method complications will be discussed.

Above, Soil incubated on an agar layer. a grain of mono-calcium phosphate fertilizer was applied at the center of each dish. Left to right: Rendzina (highly calcareous), Terra-rossa (high Fe-oxide), Aeolic Sand (medium calcite content), and Brown-Red Sand. Below, replicas of the agar layer after soil removal and P staining (blue area).



Lack of oxygen, the silent culprit behind the damage to treated wastewater irrigated orchards planted in clay soils – evidence and soil management solutions

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Treated wastewater (TWW) is becoming an important source of water for agriculture in much of the world. While the advantages of TWW for agriculture are quite clear, it is now well established that in clay soils the yield of orchards may decrease dramatically as a result of prolonged irrigation with TWW. Initial investigations into the yield-loss found no toxic levels of the elements previously associated with damage to TWW irrigated crops (Cl, B, Na). The association of the damage with clay soils led to the hypothesis that lack of oxygen may be the hidden culprit behind the damage. The synthesis of two field experiments portraying the role of oxygen limitation in the damage and the efficiency of management solutions are presented. The first field study was conducted in an avocado orchard in Akko, Israel, between 2012 and 2015 to evaluate soil oxygen status and its effects in plots irrigated with TWW compared to plots irrigated with fresh water (FW). To this end, continuous measurements of soil oxygen and redox potential were performed along with surveillance on selected tree physiological parameters. We found that the TWW irrigated plots had substantially longer periods with low oxygen levels, accompanied by lower redox potential in the root-zone as compared to FW irrigated plots. The amount of time with oxygen levels below 10% in the root zone was found to be

negatively correlated with the tree yield. We also found that while the leaves did not show toxic levels of Na, the roots and stem of the TWW irrigated trees had substantially greater concentrations of Na and substantially smaller root development as compared to FW irrigated trees. These findings led us to hypothesize that the low oxygen levels in the TWW irrigated plots leads to increased susceptibility to Na, which then adversely affects root growth. Based on this hypothesis, we suggested and tested four agro-technical management practices to recover the damage in TWW irrigated orchards: (1) switching to irrigation with FW; (2) irrigation with a mix of TWW and FW; (3) low frequency irrigation with TWW; and (4) irrigation with TWW over tuff ditches. The field study aimed at examining the efficiency of these management practices commenced in the year 2016 in an avocado orchard previously irrigated with TWW, in Yas'ur, Israel. The first two years of this study indicate that the oxygen levels in the root zone of the TWW irrigated trees in Yas'ur are substantially higher than those measured in Akko, rarely going below 10% oxygen. The differences between the two sites will be discussed and the effect of the management practices in Yas'ur will be presented.

Non-invasive geo-electrical monitoring of nitrogen transformation processes across a dynamic capillary fringe

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The capillary fringe (CF) is characterized by steep redox gradient, that is thought to be a hot spot for biogeochemical processes. Understanding chemical fate and transport in the CF is significant, however, biogeochemical dynamics here are poorly understood due to the transient nature of chemical and hydrologic conditions, and the difficulty to measure at great depth. The inspiration of this research is from the operation of the soil aquifer treatment (SAT) system of the Shafdan plant, Israel, where the hydrological regime is intense. Outside the Shafdan SAT system, the water table is at 30 to 40 m depth. Hydrogeophysics is a developing field which use minimally intrusive and quick response method to monitor hydrological properties. Of special interests are the spectral induced polarization (SIP) and self-potential (SP) methods, as they are more sensitive to the interface between the solid and aqueous phases. The challenge lies on linking the geo-electrical response with biogeochemical processes.

We conducted continuous soil column experiment (size: 19.3 × 9.9 × 90 cm3) with the Shafdan soil to study nitrogen cycle under hydrologic dynamics (groundwater fluctuation versus local infiltration) across the CF. We consider static case (static groundwater table), periodic pulse case (constant groundwater table with intermittent infiltration), and several dynamic cases (fluctuating groundwater table subjected to drying-rewetting cycles). Preliminary results of SIP signals showed a good response to nitrogen species (NO_3^- and NH_4^+), dissolved organic carbon, CO_2 emission, and major dissolved ions (Na, K, Ba, Ca, S, Mg, Fe, Mn, P), water content, matrix potential and Eh. They are likely induced by (1) biogeochemical processes of the water chemistry under different redox states (that are primarily related to water saturation); and (2) adsorption and desorption of cations to the

soil surface and cation exchange between the soil surface and aqueous phase. SP signals are shown to be effective to locate the hot zone of biogeochemical processes.

The outcome of this research will not only increase the potential use of SIP and SP methods across the CF, but also afford suggestions for efficient operation of the Shafdan SAT system.

Irrigation level and crop load effects on yield and water flow in SPAC of date palms

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The increasing consumption of dates results in continuous expansion of date palm orchard in Israel's Arava Valley. Given the agricultural quota restriction of land and water in this region, it is of great interest to investigate combined irrigation level and crop load effects on date palm, in order to improve water use efficiency and productivity. The experiment was conducted with two irrigation levels (100% and 130% recommended irrigation regimes) coupled by three crop loads (targeted yield of 70kg, 110kg, and 140kg, respectively) in palm orchard. Fruit size (length and width), mass, sugar content were measured every two weeks during the fruit growing season. Mature fruit was harvested twice for total yield evaluation. Canopy temperature was measured by infrared camera once a month. The results showed that fruit size and mass decreased with the increasing crop load in both irrigation treatments. Palms with higher irrigation level exhibited greater fruit size and mass in each crop load group. As for the sugar content, it maintained stably low values during the fruit enlargement period, and then continuously increased till the first harvest without significant differences among trees. Additionally, palms with more irrigation exhibited higher yield. Similarly, single date mass was found to be significantly higher ($P<0.05$) in palms with more irrigation compared to those with normal irrigation, except for the commercial crop load group. Finally, lower canopy temperature was detected in palms with high crop load and more irrigation, suggesting elevated water fluxes for transpiration. These results indicate and highlight the potentially additional gain of yield and high quality dates with complementary irrigation quantities, in period at which an increased demand for carbohydrates results from high crop load.

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