The 14th Dr. Dahlia Greidinger International Symposium

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Abstracts Book

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Opening session

Nitrogen and phosphorus fertilization in crop production to help shaping sustainable futures

Oene Oenema

Wageningen University

Nitrogen (N) and phosphorus (P) are essential nutrients for all life on earth. Shortages of N and P limit the growth and development of plants, animals and humans, but excess N and P pollutes the environment, decreases biodiversity and harms life on earth. The term 'balanced fertilization' reflects the need to seek a balance between demand and supply of N and P. However, recent reports about N and P balances in agro-ecosystems and about exceedances of the planetary boundaries for N and P indicate that the proper balance between demand and supply of N and P has not been achieved, although there are huge variations across agro-ecosystems and regions. Evidently, efforts to seek the proper balance between demand and supply of N and P have to increase, and have to be agro-ecosystem- and region-specific.

The sombering reports about increasing numbers of undernourished and malnourished people in the world mainly reflect inappropriate distribution of and access to the available food, but the forecasts of an increasing human population do reflect that about 50% more food has to be produced during the next few decades. Recent reports about the exceedance of the so-called planetary boundaries for N and P reflect the sobering thought that the increased food production will have to be achieved with half as much N and P inputs as used in the recent past, globally. A formidable task, which likely requires different pathways in combination.

A first pathway is precision fertilization, i.e., the spatial and temporal optimization of the supply and demand of N and P, together with other essential nutrients and in conjunction with precision irrigation and water conservation practices, in various agro-ecosystems and regions.

The spread of new precision technology and new fertilizer types will have to contribute to greater progress across the world than in the recent past has been achieved.

The second pathway is precision fertilization in combination with higher-yielding crops and improved cropping systems. The latter refer to intercropping, strip cropping, alley cropping, agroforestry, etc. Higher yielding crops and mixed cropping systems will allow to greatly increase the N and P use efficiencies, while another boost can be given through precision fertilization. There is evidence that higher yields can be obtained with similar or decreased N and P inputs.

The third pathway is increased recycling of N and P in crop residues, manures, residues from processing industries, and wastes from households. Recent studies indicate that the N and P input circularity and output circularity can be increased greatly, and that this increased recycling increases the N and P use efficiency of crop production systems and whole food systems. Evidently, there are barriers and limits here, which have to be addressed carefully.

The fourth pathway is decreasing N and P losses via volatilization, erosion, leaching and denitrification. For sure, the aforementioned pathways will greatly contribute to decreasing N and P losses to the environment, but in addition increased efforts have to be made to keep N and P within soil-crop systems through for example buffer strips, catch crops and improved water management.

A fifth pathway relates to demand side changes, i.e., decreasing the consumption of food products with a high N and/or P foot prints. Evidently, this pathway goes beyond N and P fertilization per se, but this pathway is increasingly seen as part of shaping sustainable futures. The scope and impact of this pathway are huge.

The greatest challenge is perhaps the implementation of these pathways in practice. Growers and advisors have to be involved. Incentives are needed, and new business models in case the demand of the society on food production systems goes beyond the capacity of farmers. Regulations may be needed, but the current 'Nitrogen crises' in The Netherlands suggest that restraints is in order.

The occurrence of heavy metals and radionuclides in global phosphate rocks and fertilizers: Implications for environmental impacts

Avner Vengosh

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Phosphorus is one of the primary nutrients essential for plant growth and thus its availability is critical for sustainable agricultural development and food security. Increased utilization of P-phosphate fertilizer over the last decades has caused eutrophication of numerous water resources. Elevated levels of metals and metalloids in phosphate rocks and P-fertilizers pose less recognized but significant potential risks to soil and water quality. This study presents trace element concentrations in global marine sedimentary phosphate rocks (n = 61) from major phosphate producing countries. The data show that young (<100 Ma) sedimentary phosphate ores from the Eastern U.S. and the Tethys Belt of Northern Africa and Middle East exhibit high concentrations of uranium, cadmium, arsenic, and chromium, while older phosphate ores from China and India show significantly lower levels of these metals. Systematic analysis of several pairs of phosphate ores and P-fertilizers indicates selective enrichment of trace elements in P-fertilizer, including uranium, cadmium, and chromium, resulting in elevated levels of these toxic elements in major P-fertilizers such as those utilized in the U.S. In contrast, phosphogypsum, which is the major byproduct and the solid waste of P-fertilizer production, is characterized by enrichment of the radionuclide radium over uranium. The extensive use of P-fertilizers in agriculture fields infers continuous input and accumulation of heavy metals on the fields. Over long-term, metalloids like uranium, arsenic, and chromium would likely to be mobilized with water infiltration to deep soils and/or underlying groundwater, whereas cationic metals like cadmium would accumulate in surface soils. As part of our study, we have developed a diagnostic isotope tracer of strontium isotopes that can potentially detect the mobilization of P-fertilizers-derived metal(loid)s in the

environment. Given that 47 million metric tons of P-fertilizers are globally produced every year, we postulate large fluxes of metal(loid)s are entering the environment through P-fertilizers utilization without adequate monitoring and evaluation of their impact.

Session 1a:

Frontiers in plant nutrition to promote sustainable intensification of crop production

Conveners:

Shahar Baram, Hillel Magen, Uri Yermiyahu

Magnesium and Sulphur: Key Elements in Stress Mitigation

Ismail Cakmak

Sabanci University, Faculty of Engineering and Natural Sciences, Turkey

Crop plants are often exposed to multiple environmental stress factors which cause significant reduction in growth of plants. Oxidative damage is known to be fundamental mechanism responsible for stress-related impairments in plant growth. Published evidence shows that mineral nutritional status of plants plays a key role in mitigating adverse effects of environmental stress factors. Mineral nutrients have critical physiological functions which enable plants to enhance their tolerance to stressful conditions. For example, plants grown under low magnesium or low sulphur supply are highly susceptible to heat, radiation, drought and pathogenic infection due to various particular reasons.

Impaired utilization of light energy in photosynthetic CO_2 fixation is common in plants exposed to low Mg supply, which leads to photooxidative damage to chloroplasts, especially under heat and high light conditions. Therefore, plants exposed to high-light conditions in combination with heat stress have higher physiological demand for magnesium to mitigate photooxidative cell damage. Number of protective mechanisms used by the plants against oxidative damage as well as pathogenic attack depend on sulphur-containing compounds, in particular cysteine and glutathione. Recently published results show that regulation of stomatal closure and adaption of plants to drought stress are greatly affected from sulphur nutritional status of plants. In this presentation, several examples will be presented showing how nutritional status of plants with magnesium and sulphur improves plant tolerance to stress conditions.

Fertilizing future farming

Achim Dobermann

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Global demand for fertilizer will continue to rise, albeit at a lower and more differentiated pace. IFA's long-term demand forecast to 2050 suggests annual global growth rates of 0.7–1.1% for N, 1.0–1.3% for P and 1.1–1.8% for K, depending primarily on what levels of efficiency can be achieved. Taking into account the different regional and national needs, a new paradigm for responsible plant nutrition follows a food system and circular economy approach in which multiple socioeconomic, environmental and health objectives must be achieved. For many countries the primary challenge is to decouple future growth in crop production from growth in fertilizer consumption. On the other hand, for most countries in Sub-Saharan Africa the primary challenge is to at least double or triple fertilizer application rates in a sustainable manner within the next two decades.

The coming 10-20 years will be most critical for making the transition to a global nutrient economy that is an integral component of a low-carbon, environment-friendly and circular economy, supporting the nutrition requirements of a rising global population. Four major transformations are likely to drive this process: 1) Decarbonized & decentralized fertilizer production; 2) Smarter fertilizers; 3) Data-driven, more precise nutrient management and 4) Nutrient recovery & recycling.

The fertilizers of the future will have a much lower carbon footprint, but green ammonia and other new manufacturing technologies may also imply that the age of cheap nitrogen may be over. This will stimulate innovation on mainstreaming enhanced efficiency fertilizers, including a new generation of fertilizers that are smarter in terms of nutrient release, often triggered by actual plant growth or microbes. The old ways of assessing soil fertility have numerous limitations for more precise nutrient management.

Now is the time to move towards data-driven, self-learning fertilizer recommendations for multiple nutrients, based on the actual outcomes achieved by hundreds and thousands of farmers. Computational technology is likely to be less limiting for that than current behaviours and concerns about sharing data and other intellectual property. Recovering nutrients from numerous waste streams presents an increasing opportunity for closing nutrient cycles and decentralizing fertilizer production, but we also need to be realistic about the overall quantities of novel fertilizer products that can be produced in that manner.

Researchers and students interested in soil fertility, plant nutrition, chemistry, material science, engineering and computer science will have exciting opportunities. However, science culture must change too, towards ways of working that stimulate discoveries and reward faster translation into practice. Greater focus on explicit pathways to agronomic applications, reality checks and rigor in claims of utility are needed, as well as more sharing of data, know-how and critical resources for doing good research. Transdisciplinary innovation and entrepreneurship needs to be at the core of all this.

Can oxygen promote agricultural production?

Shahar Baram

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Optimal root respiration and nutrient uptake require a continuous supply of oxygen (O_2) to the rhizosphere. However, in reality, in most soil, the rate of O_2 diffusion into the soil is lower than the rate of its consumption. Hence, O_2 concentrations in the rhizosphere are lower than in ambient air (20-21%; normoxia), and often sub-optimal or anoxic conditions develop. To date, the definition of sub-optimal O_2 concentrations is not clear, and the general perception is that in most soils, O_2 is not a crop-limiting factor. However, in recent years, more and more studies have shown that even small changes in the O_2 concentration of the soil air (i.e., >0.2%) positively impact plant growth, metabolism, and yield. Results from studies with various soil aeration methods, such as the dissolution of micro- and nano-bubbles and peroxides, show a positive response to O_2 additions, even when the additions contributed a mere 0.01-1% of the soil respiration fluxes. The governing mechanisms for such positive responses are unclear, and further study is needed.

Reforming crops' mineral diagnostics by chemometrics

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World farming requires precision fertilization to eliminate contaminations, improve crops' productivity, and ensure sustainability. Yet, chemical mineral analyses are overly expensive and labor-intensive to substantiate large datasets of plants' nutritional status, rendering farming to rely on discrete measurements for fertilization updates. Hence, we set to restructure nutritional diagnostics in agriculture. First, we developed a unique experimental setup to produce a wide range of mineral concentrations in multiple crops. Then, we turned to analytical tools in alternative industries, mainly NIR and X-ray fluorescence used by the mining and pharmaceutical industries for mineral analyses. Finally, we integrated an array of statical tools to adjust chemometric tools to the mineral matrices in various plant tissues. The novel chemometric projections fitted chemical analyses of macro and micro-elements' concentrations in multiple crops (e.g., vine, tomato, almond, citrus, and avocado leaves). The error range was ±5% of laboratory analyses (corresponding to common variability between laboratory assays), and repetitions were redundant. Moreover, it is a rapid analysis, and its procurement costs are significantly lower than current laboratory practices. We recently extended our efforts to the extension and commercial sectors, supporting field laboratories in India and Israel. Now, we are set to survey numerous crops throughout all their phenological stages at various growth conditions and produce the large datasets required for modern decision-support algorithms to guide farming.

Mineral mass balances reveal the phenology of evergreen and deciduous tree crops' nutrient uptake

Or Sperling

Plant Sciences, ARO, Israel

Recent economic, environmental, and regulative concerns force farmers to precise their fertilization practices. Yet, a critical knowledge gap concerning the temporal variability in perennials' nutritional requirements renders most fertilization applications inefficient. While mass balance studies could illustrate the dynamics of crops' mineral uptake, their association to field conditions remains a challenge. Hence, we constructed an empirical framework to convert data from lysimeter studies to applicable farming information. We fitted quadratic equations to the correlations between irrigation and drainage mineral concentrations of three perennial crops—almond, avocado, and pomegranate. Then, we derived the optimal irrigation mineral composition by the interpolation point of the nitrogen, phosphorus, and potassium curves. We also matched polynomials to the relations between leaf mineral concentrations and fertilization compositions and established mineral diagnostic references for each sampling period. Repeated measures of the crops' response curves illustrated a temporal variability in their nutrient uptake, highlighting that the evergreen avocado extracts nutrients throughout winter, early blooming almond extracts nutrients in spring, and late fruiting pomegranates obtain minerals throughout summer. Moreover, the deciduous almond and pomegranate require extensive summer fertilization for the following spring's bloom. Recurrent leaf diagnosis exhibited that almond leave's optimal nitrogen concentrations drop by midsummer. Optimal phosphorus concentrations in avocado and pomegranates doubled during summer, as did the optimal potassium concentration in pomegranates' leaves. Accordingly, we established an empirical approach to process data from lysimeter studies and constructed specific fertigation assays for almond, avocado, and pomegranate trees.

Relationship between fertilizer N load and nitrous oxide emissions – can we generalize?

Ilia Gelfand

Session 1b:

Soil Health: Towards closing gaps in both management and assessment

Conveners:

Gil Eshel and Tal Svoray

Soil quality assessment with imaging spectroscopy under land use changes

Tarin Paz-Kagan

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Global population growth has resulted in land-use (LU) changes in many natural ecosystems, causing deteriorated environmental conditions that impact soil quality. This rapid growth in the global population caused many natural ecosystems to be transformed into human-dominated ones. Such LU dynamics require greater resource exploitation, commonly resulting in degraded environmental conditions that are acknowledged in the soil quality. The effects on the soil are even more acute in water-scarce and limited resources environments such as drylands. Therefore, developing appropriate approaches for soil quality assessment and function evaluation is necessary since the soils in those areas are usually undeveloped and retain lower organic matter capacity. The research aim was to apply, measure, and evaluate soil properties based on the imaging spectroscopy (IS) differences between natural and human-dominated LU practices in the dryland environment of the Negev Desert, Israel. A flight campaign of the AisaFENIX hyperspectral airborne sensor was used to develop an IS prediction model for the SQI on a regional scale. The spectral signatures extracted from the hyperspectral image were well separable among the four LUs using the partial least squares-discriminant analysis (PLS-DA) classification method (OA = 95.31%, Kc = 0.90). The correlation was performed using multivariate support vector machine regression (SVM-R) models between the spectral data, the measured soil indicators, and the overall SQI. The SVM-R models were significantly correlated for several soil properties, including the overall SQI (R2adjVal = 0.87), with the successful prediction of the regional SQI mapping (R2adjPred = 0.78). Seven individual soil properties, including fractional sand and clay, SOM, pH, EC, SAR, and P, were successfully used for developing prediction maps. Applying IS, and statistically integrative methods for comprehensive soil quality assessments enhances the prediction accuracy for monitoring soil health and evaluating degradation processes in arid environments. This study establishes a precise tool for sustainable and efficient land management and could be an example for future potential IS earth-observing space missions for soil quality assessment studies and applications.

Optical Properties of Water-Extractable Organic Matter as Possible Indicators for Soil Organic Matter Response to Irrigation Water Quality and Management

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Water-extractable organic matter (WEOM), being only a fraction of soil organic matter (SOM), is considered sensitive to anthropogenic effects in cultivated lands. For example, UV absorbance and fluorescence emission of WEOM respond to differences in land use. Recently, this sensitivity laid the ground to consider the optical properties of WEOM extracts in developing a soil health index. An important anthropogenic effect on soil health is expected following long-term use of treated wastewater (TWW) for irrigation, especially in clayey soils. In many cases, TWW irrigation negatively affects soil quality, crop growth and productivity. Our objective was to examine the response of optical properties of WEOM and some other soil/ extract characteristics to changes in water quality and management aimed at mitigating the adverse effects of long-term TWW irrigation. An avocado orchard planted in 2009 in a clayey soil in the Western Galilee (kibbutz Yasour) and irrigated since with TWW was sampled in autumn 2021 from plots having been irrigated with TWW (control), and plots irrigated for the last 6 years with (i) fresh water (FW), (ii) 1:1 TWW-FW mixture and (iii) TWW with a reduced frequency. The soil samples were characterized for total organic C (TOC), inorganic C, and total N, and by mid-IR absorption and attenuated reflectance (ATR) spectra. Soil water extracts were characterized using absorbance at 254 nm (Abs_{254}) as an empirical measure of the concentration of aromatic compounds, concentrations of dissolved organic C (DOC) and

inorganic C, and excitation-emission matrices (EEMs) of fluorescence. The IR and ATR spectra of soil samples, and EEMs of fluorescence of extracts were decomposed into the chemically sounding components using non-negative matrix factorization and parallel factor analysis, respectively. In addition, the electrical conductivity, pH, concentrations of the major ions in soil-water extracts, and the composition of the exchangeable cations, were determined. When irrigation involved (partial or full) use of FW, there was a distinct decrease in Abs_{254} and fluorescence emission of the humic-like component in soil extracts, as compared with TWW control. This finding is in an apparent contradiction to the findings of a former study on a similar and nearby clayey soil where TWW irrigation had comparable impacts on Abs_{254} and the presence of humic-like components in extracts to that of a soil continuously irrigated only with FW. A sequence in use of different types of irrigation water is important for composition of WEOM. Importantly, soil attributes such as TOC content, DOC concentration in extracts, and the contents of IR-spectrally identified components, showed no statistically significant differences between the control and the other treatments. We concluded that (i) Abs_{254} and humic-like fluorescence of soil extracts are sensitive indicators to changes in irrigation water quality when mitigating TWW effects, and (ii) those attributes of WEOM-containing extracts have no strong relations with any of the other studied characteristics of the soil and the soil extracts. Both conclusions highlight the significance of the optical properties of extracts as essentially independent descriptors useful for evaluating soil response in different agricultural scenarios.

Quantifying spatial soil health trends at the catchment scale

Tal Svoray

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This presentation discusses the formalization of spatial information on soil health, and its implications, for estimating the quality of the remaining soil in the wake of erosion processes or intensive cultivation period. Such an approach extends the notion of water erosion damage from computation of soil budgets, to comprehensive soil health assessment and the provision of ecosystem services. The research framework described here suggests computing spatial autocorrelation of soil properties, by various methods: Moran's I, Nugget: Sill ratio, and variogram envelope analysis and the comparison between the three methods. The spatial computations are demonstrated using geoinformatics procedures to show how GIS layers of the Harod catchment in Israel can be used as an input source for the stratified random approach to further allow to apply spatial interpolation techniques—such as Ordinary Kriging, Universal Kriging and Cokriging—as efficient tools for predicting spatial variation in soil health at the catchment scale. The limited ability to scale up soil health mapping from point measurements to large agricultural areas is a major gap in soil research and is also discussed in this presentation. In this regard, the prime contribution of the presentation, scientifically speaking, is the methodology offered for studying the effect of natural and anthropogenic disturbances on remaining soils in a spatially explicit fashion. From an applied standpoint, it provides farmers and professionals with a tool for estimating the state and dynamics of their field.

Using Remote Sensing To Measure Rills Formation In A Field With And Without Cover Crops

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Soil erosion is considered one of the greatest challenges for sustainable soil management. Soil erosion leads to the loss of the top and most fertile soil layer, thus degrading the soil health and hampering its ability of providing a wide range of ecosystem services. Service crops, which are commonly called cover crops, are often sown with the purpose of protecting the soil from water erosion by directly protecting the soil from the raindrops' impact (interill erosion) and by increasing soil cohesion through service crops roots, protecting soil particles from detachment and transport by consecrated runoff flow (rill formation). Measuring soil lost in rills is challenging, as rill formation is dynamic in space and time. The use of remote sensing and photogrammetry techniques to measure rill formation is a fast growing and promising research field, especially with the use of high resolution images captured by unmanned aerial vehicles (UAVs). The acquired images, coupled with structure from motion algorithms, are used to generate digital surface models (DSM), with a high spatial resolution. This enables to extract and measure the volume of individual rills and their cross sections and thus examine rill dynamics and soil erosion mechanisms. Soil surface changes can also be detected with remote sensing. However, in real life scenarios images from before the rainfall event are often unavailable. In this study an approach was used to artificially produce a DSM which we term $DSM_{time\ zero}$, i.e. a DSM as it would have been before the rainfall event, with images captured after the rainfall event. The method utilizes height information from the areas surrounding

the rill which are unaffected by erosion. Extrapolation techniques are then used to create the DSM $_{time\ zero}$ within the rill. We used this method to measure the dynamic of rill formation in plots (1 ha each) with and without service crops in a research farm in northern Israel. Images of the field were captured with a UAV-RGB after major rainfall events in early January 2020. A DSM $_{time\ zero}$ was constructed in three locations in the field and used to measure total erosion volume. In addition, cross sections were constructed and used to measure rill width, height and surface area. In bare soil plots, the general trend was a growth in rill width and cross section area along the rill while in service crop plots the opposite trend was observed. All measured parameters were significantly lower in plots with service crops in all the studied areas. For example, in one of the locations, the average maximum rill depth in the bare soil plot was 0.35 m, while in the service crop plot it was reduced to 0.16 m. Average rill cross section area was reduced from 0.66 m^2 in the bare soil plots to 0.22 m^2 in the service crop plot. The method developed in this study suffers from a few limitations that will be discussed, yet, the initial results demonstrate its employment for a better understanding of how service crop minimize soil erosion.

Soil health index: selection of indicators for mediterranean agricultural systems

Oshri Rinot

SupPlant LTD. Afula

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Soil health indices are computed using selected measured soil properties. Evaluating soil health status in Mediterranean regions, characterized by diverse agriculture systems and wide range of soil types and land-uses, is still considered a major challenge. We aimed to identify physical, chemical, and biological soil properties that are highly sensitive to differences in the main land-uses practiced in Mediterranean agriculture, namely perennial crops (orchards), annual crops (field crops) and non-cultivated land. We conducted a comprehensive sampling campaign comprising six sampling sites at important agriculture regions of Israel. Each site included three nearby representative plots for each land use. Each plot was sampled twice (in autumn and spring) from four depths (0-10 cm, 10-30 cm, 30-60 cm, 60-100 cm). Altogether, 432 soil samples were collected. Overall, 87 soil properties were determined either in the laboratory or directly in the field. Statistical models, including ANOVA and Hierarchical clustering analyses were used to determine (i) the best sampling season; (ii) the properties most sensitive to the type of land-use; and (iii)The dependence of the tested properties on soil texture and sampling depth. The statistical analyses resulted in twenty-two indicators representing a comprehensive assemblage of important properties and processes in the soil system. The selected indicators included common ones (e.g., mineral N and soil organic C contents, soil bulk density, etc.) alongside novel indicators such as free-living nematodes and microbial community functionality indicators, fluorescence emission of dissolved organic carbon, and field-based measurements as weeds and visual soil assessments (VSA). Some of the selected soil indicators were significantly affected by soil depth. In addition, most of the selected indicators were significantly affected by soil texture, highlighting the need to account for these factors for constructing the soil health index.

Ecosystem services of soil predatory mites depend on a functional soil food web

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Species of soil predatory mites feed on a diverse diet making them excellent candidates for conservation biological control programs. Free living nematodes (FLNs) are commonly found in soils at all trophic levels and serve as prey for many soil predatory mites (SPMs) in a functional soil food web. Here we present highlights of two case studies and the preliminary results of one ongoing study, all with the common aim of improving the conservation of soil predatory mites for the control of soil pests. In the first study, we used *Macrocheles embersoni* for housefly control, in the second, *Stratiolaelaps scimitus* for the control of the root knot nematode (RKN) *Meloidogyne incognita*, and in the third, we use frass of black soldier fly *Hermetia illucens* an organic amendment for harnessing the local soil food web for the control of RKN. In the first two studies, complementing the diet of predatory mites with the FLN *Rhabditella axei* in their culture medium resulted in higher predator abundance and better biological control, compared to the negative control and the release of predators without FLNs and microbiota. In the third study the effect of black soldier fly frass as a soil amendment on soil biota and RKN control differed among soils. We expect that soil amendments alter biocontrol efficacy, and that these effects are dependent on the biodiversity of soil biota as well as abiotic soil properties, and that caring for soils is a pre-requisite for successful conservation biological control.

Slow release of copper from jellyfish-based hydrogels for soil enrichment

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Nanotechnology has shown great potential to increase global food production and enhance food security, suggesting alternatives to plant-protection products (e.g., fertilizers and pesticides). However, large-scale application of nano-enabled plant agriculture necessitates careful adjustments in design to overcome barriers associated with targeted nanomaterial delivery and their safety concerns. The research herein proposes the delivery of copper from immobilized and non-immobilized copper oxide nanoparticles (Cu_2O), an active nanomaterial with antifungal and micro-nutrient properties. A benign and biodegradable jellyfish-based hydrogel was used as a platform during Cu_2O delivery to soils. The delivery kinetics and Cu dissolution from the nanocomposite were compared to those obtained with crosslinked ionic copper in hydrogel, which was found to be a less controlled composite. In addition, changing environmental conditions from DI to soil extracts resulted in a decrease in the Cu dissolution rate (from 0.025 to 0.015 h^{-1}) and an increase in the overall normalized Cu release (0.27 to 0.72 mg g^{-1}). Use of hydrogels from natural sources allowed biodegradability over several months, adding nutrients (in the form of elements such as sulfur, nitrogen, and carbon) back to the environment, which ultimately minimizes nanomaterial required for a given desired nanomaterial yield and enhances the overall performance. Altogether, this work demonstrates the potential of Cu_2O/hydrogels as a benign composite for copper slow-release and therefore bolsters the field of nano-enabled plant agriculture and supports its safe deployment at large scales.

Session 2a:

Frontiers in plant nutrition to promote sustainable intensification of crop production

Conveners: Shahar Baram, Hillel Magen, Uri Yermiyahu

Fully biodegradable coating technology brings controlled release fertilizers into a new era

Terlingen, Leon

ICL Group Ltd.

ICL recently launched the next generation controlled release fertilizers (CRF) into the agriculture market. This new generation of CRF is targeted to comply with the new European Fertilizer Regulation (2019/1009) which is the first legislation globally targeted to reduce microplastics emissions of fertilizers to the environment. For this we developed the eqo.x coating technogy to make the coating fully biodegradable. Eqo.x was successfully tested in field trials versus growers practice and current commercial polymer coated products. Furthermore detailed work at Nutrient Management Institute, Wageningen (Netherlands) showed the potential to significantly reduce leaching, ammonia volatilization and N2O emissions of controlled release fertilizers, including the new eqo.x technology applied on urea. So eqo.x can help farmers to reduce nutrient losses and increase nutrient use efficiency while maintaining yields.

Desert dust, volcanic ash and forest fire ash as plant fertilizers in an ambient and elevated CO_2 levels

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Desert dust, volcanic ash and fire ash are the most abundant natural atmospheric particles. These particles considered as an important nutrient source that controls the long-term productivity of infertile terrestrial ecosystems, by replenishing soil nutrient stocks. However, currently we do not know whether atmospheric deposition can act as a direct, alternative source for nutrients. These are particles enriched with phosphorus (P) and other essential macro and micronutrients such as: K, Ca, Mg, Zn, Cu, Fe, Mn, Zn, and Mo. These nutrients are vital for plants and support their growth.

The current research shows that elevated CO_2 (eCO_2) in the atmosphere has positive and negative effects: On the positive side, increase of CO_2 levels is predicted to result with an increase in photosynthesis leading to improved primary biomass production and thus enhancement of CO_2 capture. On the other hand, at eCO_2 plants show decreased concentrations of mineral nutrients in most of their organs, suggesting downregulation of the activity of the membrane transporters involved in root nutrient uptake; a decreased ability to assimilate nutrients from the roots system.

Preliminary results of recent studies had shown that plants can utilize P via foliar nutrient uptake mechanism, directly from dust that settled on the plant's leaves. Since the efficiency of roots to assimilate nutrients is projected to decrease in future eCO_2, foliar nutrient uptake may be a significant alternative pathway for plants to gain needed nutrients. In this work, we used atmospheric fertilization experiments – where we deposited dust directly on plant leaves

– to show that atmospheric deposition boosts plant growth and fertilizes them through direct foliar nutrient uptake pathway. The foliar nutrient uptake mechanism was shown both in an ambient and eCO2 levels for the three primary atmospheric particles mentioned above. We saw that volcanic ash had significantly increased biomass at eCO2 compared with ambient CO2 levels. Our results demonstrate that foliar nutrient uptake is a significant mechanism at immediate timescales. Furthermore, that the direct alternative pathway of foliage nutrients assimilation has a potential to regulate carbon sink processes in a terrestrial ecosystem in a future climate.

Concomitant Tracking of NH_3, N_2O and Soil Mineral-N for Evaluation of Fertilization Practices Sustainability; Benchtop to Greenhouse Scale Experiments

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Enhancing Nitrogen Use Efficiency (NUE) to assure sustainable intensification of crop production, while minimizing N-environmental threats, is a major challenge. Urea ($(NH_2)_2CO$), the most widely used N-fertilizer, dissolves rapidly and decomposes to $(NH_4)_2CO_3$ by enzymatic hydrolysis that may enhance $NH_{3(g)}$ emissions and NO_2^- accumulation. Furthermore, excess use of N-fertilizer (relative to plant uptake capability) can result in NO_3^- leaching and emissions of the greenhouse gas $N_2O_{(g)}$.

Enhanced Efficiency N-Fertilizers (EENFs) offer slow-pace and improved matching of nitrogen supply throughout the growing cycle, reducing losses and enhancing NUE.

Yet, improvements based on local field-specific information, and particularly with new N-fertilization approaches, are needed. Because of the complex N-dynamics in soil, it is difficult to pursue these improvements on a real-field scale. Here we present a laboratory steady-state incubation system connected to a Long-Path IR gas cell, allowing fast determination of NH_3 and N_2O emissions concomitant with mineral N-dynamics in soils under different N-fertilization approaches and conditions. The system was tested with four representative soils, fertilized with surface applied urea or urea amended with urease inhibitors (UI). Different soil water saturation (WS) levels and urea application rates were tested over 14 days of incubation.

Complimentary to the bench-top system, we present a greenhouse scale experiment, which provides a more realistic and improved mass-balancing tool of N resources (inputs, outputs, and losses in *all* phases). Environmental and agronomic performance of three urea-based EENFs (UI, 2-months and 4-months controlled release urea) were compared with the common split surface application of granulated urea, using Basil seedlings that were grown for three consecutive growing cycles. A comprehensive multi-phase nitrogen analysis was conducted along the growing cycles, including measurements of $NH_{3(g)}$ and $N_2O_{(g)}$ emissions, nitrogen content in plants, and inorganic N-species (NH_4^+, NO_3^-, NO_2^-) in soil and drainage. An Open-Path FTIR system was also tested for continuous measurement of gaseous emissions.

Obtained data from both benchtop and greenhouse experiments demonstrate the disadvantages of regular urea surface application, as commonly used in cropping systems, and the enhanced efficiency fertilizers potential to reduce environmental impacts along with improving agricultural and economic benefits. While EEFs help reduce N_2O and NH_3 emissions, the latter's observed emission rates are shown to be sensitive to the gas phase monitoring methodology.

Overall, the systems presented here provide relatively simple and practical platforms for comprehensive evaluation of EENFs performance under different conditions and application practices. The obtained Information and experimental set-up can contribute to improving N-use efficiency in various systems.

Diurnal nutrient uptake as affected by environmental conditions

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The uptake and movement of calcium (Ca) are strongly connected to the transpirational water flow, which carries Ca from roots to the plant organs, particularly those with high transpiration rates. Hence, the organs with low transpiration rates (e.g., fruits and tubers) typically have low Ca concentrations, which occasionally lead to Ca-related physiological disorders. One of those disorders is Blossom End Rot (BER) which causes substantial economic damage to pepper and tomato producers.

Tracing changes in Ca delivery can be challenging despite the connection between Ca and water uptake. Luckily, plants usually cannot discriminate between Ca and Strontium (Sr), making Sr a good Ca tracer. Nevertheless, plant toxicity exhibited by Sr often puts its use into question. Therefore, we conducted several long-term and short-term experiments on tomato plants using the nutrient depletion method to test the feasibility of using Sr as a diurnal tracer of Ca in tomato plants. The results of the experiments indicated that in tomato plants, Sr is a good analogous to Ca in terms of diurnal root uptake rate and plant organ distribution, particularly in fruits where Sr was able partly to substitute for Ca and even prevent BER formation.

Moving forward, we considered the relationship between diurnal environmental conditions (stress in particular) and nutrient uptake and delivery, as many plants' physiological processes are significantly diurnally regulated, including water and nutrient fluxes. Therefore, in our experiments on tomato plants, we utilised Sr as a tracer of Ca to characterise the diurnal Ca delivery and nutrient depletion method to characterise P, K and Ca uptake under optimal and stressful conditions. These experiments showed that Ca delivery to fruit and apical meristem is higher at night than during the day and established a significant positive correlation between total plant Ca accumulation and plant transpiration (during the day and at night) while disproving any connection between Ca allocation to tomato fruits and night-time plant transpiration. In addition, under stressful conditions, we found significant diurnal dynamics of nutrient uptake, with plants under stress maintaining their nutrient uptake at night and increasingly diminishing their nutrient uptake during the day.

All of our studies clearly illustrate the importance of considering the diurnal water and nutrient delivery, specifically during the night and under stress, as their utilisation can lead to better future irrigation and fertilisation practices aimed at mitigating the adverse effects of global climate change.

Effect of macronutrients fertilization on virgin olive oil quality

Arnon Dag

Volcani Center, ARO, Israel

Over the last few decades, the oil olive industry had been shifting from non-irrigated, extensive olive orchard management to irrigated, intensive practice. Introduction of the later includes the installation of irrigation and fertilization systems as well as the adaptation of new irrigation and fertilization practices that affect both yield and oil quality. The current study present findings on the effect of different application levels of nitrogen, phosphorous and potassium on olive oil composition and quality over 6 years in a commercial intensive cultivated 'Barnea' olive orchard in Israel.

Olive oil quality and composition were affected by N, but not P or K availability. Elevated N levels increased free fatty acid content and reduced polyphenols level in oil. The relative concentrations of palmitoleic, linoleic and linolenic fatty acids increased with increasing levels of N application, whereas that of oleic acid, monounsaturated-to-polyunsaturated fatty acid ratio and oleic-to-linoleic ratio decreased. The results indicate that intensive olive orchard fertilization should be carried out carefully, especially where N application is concerned, to avoid a decrease in oil quality due to over fertilization. Informed application of macroelements requires soil and leaf analysis to establish good agricultural practice, especially in view of the expansion of olive cultivation to new agricultural regions and soils.

Amorphous iron montmorillonite composite for phosphate adsorption and reuse

Neriya Peretz Lapid

Civil and Environmental Engineering, Technion

As the human population increases the demand for food increases as well. as a result, demand for fertilizers rich in phosphate (P) increasing dramatically in recent years. Environmental hazards due to P overuse such as habitat loss and eutrophication of water bodies are a growing problem. Eco-friendly P resources and removal of P from contaminated water are necessary.

To date, numerous methods have been studied to remove P and can be divided into three categories: biological, chemical, and physical. Biological P removal is highly sensitive to operation parameters so its efficiency is unstable, and chemical methods will generate a large amount of sludge. Physical methods for P removal are more stable and will not generate excessive material which will require further treatment. adsorption is a highly effective and efficient treatment and much cheaper compare to other physical treatments.

We propose a novel sorbent that is based on montmorillonite clay decorated with iron oxide nanoparticles (FeOx-MMT). The sorbent is low cost and environmentally friendly. We suggest that nano-sized iron-oxides deposited on the MMT will increase phosphate adsorption due to the increase in reactivity and surface area. Results show a rapid pseudo-second-order kinetic. the adsorption is specific and unaffected by competing anions or organic matter. Adsorption is mainly pH-controlled and occurs best in an acidic medium however ionic strength has an effect as well, increasing ionic strength increases the capacity. Desorption tests show recovery ability of P post adsorption.

Alternative Phosphorus Sources for Efficient Plant Fertilization Management

Ran Erle

Gilat research center, ARO, Israel

Large portions of the agricultural P requirement end in wastewater treatment plants, usually in forms that have low bioavailability. Hence, P recovery from wastewater and biosolids is an emerging approach. Here, we aimed to test the final products from three different recovery processes: sewage-sludge ash (SSA), struvite, and hydrochar versus grounded rock-phosphate (RP) and synthetic P fertilizer (TSP). The five forms of P were tested in large pots with maize-tomato crop rotation. Later, we evaluated struvite performance in potato field under contrasting soil-P availability. We found that the bioavailability of the "alternative" P sources increased from the first to the second crop rotation, indicating prolonged release of P in the SSA, struvite and hydrochar but not in the RP and TSP. Of the four alternative P, hydrochar stood out as the most bioavailable P-source. In the field, potato yield increased with P supply. For any P level, replacing part of the synthetic P with struvite significantly increase tuber yield by an average of 0.4-ton ha^{-1}. The consistent positive effect of struvite in the field trial along with pronounced positive effect of hydrochar indicates these alternative P sources have an indirect positive impact, probably by enhancement of synergetic microbial activities.

Session 2b:

Advanced treatment of organic waste for sustainable use in crop production

Conveners:

Liora Shaltiel-Harpaz and Avi Shaviv

The black soldier fly, a multi-directional contribution to agriculture, from pest reduction to fertilization through waste deposing and feed proteins production

Shaltiel-Harpaz, L[1-2]., Jonas-Levi A.[2], Danay O.[1], Martinez J-JI[1-2]., Gutman R[1-2]., Horovitz A[3]., Opatovsky I.[1-2], Sivan R.[2], Solomon A.[4]

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Millions of tons of agricultural plant wastes are produced annually all over the world, mostly handled in an environmentally inconsiderate way, emitting vast amounts of greenhouse gases and being an important source of regional re-infestation of pests. In a decade of research, at Tel Hai College and Migal, we investigated the use of the black soldier fly larvae (BSFL), *Hermetia illucens* (L.), (Diptera: Stratiomyidae) to treat various agricultural wastes as apples, tomatoes and mushroom which are a source of re-infestation of pests. This insect is wide spread around the world and considered harmless to humans, animals, and plants. BSF larvae consume great quantities of organic matter, and convert it to protein fat and residues from production — mainly faeces but also undigested substrate addressed as frass Here we report our multi-directional study of BSF contribution to agriculture. We studied the nutritional needs of the BSFL, define parameters of waste decomposition and developed formulas to build optimal diets for the BSF from local wastes and revealed the impact of yeast supplementation in its diet to improv growth parameters. We investigated BSFL effect in reducing several pest populations, studied BSFL meal as a protein source for monogastric mammals, demonstrated the positive impact of frass on plant growth and finely calculated its economic feasibility.

Can P Availability of Rock Phosphate be Increased Through Co-Composting with Agricultural Plant Residues?

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Large amounts of low-grade rock phosphate (RP) are byproducts of phosphate mining. Besides environmental and waste management considerations, this waste is a substantial source of phosphorus (P), a plant-essential nutrient found in limited reservoirs on earth and threaten global food security. However, the low P solubility in soil solution limits the potential use of this waste as a plant fertilizer, especially in alkaline soils. In Israel, waste RP sludge have accumulated in huge amounts and are currently not used (Oron-Zin in the Negev Desert). In this study, we explore the potential benefit of co-composting waste RP and greenhouse plant residues as a major component to enhance RP-P availability. This practice was examined in several previous works with mixed results. Lab-scale incubation experiments were performed using five mixtures of different ratios between plant residues, livestock manure, and RP (10% dry weight). The mixtures were incubated under thermophilic temperatures (55°C) and aerobic conditions for 60 days and then screened for phosphate-solubilizing microorganisms on Pikovskaya's Agar (PVK). Three dominant phosphate-solubilizing fungi (PSF) species were isolated and identified as *Aspergillus brasiliensis*, *Aspergillus fumigatus*, and *Aspergillus tubingensis*. The kinetics of phosphate solubilization and the associated dynamics of solution pH were measured in the presence of the isolated PSF. These results support the mechanism of inorganic phosphate solubilization through the production of organic acids. A pilot-scale setup was conducted to produce RP-enriched compost for the following tomato field growing experiment. The compost was prepared in enclosed polyethylene sleeves, about 12-m^3 each.

The sleeves were forced-aerated periodically and the temperature was monitored continuously. The mixture with RP contained (% dry weight): greenhouse tomato plant residues (80%), cattle manure (10%) and RP (10%; courtesy of ICL), while the control sleeve had the same ratio between plant residues and cattle manure but without RP. After two months of composting, the resulted compost was used in an open field tomato growing experiment in Ramat-Negev R&D center. No significant differences in total and marketable yields were observed between the RP-enriched compost (co-composted RP) and the control compost when it was amended together with raw RP of the same quantity. Yet, in both cases, the yields were higher compared to the control compost, which received no addition of raw RP. Overall, although we recognized potential activity of PSF under lab conditions, the results at this stage do not show an advantage for the co-composting of RP in a mixture of plant residues as a major component. In the next stage of the study, we aim to assess the specific contribution of P originated from the RP and that from the co-composted agricultural wastes, as well as the long-term phosphate solubilization in the amended soil.

Recycled phosphate fertilizers from organic waste streams for more sustainable food production

Patricia Imas

ICL Israel

Most of the phosphorus used in fertilizer comes from phosphate rock which is a critical raw material. It is a finite and non-renewable resource formed over millions of years in the earth's crust. Methods are underway to recover and recycle phosphates from other sources such as sewage biosolids, manures, and other digestates and biowaste from urban populations. These organic sources can be directly used, composted, combined with other materials, and used as soil amendments. However, there are many challenges that need to be overcome, and sometimes, incineration is a most convenient option to valorize streams of organic waste. Organic waste streams can be incinerated into ashes. In case of sewage sludge, it can be incinerated into sewage sludge ash (SSA). SSA can be used as replacement for phosphate rock for fertilizer manufacturing.

ICL, a leading global specialty minerals company, established a phosphate recycling unit to replace part of the phosphate rock with recycled phosphate in compound fertilizers in its factory in Amsterdam. The phosphate recycling unit can use phosphates in the form of SSA, struvite and precipitated phosphate salts replacing up to 100% of the phosphate rock previously used in the production of PK compound fertilizers. This pioneering process allows a circular phosphate economy, i.e., using a valuable ingredient more than once and increasing recycling rates for food production. This innovative effort is unprecedented in the global phosphate industry.

Adequate extension and communication efforts to the stakeholders is critical, as well as environmental certifications. The adoption of fertilizers containing recycled phosphate by farmers will depend on the farmer’s perception which will depend on the product performance and crop response. The food chain can also support to create a favorable framework for the use of recycled nutrients.

Agronomic demonstrations and field trials of fertilizers containing recycled phosphate with conventional fertilizers are being conducted to prove its performance. The agronomic efficiency of the new P fertilizers that contains recycled P from SSA is being evaluated versus common (traditional) P fertilizers, in pot and field trials in Israel and in Europe. The results show that the SSA based fertilizers are very promising in term of P availability, and response in growth and yield of different crops.

Subcritical water extraction – a circular economy approach for food waste valorization and for sustainable use in agriculture

Roy Posmanik

ARO, Israel

The global challenge of achieving food-security requires smart recycling of energy, water and agrochemicals. Increase in production of food waste under intensified agricultural systems represents a major obstacle worldwide. The majority of these residues, rich in organic carbon and valuable nutrients, are currently disposed in landfills. Recycling these waste streams, however, may lower the use of energy-intensive resources and reduce "end-of pipe" pollution such as greenhouse gases, and soil and water pollutants. The hydrothermal technology, using subcritical water (170–350°C; 1–20 MPa) as the conversion media has been intensively studied for a wide range of waste feedstocks including food waste. Most of the research in this area was motivated by energy recovery and therefore focused on the solid and oil phases. However, less attention has been given to the aqueous condensate – the process water remained after the hydrothermal reaction. Moreover, pyrolysis aqueous condensate (PAC), a by-product of dry pyrolysis, was reported to be highly toxic, hindering its use. This talk will review two implementation opportunities of the hydrothermal aqueous condensate (HAC), focusing on the recovery of valuable agrochemicals. The first pathway is for an integrated weed management. We demonstrate the high potential of using HAC for pre-emergent herbicidal activity. A different seed germination behavior of three tested species suggests a promising selectivity pattern. Heterocyclic aromatic organic compounds such as pyrazine and its derivatives were identified in all HAC samples and their concentration was found higher at high-temperature (250–300°C) HAC samples, where higher herbicidal activity occur. The second utilization approach is by using diluted HAC as a bio-stimulant aimed to induce plant resistance against pathogens. HACs at low temperatures (175–200°C) indicated an advantage in physicochemical parameters and especially regarding antioxidant activity. In addition, the same HACs showed systemic resistance induction that was tested in three plant-pathogen systems. A greenhouse trial demonstrated the capacity of the low-temperature

HAC to improve growth and yield parameters. Those two valorization pathways of HAC may expand the applicability and the circular economy of the hydrothermal technology. Utilization of these pathways will enable the recovery of both energy and valuable agrochemicals from food waste by using subcritical water extraction.

Volatile organic compounds (VOCs) as indicators for biodegradability of plastics for agricultural field mulching

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The use of plastic materials in agricultural applications, also known as Plasticulture, is a common practice around the world. Plasticulture consumes about 7 million tons of plastics every year, which is about 2% of the overall global plastics' production. For different reasons (such as contamination and logistics), plastic materials used for agriculture are difficult to recycle. Consequently, a large portion of the total plastic used in agricultural practices is either buried in fertile soils or at “best case” end in landfills. In landfills its half-life is measured in decades and even centuries and in soils it can significantly cause deterioration of their properties. Hence, developing biodegradable plastic materials suitable for agricultural applications is a vital and inevitable need. One of the main gaps today is the ability to assess how much and how fast those plastic polymers that are considered as biodegradable, are being degraded in the soil. One novel solution that can be put into use is looking into volatile organic compounds (VOCs) that are being produced during the degradation process.

In this study, two types of potentially biodegradable plastic polymer films were prepared and characterized in terms of their bio-degradability. In the first type, polymers made of ionic liquid monomers were prepared using photo radical induced polymerization of ionic liquid monomers. The second type relies on formation of polyethylene-like n-alkane disulfide polymers from 1,ω-di-thiols through oxidation of thermally activated air. These two families of materials were tested for their biodegradability in soils by using a simulation system that combines a controlled environment chamber equipped with a respirometer and a Proton-transfer-reaction time of flight mass spectrometer (PTR-TOF-MS) system to directly measure the omitted VOCs. This system provides a time-dependent and comprehensive fingerprint of volatiles emitted in the degradation process. The results obtained thus far indicate that whereas the ionic-liquid based polymer did not show significant bio-degradability under the test conditions, the building block monomer, 1,10-n-decane dithiol, as well as its disulfide-based polymer, are bio-degradable. The latter reaching, under basic soil conditions and in room temperature, ~20% degradation within three months. These results suggest that by introduction of disulfide groups into the polyethylene backbone one may be able to render it biodegradable, thus considerably shortening its half-life in soils. Principal component analysis, PCA, of the data about the total volatiles produced during the degradation in soil indicates a distinctive volatile “fingerprint” of the disulfide-based bio-degradable products which comes from the volatile organic compounds portfolio as recorded by the PTR-TOF-MS. The biodegradation volatile fingerprint of this kind of film was significantly different from the “fingerprint” of the soil background which served as a control. These results can help us to better understand and design biodegradable films for various agricultural practices including mulching.

Hydrothermal Decomposition of Plastic – a New Technology to Fight the Long-Term Effects of Agricultural Plastic Usage

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Plastic usage in agriculture was recently estimated as 3.5% of global plastic production. Plastics in modern agriculture serve numerous purposes, all required for food security. Agricultural plastic waste poses difficulties to recycling processes with the current mechanical technologies. It often contains inseparable mixed-polymer products, UV-degraded, and with high content of contaminations (soil, biomass, organics, agro-chemicals). Thus, agricultural plastic waste is mostly landfilled and often leaks into the environment, creates environmental and health risks. Our research suggests a new platform for plastic waste valorization, using a hydrothermal process. The technology is based on decomposition of polymers in a water medium at high temperature (300–400°C) and high pressure (10-22 MPa). This seminar will summarize our current knowledge in 1) degradation mechanisms of various polymers and their mixtures in sub-critical water; and 2) advantages of this technology over commonly used recycling practices and specifically for agricultural plastic waste. Decomposition patterns of three commonly used polymers (LDPE, PET, PA6) will be presented as well as the fate of a multi-layered (LDPE+PA) agricultural mulch film. Identified reaction products and chemical pathways will be given, based on the comprehensive chemical analyses in all phases (solid, liquid, and gas). Our results demonstrate how PET and PA6 polymers can be converted into valuable monomeric compounds, from which a new pristine plastic can be produced. On the other hand, we show that LDPE decomposition is limited, but its presence does not inhibit the decomposition of other polymers during co-processing. The multilayered mulch film treatment resulted in monomer recovery from the PA layer, while the remained solids were identified as LDPE. These results indicate the potential of the hydrothermal technology to achieve closed-loop recycling of plastic waste and promote complex waste processing.

Consequential study of decomposition mechanisms and process efficiency is required to improve waste treatment alternatives and move towards a circular economy and sustainable agriculture.

Poster Session

List of posters

Potential benefits of biochar application to tropical soils: Greenhouse gas emissions, soil improvement and crop yield | *Carlos Eduardo Cerri*
Bioremediation Of cutting fluid using petroleum remediation product | *Jegathambal Palanichamy*
Optimal control of nitrogen processes for groundwater leaching control | *Natasha Katsevman*
Silicon crystals based FTIR-ATR for the rapid monitoring of phosphorus in water coupled with the algorithms of deconvolution and partial least squares regression | *Du Changwen*
Scaling elastic and plastic deformation with porous media permeability during pressurized flow|*Shaimaa Sulieman*
Quantifying the spatial variation of labile phosphorus in the soil by spectroscopy methods | *Yuli Shaham*
Simulating water flow and solute transport at unsaturated soils with unknown initial conditions using physics-informed neural networks trained with time-lapse geoelectrical measurements | *Ziv Moreno*
Monitoring nanoparticle progression and fate in the soil using spectral induced polarization | *Shany Ben Moshe*
PGPR liquid-core capsules to increase available phosphate in soils | *Shir Rabinovich*
Integrated weed mmanagement utilizes sewage sludge by using the hydrothermal technology | *Matat Zohar*
Assessment of the temporal and spatial variability in tree canopy nitrogen content to yield Gap in Almond Orchard Using Remote Sensing | *Ofek Woldenberg*
Simulated herbivory enhances Cd phytoextraction efficiency of sunflowers | *Eyal Grossman*

On the coupling of pressurized flow and elastic expansion of artificial rocks | *Arnold Bachrach*
Evaluating the effects of environmental conditions and biotic factors on antimicrobial activity of algal biocontrol agent | *Bernard Ng'eno*
Impact of soil microbial diversity on seed microbiome and plants productivity | *Uttam Kumar*
Impacts of combined and separate land cover and climate changes on hydrologic responses of dhidhessa river basin, Ethiopia | *Gizachew Wedajo*
Protists modulate enteric bacterial communities in treated wastewater irrigated soils | *Uttpal Anand*
Lateral technology transforming: Bringing an innovative technology from wastewater treatment sector into hyper-intensive aquaculture systems | *Ofir Menashe*
A novel hybrid cross bore - hole ERT inversion method for improved subsoil anomalies detection | *El'ad Gips*
Performance evaluation of biochar from six types of agricultural residues in removal of textile | *Jegathambal Palanichamy*
Identifying the mechanism of complex polyphosphate hydrolysis in plant roots | *Natalie Toren*
Nutrient recovery from waste activated sludge via hydrothermal carbonization to promote sustainable development and food security | *Osama Khoury*
Applying thermodynamic framework to analyze transport self-organization due to dissolution/ precipitation reaction in porous medium at varying peclet number: Entropy, enthalpy, heterogeneity | *Evgeny Shavelzon*
Cation exchange reversibility in organic materials and natural soils | *Bich-Thao Nguyen*
Effect of water and nutrient availability on soil activity in the negev desert | *Martha Osei – Yeboah*

Real-time monitoring of various contaminant adsorption in soil and activated carbon filters using spectral induced polarization | *Jyoti Tyagi*
Effect of NPK Deficiencies on Theobroma Cacao L. Growth and Productivity | *Maya Weinstein*

Session 3a:

Precision agriculture and robotics for improved resource efficiency

Conveners:

Amir Degani and Tarin Paz-Kagan

AI applications for crop health

Spyros Fountas, Borja Espejo

Department of Natural Resources Management and Agricultural Engineering, Agricultural University of Athens

With an expected world population of more than 9.7 billion by 2050, food security is one of the biggest challenges of this century. Efficiently obtaining a high yield while saving resources is a critical objective to achieve. For instance, the reduction in the use of plant protection products, which are often perceived as harmful to human health and the environment, while still obtaining high-quality crops is one of the aims.

In parallel, the use of Artificial Intelligence (AI) to detect as soon as possible the appearance of weeds, or any kind of nutrient deficiency is taking special relevance thanks to its promising results. Moreover, these techniques can also be used for classifying different growth stages and even predicting the final yield based on vegetation indexes. Another advantage of these AI techniques, based on image processing and deep learning, is that they can work in real-time and are less invasive than other traditional methods since they work on platforms like robots, drones, or satellites.

However, deep-learning-based methods have the disadvantage of requiring large amounts of input images, which are usually scarce in the agricultural domain. For that reason, several techniques have been implemented to mitigate this issue and address different agricultural problems. For the purpose weed identification the following applications have been performed: i) the use of transfer learning with Convolutional Neural Networks (CNNs) obtained 99% accuracy on small datasets (less than 1,000 images) with a reduced number of plant species; ii) the use use of synthetic images generated by generative adversarial networks complemented the transfer learning approach boosting the performance to 99.3% and increasing the reliability in noisy images; iii) the use of Automated Machine Learning (AutoML) reduced the engineering time for finding the best architectural configurations; and finally, iv) the use use of transformers instead of CNNs boosted the state-of-the-art performance in a dataset with more than 17,500 images and 9 plant species. For nutrient deficiency detection, the use of an architecture designed by neural architecture search and training with the noisy-student technique achieved an accuracy greater than 98% in sugar beet and greater than 99% in orange trees. For phenology recognition, the detection and classification of different growth stages in broccoli crops reported performances over 80% mAP@50. Finally, in quality and yield prediction, the use of AutoML was able to find the best regressors, vegetation indexes, sensors and growth stages to make the most efficient measurements with an adjusted R^2 of 0.65.

Demonstrating Precision Agriculture with VENμS

Arnon Karnieli

Ben Gurion University

The field of remote sensing enables the acquisition of information about objects on Earth through detecting reflected or emitted electromagnetic radiation in different spectral regions. In agriculture, remote sensing can be applied to explore plant health and characterize different crop cycles in order to save resources, increase profits, and protect the environment. The Israeli-French research satellite VENμS was launched in August 2017 to provide frequent time series of plant characteristics for using precision agriculture with high spectral and temporal resolutions and a fixed viewing angle.

The presentation will demonstrate the advantages of the VENμS spacecraft in terms of unique band setting and frequent revisit time. Three years of the VENμS images were used for characterizing phenological cycles of different crops and evaluating the health and amount of vegetation throughout the period. The findings revealed that it is possible to classify different crops, identify variance within groups of the same type according to their purpose, identify stress, and distinguish different amounts of irrigation and their effect on the yields.

We conclude that precision agriculture combined with remote sensing archives make it possible to identify anomalies and patterns in crop plots and thus make real-time decisions that optimize the management of the agricultural economy.

Almond's flowering phenology assessment by multi-spectral satellite imagery

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Climate change has impacted tree crop production and challenged our understanding of the physiology of deciduous fruit and nut trees during dormancy. A recently developed model establishes a metabolic link between weather temperature, carbohydrates in dormant trees, and their blooming time. To expand the study, a large-scale approach to determine bloom patterns in different environments is needed. In this study, we are developing a method to monitor the flowering dynamics of deciduous tree orchards and detect the flowering's start, peak, and end at each orchard using time series of satellite images. With satellite images' spatiotemporal coverage, this method can monitor orchard conditions and research factors driving almond phenology. The study is focusing on almond orchards in California and Israel. Due to the relatively similar warm climate and the spread of almond orchards across a climate gradient, we will be able to evaluate the effects of climate change on bloom patterns across a wide range of landscapes.

Estimation of Tomato Leaves Orientation for Robotic Early Diseases Detection Using Deep Neural Network Model

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Early detection of diseases in tomato is essential to minimize spreading of the disease in the plot and to reduce crop losses and maintain quality. A robotic system equipped with an electric resistance sensor is developed to reach, grasp, and measure the conductivity of a tomato leaf. The electric resistance is proven to be a significant indicator regarding the plant's condition in early stages of the disease. To grasp a leaf and perform the measurement with a robotic arm, a method for automatically identifying the leaf orientation was developed using data from images of leaves as input to a Deep Neural-Network (DNN) model. An experiment was conducted using an UR5 robotic arm to collect and label leaf images at different orientations and distances. Each image was processed to extract an array containing a list of points of the leaf boundary as well as information of the manipulator position and orientation, and this data is then used as input for the DNN model. The measured information of the robotic position, and the primary known orientation of the first image taken for each leaf, are used to label the "ground truth" orientation with respect to the camera. These labels are used in the process of training the DNN. The DNN then receives the input and produces a spatial vector normal to the leaf's surface. To determine the leaf orientation, several analyses were conducted using one, two and three images of the same leaf in different poses and the differences in the manipulator orientation to take them. The main results show an average accuracy of 11.5 degrees between predicted and real orientation of the leaf's surface. and less than 15 degrees in 90% of the cases, which in most cases, it is sufficient to grasp the leaf and perform the

measurement. In addition, the DNN model results were analyzed to optimize the robotic motion to best predict the leaf's orientation and improve the accuracy. Those results are satisfying for the robotic end effector to perform the measurement of the leaf's resistance.

How Sensitive is Thermal Image-based Orchard Water Status Estimation to Canopy Extraction Quality?

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Orchard water status estimation can be significantly affected by the extraction of canopy pixels from a thermal image. While a number of techniques are described in the literature, as yet there is no comprehensive quantitative comparison of orchard water status estimation using different canopy extraction methods. This study tested the hypothesis that orchard water status estimation is significantly sensitive to canopy extraction quality. The accuracies of four canopy extraction methods were compared and the effect on water status estimation was explored. The methods included: 2-pixel erosion (2PE) where non-canopy pixels were removed by thresholding followed by morphological erosion; edge detection (ED) where edges were identified and then morphologically dilated; vegetation segmentation (VS) using statistical analysis of the temperature histogram followed by spatial watershed segmentation;

and RGB-binary masking (RGB-BM) where an RGB image was used to statistically extract a binary canopy layer to mask the thermal image.

Field experiments took place in a 4 ha commercial peach orchard during the primary stage of fruit growth (stage III) that was divided into 22 management cells (MC). The relationship between stem water potential (SWP) and crop water stress index (CWSI) was established in 2018. During 2019, ten thermal infrared and two RGB images were acquired. The canopy extraction methods yielded differences in accuracy: on 12 Aug, the overall accuracy was: 83% (2PE), 77% (ED), 84% (VS), and 90% (RGB-BM), indicating that the RGB-BM method was the most accurate. Despite the high accuracy of the RGB-BM method, canopy edges and between-row weeds were misidentified as peach canopy pixels, resulting in a skewed right distribution of temperature. The VS method was unable to adequately remove warm canopy edges. Canopy temperature and CWSI were alternatively calculated using the average of 100% of canopy pixels (CWSI_T100%) or the average of the coolest 33% of canopy pixels (CWSI_T33%) per MC. The CWSI_T100% produced substantially higher average values than CWSI_T33% per canopy extraction method with the VS and RGB-BM values considerably higher than 2PE and ED. SWP-CWSI models based on CWSI_T100% values were found to be inferior to those using CWSI_T33%. Moreover, the CWSI_T33% dataset produced similar SWP-CWSI models irrespective of the canopy extraction method while CWSI_T100% yielded very different models.

This study's results highlighted that: 1) The contribution of the RGB images is not significant for the canopy extraction stage and canopy pixels can be extracted with high accuracy and reliability solely with thermal images if spatial analysis is incorporated; and 2) the T33% dataset produced similar SWP-CWSI models, despite differences between canopy extraction methods, implying that the T33% approach to canopy temperature calculation is more robust and superior to the simple mean of all canopy pixels. The results from this study support the use of thermal images for water status estimation in peach and apparently for other orchards as well if statistical and spatial analysis are used together with the T33% approach to calculate canopy temperature.

Leveraging Data Standardization to Allow Data Sharing, Better Collaboration and Agronomic Big Data Analysis

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The quantity and scope of agronomic data available for researchers in both industry and academia is increasing rapidly. Data sources include a myriad of different streams, such as field experiments, sensors, climatic data, socioeconomic data or remote sensing. The lack of standards and workflows frequently leads agronomic data to be fragmented and siloed, hampering collaboration efforts within research labs, university departments, or research institutes. Researchers and businesses therefore allocate significant time resources into unifying these fragmented data layers to a coherent structure. Implementing data standardization schemes can enable efficient collaboration, and leveraging the collective power of the research community to address critical agronomic knowledge gaps. This presentation will provide an overview of available research data standardization tools and explain the underlying FAIR and other data management principles. Using Agmatix's Axiom platform as an example, we will demonstrate how data from multiple sources can be standardized and used for insightful modeling. Three use cases will be presented: i) the GCNRD, a new global database of crop nutrient removal rates, the result of a collaborative effort of IFA, APNI, WUR and ISDA and many other partners; ii) A machine learning based corn prediction model developed using multiple data sources in the US – machinery data, public databases and experimental data; and iii) a machine learning model to predict soybean Sudden Death Syndrome in the US, the collaborative work of 7 universities and research centers in the US and Canada. Standardization unifies all datasets to common headers and

units, allowing to explore data distributions and trends. Furthermore, standardizing the data enables researchers to gain new insights, which were previously unavailable when the data files were fragmented. Thus, standardization can accelerate the finding of new insights and efficient collaboration between multiple stakeholders. We call on the agronomic research community to adopt data standardization schemes, boost their collaboration efforts, and increase the potential for tackling the current global agronomic challenges.

Session 3b:

Addressing the agricultural water cycle

Conveners:

Adi Radian and Itamar Nadav

Towards a more sustainable reclaimed water reuse practice: Facts and Figures

Despo Fatta-Kassinos

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Even though wastewater reuse is a strategy that is rapidly expanding on a worldwide level, there are still several issues to be addressed with respect to the presence of contaminants of emerging concern (CEC) and Antimicrobial Resistance (AMR) in treated wastewater. The need to look beyond the conventional contaminants when assessing the potential risks of wastewater with respect to ecosystems and human health is recognized as a priority issue in all policy areas at the EU level and beyond. This talk will address the global challenges in relation to water stress conditions, and the considerable efforts made regarding the application of advanced treatment technologies, such as membrane filtration, adsorption on activated carbon and advanced chemical oxidation processes (AOPs), to improve the effluent quality with respect to the presence of such contaminants, in an effort towards a more sustainable practice of reclaimed water reuse. Several knowledge gaps regarding wastewater discharge and reuse in relation to CEC and antimicrobial resistance (AMR) will be highlighted. It has become clear that new strategies consistent with the precautionary principle and the "One Health" approach are needed to assess the overall quality of wastewater intended for reuse. Knowledge regarding risks that relate to low-dose exposure of CEC to non-target organisms, crops' uptake, and AMR is only now starting to shape. This talk aims at addressing these important issues.

Restoring riparian ecosystems to provide multiple sustainable agricultural benefits

Orah Moshe

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Riparian areas, especially in the Mediterranean, offer many ecosystem services that protect and support the environment and benefit society. Despite this, these areas have become highly degraded, especially on farms. Strong pressure exists on aquatic ecosystems and water resources, deriving from agricultural production, climate change, and population growth, threatening our water resources and riparian ecosystems. To optimize agricultural production, native riparian vegetation is often completely eradicated and replaced with crops, sprayed with herbicides until the stream edge, or left with only a narrow strip of ruderal herbaceous vegetation. The Mediterranean Basin is considered one of the most sensitive regions to climate change impacts, with riparian ecosystems one of the most threatened, increasing the importance and value of our stream network and their riparian ecosystems. Rain-driven soil erosion commonly occurs in Israel at the onset of the rainy season, while many fields are bare, and lack vegetation cover. Soil erosion results both in a loss of soil resources, especially on sloped lands, and degradation of soil health and water quality. Transported in rainfall-runoff with the sediments are both dissolved and sediment-bound agricultural chemicals (fertilizers and pesticides). This transfer during storm events from fields to streams results in decreased soil productivity and degradation of water quality in receiving waters. Climate changes will likely exacerbate this problem with more intensive storms and higher erosion rates. Restoring functional native vegetation at the land-water interface has the potential to mitigate agricultural impacts, as it can provide multiple ecosystem benefits, such as reduced soil and streambank erosion, while simultaneously capturing eroded sediments, thereby conserving soils and reducing nutrient losses by increasing plant nutrient uptake, protecting water quality. The goal of this research is to restore riparian ecosystems and quantify potential ecosystem benefits to soil conservation, runoff filtration, water quality protection, and accumulation of organic matter. Global studies show advantages of this strategy as improved soil biota leads to improved soil health, improved infiltration capacity leads to reduced flooding, and habitat creation leads to increased biodiversity on farms. This practice can result in a win-win scenario with restored riparian ecosystems providing recreational value and improving real estate values. A better understanding of the interconnectedness between our land uses, stream networks, riparian ecosystems, water quality, and the strategic role of individual plant species will support long-term sustainable agricultural objectives. *We present examples of riparian ecosystem restoration projects that* provide a range of ecosystem services and improve resilience to climate change. Results from this study support targeting riparian ecosystem restoration as an important part of sustainable agricultural practices and facilitates the adoption of this practice as an agroecology best management practice. More data are needed to support implementation by farmers, drainage authorities, municipalities, and other stakeholders interested in restoring riparian ecosystems and other conservation agricultural strategies.

Soil Moisture Data Assimilation to Estimate Irrigation Water Use

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Knowledge of irrigation is essential to support food security, manage depleting water resources, and comprehensively understand the global water and energy cycles. Despite the importance of understanding irrigation, little consistent information exists on the amount of water that is applied for irrigation. In this presentation, we present the development and evaluation of a new method to predict daily to seasonal irrigation magnitude using a particle batch smoother data assimilation approach, where land surface model soil moisture is applied in different configurations to understand how characteristics of remotely sensed soil moisture may impact the performance of the method. The study employs a suite of synthetic data assimilation experiments, allowing for systematic diagnosis of known error sources. Assimilation of daily synthetic soil moisture observations with zero noise produces irrigation estimates with a seasonal bias of 0.66% and a correlation of 0.95 relative to a known truth irrigation. When synthetic observations were subjected to an irregular overpass interval and random noise similar to the Soil Moisture Active Passive satellite (0.04 cm3 cm−3), irrigation estimates produced a median seasonal bias of <1% and a correlation of 0.69. When systematic biases commensurate with those between NLDAS-2 land surface models and Soil Moisture

Active Passive are imposed, irrigation estimates show larger biases. In this application, the particle batch smoother outperformed the particle filter. The presented framework has the potential to provide new information into irrigation magnitude over spatially continuous domains, yet its broad applicability is contingent upon identifying new method(s) of determining irrigation schedule and correcting biases between observed and simulated soil moisture, as these errors markedly degraded performance.

A Comparative Study on Uptake of Chromium and Zinc in Pulses from Electroplating Effluent Using Electro-Kinetic Remediation

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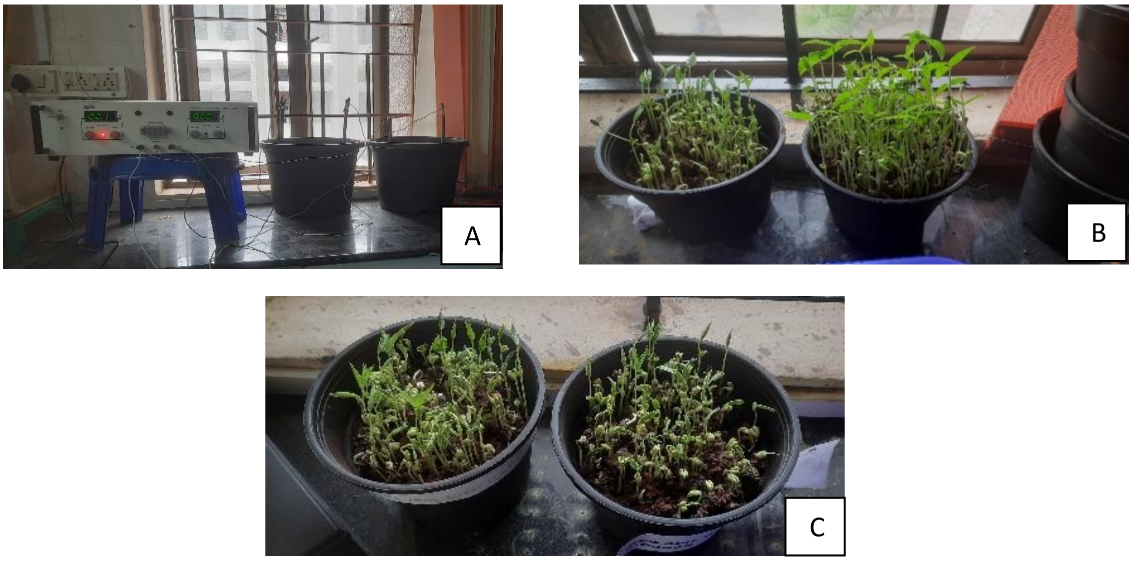
Water Institute, School of Agricultural Sciences, KITS, Coimbatore

Coimbatore district has agriculture land area of 165260 hectare. The major crops in this district include pulses. There are nearly 25000 small, medium and large-scale industries in the city. Heavy metals present in the industrial effluent affect the plants by damaging cellular biomolecules like nucleic acid, lipids and proteins. This study is conducted by using the effluent water from electroplating industry for growing black-gram. It involves electro-kinetic remediation of contaminated soil. Chromium is one of the main heavy metal present in the waste water from electroplating industry. At lab level, the experiment was conducted by mixing loamy sand soil with the waste water collected from the electroplating industry. The Ph of the water used was found to be 11.81, TDS value was 2.95g/L and hardness was found to be 0.0021mg/L. Carbon electrodes are inserted to the soil through which electricity is passed. A constant voltage of 22v is supplied to the electrodes. A controlled column without electrokinetic remediation is set-up for comparison of results. The results are inferred based on three observations- test on water quality parameters such as pH, electrical conductivity, chromium content, chlorides, fluorides, sulphates and nitrates, test on soil parameters such as physical properties, organic carbon content, pH, electrical conductivity and NPK values and plant nutrient uptake. The results were monitored in 15 days interval and the required tests were conducted and the results were recorded. It was observed that more than 80% of chromium is removed from the centre of the reactor whereas 60 % removal occurred near anode. Also the growth of the plants is higher in the rector with biochar than in the control reactor (Fig B).


A
B
C

Identifying "under the radar" pathogen indicators and antibiotic resistance genes in treated wastewater irrigated produce and soil

Eddie Cytryn

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Treated wastewater contains antibiotic resistance determinants, but there is conflicting evidence regarding the persistence and epidemiological potential of antibiotic resistance constituents in irrigated ecosystems. We explored the fate of antimicrobial resistance determinants in treated wastewater, irrigated soil and crops, and the capacity of wastewater-derived determinants to persist or proliferate following prolonged residence in the environment. Antibiotic resistant bacteria and associated resistance genes persisted poorly in-irrigated crops and soil, seemingly due to the resilience of environmental microbiomes. Nonetheless, short-term inoculation of soil and produce in nutrient-rich medium resulted in proliferation of wastewater-derived multidrug resistant E. coli, underlining the fact that "not detected" is not necessarily "not present". Similar inoculation experiments revealed anthropogenically-facilitated differences in microbiomes and resistomes that were not apparent in direct analyses .

Collectively, our results demonstrate the power of ecosystem functioning in mitigating antimicrobial resistance, but also provide evidence that hazardous antibiotic resistance determinants can persist "under the radar". Application of "under the radar" data to quantitative microbial risk assessment models can be fundamental in understanding and mitigating epidemiological risks associated with treated wastewater irrigation.

Diluting effluents for irrigation as an alternative for disposal of dairy wastes

Itamar Nadav

Netafim Ltd.

Animal farming, as well as biogas energy production, causes an increasing environmental challenge due to their environmental footprint which includes CO^2 and NOx gas emissions, soil and water pollution by nitrates, and more. Public pressure, as well as regulation, forces farmers to more efficient and environmental effluents spreading methods, but also economically feasible. Nitrogen pollution is one of the main concerns in EU, and in fact, limits the amount of applied nitrogen in open fields which means, limiting the amount of effluent spreading. The allowed nitrogen application by regulations in the EU stands on 170 Kg of nitrogen per hectare, annually. This limitation forces farmers to find more fields to apply their effluents in the cost of long traffic and land rental. The common practice today for effluent spreading in the EU and USA is on surface by tractor pulled tankers or draglines. This spreading practice limits the spreading period to early season, before planting, or late season, after harvest, when the filed has no crop. Those spreading periods have both high risk of rainfall which can cause high nitrogen leaching and runoff during rain events. In addition, the spreading of the nitrogen outside the growing season, reducing the effluent originated nitrogen use efficiency. In some of the dairy farms in the USA, flood irrigation is still the most common practice, and when the dairy farm effluents are diluted in the flood water, the risk of nitrogen leaching increases. Our solution suggests the use of the drip irrigation system as an effluent spreading platform, where the effluents are filtered and then diluted in the irrigation water and applied during irrigation events in small quantities. In a biogas facility pilot, effluents were diluted in 1:10 ration with freshwater for corn irrigation with SDI (subsurface drip irrigation). In this experiment, the nitrous oxides emissions reduced by almost 50% compared to the conventional on surface spreading. In a dairy farm in California, USA, the effluent spreading with SDI has reduced the nitrogen application by 45% and reduced water application by 35%, compared to flood irrigation with effluents. Those experiments demonstrate alternative method for economically and sustainable disposal of effluents from animal and energy production using simple drip irrigation system.

Session 4a:

Precision agriculture and robotics for improved resource efficiency (cont.)

Conveners:

Amir Degani and Tarin Paz-Kagan

Development of Autonomous Robotic Weeding System

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Weeding in crops such as watermelons is usually conducted manually due to unstructured growth in all direction and the limitation on herbicides that can be used. The automation of the weeding process will contribute to coping with the decline in the number of workers in agriculture and the high variability among working days due to weather, time of operation, crop growth status, and more. The operation of an autonomous robotic weeding system is twofold: 1) A robotic platform that can navigate the plot and reach the weeds, and 2) a real time weed detection system to determine which plants need treatment. A prototype of such robotic system is developed at Agricultural research organization (ARO). The robotic platform is a skid steer four wheels driven by two brushless motors, the platforms facilitate an electrostatic weeding device attached to two linear stages. The weeding device can reach the target weeds with less than 3 millimeters in each axis.

The weed detection system composed by custom built multispectral imaging system that uses four monochromatic cameras, each with a 10nm band pass filter. The centers of the filters are at 480, 550, 680 and 750 nm. An experiment was conducted in June 2022, with 20 crop plants of the cultivar 'Mallali' watermelon and 47 plants of different weeds types, 20 Solanum nigrum, 20 Setaria and 7 Sinapis alba. The plants images were captured in five different days and hours during the days. A semi-automatic labelling process used NDVI to segment the vegetation from the background. Images with only watermelon plant were labelled as crop where the other images with single vegetation type were considered as weed. More than 11

million pixels were extracted from the images, 48% of the pixels labelled as crop. The labelled data was used to train an XGBoost classifier with an 80-20 train and test split. In this case we only used the spectral reflection that was captured by each of the cameras through the band pass filters. The classifier showed 69% accuracy on the test data. The validation of the classifier was on images with mixture of crop and weed plants. In these images the crop leaves were classified correctly with high accuracy, however the stems of the crop plant were classified as weed. Furthermore, for Solanum nigrum weed some of the leaves were classified as crop.

The use of open-source, affordable hardware in precision agriculture

Elad Levintal

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

The development of new affordable sensors, and the ability to log high-resolution data for long periods of time at a low cost can add new capabilities for precision agriculture applications. The use of novel open-source sensors, defined as hardware whose design is made publicly available, lowers the cost dramatically compared to commercial solutions and allows implementing higher spatiotemporal resolution sensor grids that are imperative for more efficient and sustainable agriculture. Here, I will present the basic concepts, advantages, and challenges of using open-source, low-cost, do-it-yourself hardware for agriculture monitoring, including examples in which open-source hardware was utilized to solve research questions. For example, the development and validation of a low-cost wireless underground sensor network for agriculture soil monitoring using the relatively new and open low-power long-range (LoRa) communication protocol. The cost of the data logging, power, and communication components is only ~$150, one or two orders of magnitude smaller than other available commercial solutions. Another example is a portable, low-cost incubation chamber for quantifying agricultural soil microbial activity. In-situ sensors within the chamber measure carbon dioxide, oxygen, and air temperature at high temporal resolution (1 min). In all the presented studies, only readily buyable hardware was used, and complete technical guides on design, assembly and installation were provided. By doing so, the adoption and cost barriers can be reduced, allowing easier reproducibility and opening the technology for new applications in precision agriculture, soil, and environmental monitoring studies.

A methodology to characterize an optimal robotic manipulator for selective spraying of nano materials in vineyards

Roni Azriel

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In this research, a methodology for finding the optimal kinematic configuration of a robotic manipulator for a specific task is presented. Optimizing the manipulator's design would allow it to perform the task more effectively than a universal robot. For an investigated spraying task, manipulators with 4,5 or 6 DOF were considered. By using environmental and conceptual assumptions and constrains 3,250,733 potential manipulator configurations were defined. The optimization objective composed by three criteria: Manipulability Index, Mid-Range Joint Proximity and Reachability. The performance of each robot configuration has been evaluated through simulation developed using ROS, Gazebo simulator, and Moveit motion planning framework . To simulate the robot performing the task approximately 30 seconds are required and due to the size of the search space, not all potential arms can be sampled. Therefore, a Particle Swarm Optimization (PSO) algorithm was implemented to find the optimum. The algorithm was further optimized by training an artificial neural network (ANN) to predict if the robot managed to reach the clusters, to reduce the use of simulator during the optimization process. Results shows that the ANN is able to predict the reachability with accuracy of 83%, therefore can perform as threshold for using the simulator. The rest of the research deals with comparing the results of the algorithm with and without the combination of the network.

Predict crop yield using Satellite solar-induced chlorophyll fluorescence-based semi-empirical model without calibration

Oz Kira

The estimated increase in food demand and predicted agricultural vulnerability to climate change pose a significant threat to global food security. This is of international concern, especially for developing nations in the coming decades. Accordingly, it is critical to monitor agriculture to help mitigate expected short- and long-term disruptions in the global food supply. An agricultural monitoring challenge is remotely estimating crop yield in real-time with high accuracy and at a low cost. This is especially important for areas with a limited framework for in-situ surveying.

The recent advent of satellite Solar-Induced chlorophyll Fluorescence (SIF) remote sensing promises to improve real-time crop monitoring. In this research, we offer the use of semi-empirical mechanistic models for predicting crop yields (MLR-SIF). The advantage of such a model is that it does not need preliminary information for calibration compared to statistical models, e.g., machine learning. We used the MLR-SIF model to estimate crop GPP and predict the crop yield of corn and wheat in USA and India, representing two regions that differ in location, conditions, and ground data quality. Additionally, we harnessed recent advances in SIF products to improve crop yield prediction by overcoming technical limitations related to spatial/temporal resolution and retrieval noise.

In the US corn belt, the MLR-SIF-based yield model yielded a %NRMSE of 8.87% and R2 of 0.53, while the neural network model yielded a %NRMSE of 7.2% and R2 of 0.65. After optimization, the MLR-SIF-based yield model precision was improved to a %NRMSE of 7.02% and R2 of 0.67. In India's Wheat belt in the eastern Indo-Gangetic Plain, the MLR-SIF-based yield model yielded a %NRMSE of 15.7% and R2 of 0.56, while the neural network model produced a %NRMSE of 24.2% and R2 of 0.02 .

The MLR-SIF model utilizes a newly developed parasomnias SIF-dependent model to estimate GPP and crop yield. This is a standalone model that does not need preliminary data for calibration. While statistical models (such as the NN presented in this study) are highly accurate with high-quality data input, the MLR-SIF models can predict single field yield, better for developing regions with smaller farms. In the IGP-WB region, the MLR-SIF model was superior to the NN model but came short due to the limited ground data.

Assessing the Effects of Pollution on Vegetation cover using Remote Sensing in a Desert Environment

Julius Bamah

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In mining communities, soils, vegetation, streams, springs, and groundwater are at risk of pollution by its by-product storage mode, ore hauling, pit water, and ore processing wastewater. During the 1980s, the warden of the Nature Reserve Authority reported a significant increase in chlorinity and nitrate concentration in the water of Ein Aqrabim spring that flows in Israel's Negev desert. The cause of pollutants in the spring was traced to a wastewater reservoir derived from the extraction of phosphorite ore in the area.

In this regard, we measured the contaminates in the polluted spring and investigated the possible changes caused by pollution in the leaf spectral, biochemical, and physiological composition of maize (Zea mays) and basil (Ocimum basilicum) in the greenhouse environment.

Our results revealed that the polluted spring contained elevated concentrations of heavy metals; As, B, Se, Sb, Ni, and Mo, about three times beyond the maximum concentration limit for drinking water. Decreased chlorophylls and stomatal conductance were observed with increased concentrations of contaminants on the selected species in the greenhouse experiment. The hyperspectral curve in the visible spectral range showed strong sensitivity to pollution exposure.

Based on our work, we conclude that remote sensing technology has the potency for early detection of pollution and its effects on vegetation.

Predicting of canopy nitrogen content based on UAVs and satellites data fusion in citrus orchards

Avioz Dagan

Faculty of Civil and Environmental Engineering, Technion, Israel

Nitrogen (N) is often regarded as the most critical nutrient and the growth-limiting factor in soil for plant growth and often needs to be supplemented by N-fertilization to minimize yield loss. However, the over-application of N fertilizers may cause nutrient imbalance and contribute to groundwater contamination by nitrate (NO3-) leaching and NOx air pollution. Today the evaluation of plant nutritional status (including N content) is mainly based on chemical analysis of leaf samples in the lab'. These are costly and time-consuming, not represent the agricultural system's spatial and temporal variability. This study suggests investigating the ability to combine Sentinel-2 data with unmanned aerial vehicles (UAV) to derive canopy nitrogen content (CNC) in citrus orchards. A new framework to infer the N content in citrus-tree canopy-level using spectral data and vegetation indices with the ML algorithm wad suggested. The framework includes six steps (1) leaf sampling for N content data, (2) image preprocessing of UAV and satellite data, (3) segmentation of canopies and estimation of plant area index, (4) feature extraction, (5) model calibration and validation based on ML models, and (6) the development of site-specific N management model. We integrated data from Sentinel-2 satellite and UAV images using bi-monthly data collected in the past three years to estimate CNC. Several machine learning algorithms were tested to assist tree CNC derived from UAV data, resulting in R2=0.86, RMSE=0.84 based on a random forest model. The suggested model was proven flexible and could include different or additional variables, enabling the delineation of site-specific nitrogen management (SSNM) zones in orchards. These could be used to reduce the need for chemical analysis of the leaf tissue and optimizes the CNC monitoring by considering the spatial and temporal variability in the citrus orchard on different scales.

Combining Data Assimilation and Model-Based Optimization for Managing Irrigation: Some Lessons Learned from a Simulation Study and a Field Test

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In previous works we have developed a number of model-based optimization frameworks for irrigation scheduling. Although the performance of such approaches are affected by weather forecasts uncertainty, we have shown that the impact of imperfect weather forecasts can be mitigated by repeating the optimization and updating the irrigation schedule several times throughout the season. Another obvious limitation of any model-based optimization framework is the imperfectness of the model which is used in the optimization process. To address this issue we have developed a framework in which data assimilation and partial re-parametrization of the model are performed before each optimization in order to reduce the model imperfectness. Since the number of measurements are typically small while the model includes a large number of parameters, sensitivity analysis is performed before performing data assimilation, which ensures that only influential parameters are adjusted. The framework was tested with the model DSSAT-CROPGRO for a processing tomato crop in Davis, CA, both via simulations and in a field trial. In the simulation study several scenarios that differed in terms of the measurements assumed to be available for assimilation (leaf area index, biomass and/or soil water content) were investigated. The results were compared to a benchmark scenario involving a perfect model, as well as a scenario in which data assimilation was not performed. Compared to the “no assimilation” scenario, assimilating weekly measurements of leaf area index improved the results dramatically and led to overall performance that was within 3% of the benchmark performance. Adding weekly measurements of biomass or daily

measurements of soil water content did not improve the performance. However, the results of the experimental trial were less conclusive and the assimilation of LAI measurements led only to minor changes compared to the “no assimilation” case. Possible explanations for these contrasting results will be discussed in the talk.

Session 4b:

Addressing the agricultural water cycle (cont.)

Conveners:

Adi Radian and Itamar Nadav

UV-LEDs for biofouling mitigation during drip irrigation with reclaimed wastewater

Yael Gilboa, Barak White, Inbar Shlomo, Ilan Katz, Yuval Alfiya, Ariel Weinstock, Eran Friedler

Faculty of Civil & Environmental Engineering, Technion, Israel

Drip irrigation with treated wastewater effluent (TWW) has become common in the last decades and is advantageous because it is water efficient, maximises root nutrient uptake, minimises weed growth, and reduces farmers' exposure to pathogens possibly present in the irrigation water. Unfortunately, emitters often clog due to biofilm formation. Chlorination is the most common method for reduction of emitters' bio-clogging; however, it has many disadvantages including chemical handling, capital/operation costs, formation of disinfection by-products, and detrimental agricultural and environmental effects. UV-LEDs (ultraviolet light emitting diodes) are a non-contact, non-chemical disinfection method that has great promise for disinfection and biofouling prevention in drip irrigation systems. UV-LEDs have small size, robust construction, low power requirements, and long serviceable life. UV-LEDs do not require start-up time and can be turned on/off frequently making them ideal for intermittent flow applications typical of drip irrigation systems.

This research applied UV-LED irradiation to reduce biofouling of drip irrigation lines fed by TWW and explored whether UV-LEDs may serve as an alternative to chlorination. Bench-scale experiments were conducted to demonstrate fundamental principles of UV-LED disinfection and evaluate its inactivation efficacy of biofilm-forming bacteria. Fluence of UV-LED was characterised using irradiance measurements and inactivation experiments in a collimated-beam apparatus and a flowthrough reactor. These analyses enriched the knowledge of operating and controlling of UV-LEDs in any structure.

Pipe loops laboratory-scale pilot (Fig. 1) was constructed to study the biofilm formation reduction efficiency of UV-LEDs and chlorination. The experiment used synthetic TWW for irrigation, distributed to three lines (treatments): Chlorination, UV-LEDs, and Control.

Flowrate was continuously monitored in selected drippers of each line and data was stored in a datalogger. The pipe loops experiment lasted eight weeks with six hours irrigation per day.

The drippers' discharge in the control line decreased to 60-70% of their initial discharge, while drippers' discharge of the chlorine and UV-LED lines remained higher (above 90%). Similar results were obtained for the uniformity coefficient.

Biofilms were assessed using traditional tools (TSS, CFU etc.) and Extracellular Polymeric Substances (EPS) analysis, which evaluates the fundamental components of the biofilm and determines its physicochemical properties, and by Optical Coherence Tomography (OCT), which visualises the biofilm structure. The total amount of extracted EPS was 4.7 and 1.5 times higher in the biofilm of the control line compared to UV-LED and chlorine biofilm, respectively. OCT strengthened these results; almost complete clogging was observed for the control line and a limited clogging at the chlorine and UV-LED line.

The results indicated that UV-LED can significantly reduce biofouling of drip irrigation fed by TWW compared to the control. The UV-LED and chlorine effects were quite similar; however, UV-LED may be located along the irrigation line as an integral part of the system and does not require chemical addition, and therefore may serve as a suitable replacement chlorine.

Based on these promising results a field-scale system was constructed to assess the UV-LEDs performance using real TWW under realistic conditions.

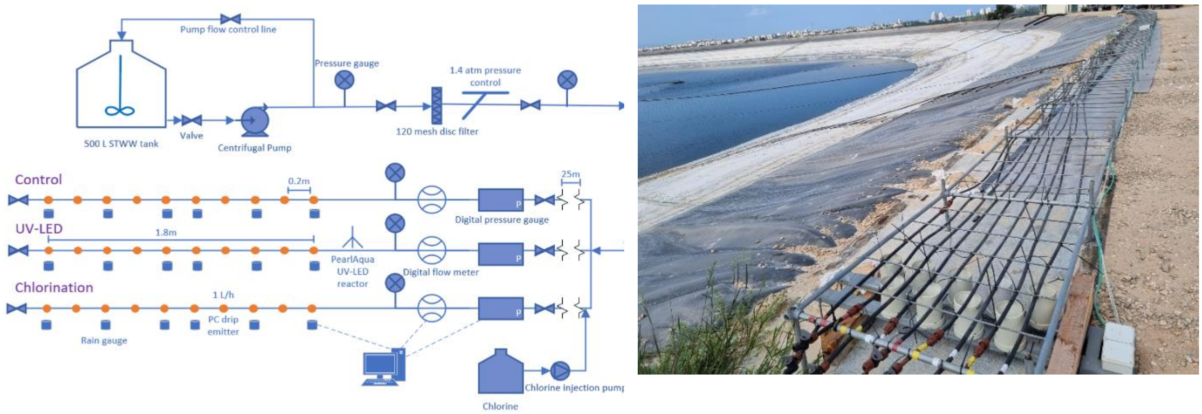

Figure 1. The experimental systems

Left – Laboratory-scale pipe loops (schematic); Right field scale irrigation system

Towards robust mainstream anammox: the tale of NOB control

Xiaowu Huang

Guangdong Technion - Israel Institute of Technology

Global challenges related to water shortage and energy security have become unrelenting with the fast population growth, urbanization and large-scale industrialization. Wastewater treatment plant (WWTP) plays a central role in recycling the water resource in ecosystem, but unfortunately with a high demand of energy consumption, accounting for approximately 3% of the electricity load of a nation. Mainstream anammox – an innovative energy-efficient biological nitrogen removal alternative to traditional nitrification and denitrification – promises energy-autarky or even energy-positive WWTPs. Hitherto, anammox has been mainly developed and applied in full-scale to treat ammonia-rich wastewaters, known as sidestream anammox (over 100 installations by 2014). Mainstream anammox has been attested at laboratory-, bench- and pilot-scale in many places, and its full-scale applications are still restricted. The control of nitrite oxidizing bacteria (NOB) has been previously regarded as an outstanding obstacle towards robust operation of mainstream anammox processes. This talk will serve as an idea-exchange and experience sharing on the tale of NOB control in mainstream anammox from laboratory and pilot-scale trials with the intention of brainstorming peers to conduct advanced studies to further impel the development and wide application of mainstream anammox. Our laboratory-scale mainstream anammox study presented stable nitrogen removal of 109.9±15.3 g N/m3/d with the persistence of Nitrospira, representing 1.5%-1.9%. Batch tests and microbial analysis jointly suggested that partial denitrifying populations (3.6%-10.3%) offset the NOB's activity by redirecting NOB-produced nitrate to nitrite, which in turn reinforced the growth and activity of anammox bacteria. The pilot-scale trial of saline mainstream anammox also delivered stable nitrogen removal of 50.1-78.3 g N/m3/d whilst Nitrospira persisted (over 1%) in over 2-years operation. More noticeably, the steady proliferation of anammox bacteria on biofilms coincided with the incursion and overgrowth of Nitrospira. The genomic study revealed the C-N-S synergy of nitritation, anammox, sulfate reduction, and mixotrophic denitrification in the system.

Especially, sulfur-dependent denitrifiers played a vital role in offsetting the NOB activity. Collectively, we proposed that the washout of NOB is not obligatory towards robust mainstream anammox, and the control of limited dissolved oxygen and temporary introduction of anaerobic operation are effective to convey good control of NOB, through the mysterious synergetic microbiome. Further, remaining challenges including the enrichment of anammox bacteria and biomass retention will be outlined so as to inspire the development of innovative and concrete technologies.

Agricultural streams are the "Canary in the cage" of the agriculture water cycle

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Agricultural streams are degraded riverine systems. They are dysfunctional systems hydrologically, geomorphological, and ecologically due to long-term negative anthropogenic impacts, therefore, they reflect the lack of resilience and sustainability of the agricultural system at large. We demonstrate that agricultural streams can be considered the "canary in the cage" analog for the agricultural water cycle. This study provides a holistic overview of the causes and outcomes of the interweaving complex feedback that we are to understand and solve if we aim to restore and rehabilitate agricultural streams as a fundamental requirement for sustainable and integrated water resource management at the catchment scale.

The study identifies four stressors related to the agriculture water cycle (i.e., in Israel): 1. Land use fragmentation and poor management - reduced rainfall infiltration into the soil and accelerating runoff water route to the stream, and large quantities of soil losses; 2. Freshwater harvesting reservoirs - decrease the natural flow regime (base- and, flood flows) and damage the riverine system's self-process-based maintenance and recovery mechanisms; 3. Reclaimed water discharges to streams and their water quality – nutrient-rich fluxes via surface and subsurface drainage lead to changes in riparian vegetation diversity and fluvial dynamics; 4. Flood protection management and regulation – enforcing high carbon intervention actions, such as dredging bed sediment to maintain channel capacity to convey designed water discharges.

We elaborate on each cause and use the Nahalal Stream Watershed as a living laboratory, which is part of the Model Farm for sustainable agriculture at the Neve Ya'ar Agricultural Research Center. In addition, we demonstrate potential solutions for improving the agricultural water cycle and gaining a resilient agricultural system. As part of this effort, we run extensive research and monitoring programs. The latter includes climate parameters (rainfall quantities and intensities, evaporation); stream water discharge; water quality (heavy metals, agro-chemicals, pH, EC, and nutrients); suspended sediment concentrations and dredged sediment quality; morphological parameters; and riparian vegetation surveys. The big data set is used to base success indicators for the upper Nahalal Stream restoration project.

Removal of micropollutants of emerging concern from treated effluent used for agriculture irrigation

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As water shortage has become a worldwide problem, many countries see irrigation with treated wastewater effluent as means to secure agricultural production in areas suffering from freshwater scarcity. Such effluent reuse requires advanced treatment to remove micropollutants of emerging concern (MPs) that are not efficiently removed in conventional wastewater treatment, and to minimize environmental and health concerns. The effluent of wastewater treatment plants contains a wide range of MPs, which remain in the water after the treatment process. In countries like Israel, where extensive agricultural wastewater reuse is practiced (reusing ~90% of all treated effluent generated), the effluent should meet higher quality requirements in order to minimize risks.

Advanced oxidation processes (AOPs) are promising solutions for removing MPs traces from various water types, including wastewater effluent. AOPs are based on in-situ generation of highly reactive oxidants, mainly hydroxyl radical (·OH), that degrade MPs up to full mineralization. Vacuum UV radiation (VUV; wavelengths < 200nm) has been successfully applied for AOP. The high energy photons generated by the VUV irradiation photolyze water and generate ·OH without the need for chemical (e.g., H_2O_2 or O_3) and catalyst (e.g., TiO_2) addition, giving the process potential economic, operational, and environmental advantages over conventional AOPs. VUV-AOP usually uses low-pressure mercury lamps (LP-Hg) emitting mainly at 254nm (~90% of the radiation flux) with a small VUV emission at 185nm (~10% of the flux). Using this technology, we investigated the removal efficiency of many MPs from different groups (such as personal care products, chlorinated organic pollutants, and pharmaceuticals), under different water matrixes (deionized water, synthetic solutions, groundwater, surface water, greywater, and wastewater effluent). In all cases, addition of VUV radiation enhanced the process efficiency, but in realistic water matrices, the effect was weaker due to presence of organic and/or inorganic compounds that compete for the photogenerated OH radicals (e,g, carbonate/bicarbonate, chloride ions). This phenomenon is not unique to VUV-AOP but appears in all AOPs. Several treatments for reducing inorganic-alkalinity prior to VUV irradiation were tested, including ion separation by electrochemical desalination technology and acidification to pH 5 (the letter shifts the carbonate system to its most protonated form (H_2CO_3) that has negligible reactivity towards ·OH). Both methods improved the effectiveness of the VUV-AOP significantly.

An additional path to improve the applicability of VUV-based AOP, is development of an affordable new light source that emits mainly in the desired VUV spectral region. Here we compare the degradation of carbamazepine (antiepileptic medication) and its main by-product acridine in water solutions under a commercial LP-Hg lamp and under a new custom-built Xe_2 microcavity plasma (McP) lamp with a phosphor wavelength converter film that has a broadband emission range 165-200 nm. The results indicate that the McP lamp has a high potential for water treatment but its emission spectrum is not yet optimized. Furthermore, this type of lamp provides additional advantages relative to the commonly used LP-Hg lamps, such as zero warm-up time and flat geometry that provides much higher flexibility in reactors' design.

The Economic Cost of Wastewater Quality Standards

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Population growth steadily increases the demand for food and for freshwater for domestic and industrial usage, where the former rises the demand for irrigation water and the latter generates sewage. Consequently, water masters in dry and populated areas such as Israel, Spain, and California view sewage as an irrigation-water source, which can substitute freshwater irrigation provided that it is treated to meet specific quality standards. To meet these standards, various wastewater-treatment technologies can be applied, which differ in costs and reclamation efficacy with respect to different wastewater-quality measures. The quality standards of treated wastewater (TWW) thus affect the economic viability of wastewater agricultural reuse, and thereby the whole structure of water allocation and infrastructural development of water-supply systems. We assess the implications of three wastewater-quality regulations on the water economy of Israel: (1) the "In Practice" standards enforced since 2010 (known as the Inbar-committee criteria), (2) the previous "20/30" regulation (20mg/l BOD, 30mg/l TSS), and (3) a hypothetical strict regulation entitled "RO-Only", which mandates desalination of all TWW. To that end, we develop a dynamic mathematical programming model that integrates the Israeli water and vegetative agricultural sectors. The model maximizes the welfare in both sectors by setting the trajectories of water infrastructural development and allocation of different water types to the urban and agricultural demand regions, subject to a set of constraints, among them the TWW quality standards. We find that the optimal combination of wastewater-treatment technologies under the In-Practice standards integrates AS (Activated Sludge), BNR (Biological Nutrient Removal), MF (Micro Filtration), and RO (Reverse Osmosis). The costliest standards are those associated with TSS (Total Suspended Solids) and salinity (measured in dS/m (deciSiemens/meter) indicating EC – Electrical Conductivity), with an average per cubic meter shadow value of 0.14 cents per mg/l and 0.16 cents per dS/m, respectively. Relative to the In-Practice scenario, the transition back to the 20/30 regulation saves $166×10^6 a year (on average, ¢6/m^3)—this is a measure of the minimal benefit associated with the cleaner wastewater obtained by the In-Practice regulation that renders it warranted from a social perspective. Similarly, the minimal added benefits associated with the enactment of the RO-Only regulation instead of the In-Practice one amount to $315×10^6 a year (on average, ¢12/m^3). The water consumers in the urban sector face almost all of the changes in the wastewater-treatment costs, whereas changes in the welfare allocation in the agricultural sector are minor.

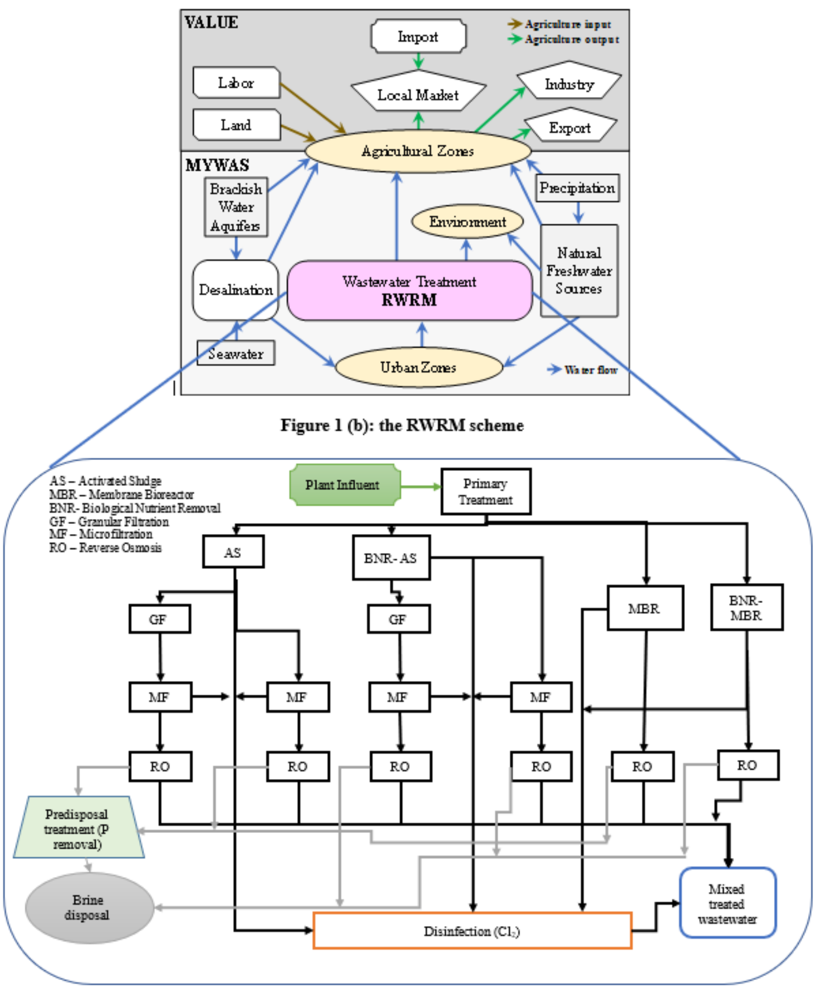

Figure 1 (a): the MYWAS-VALUE-RWRM scheme

Figure 1 (b): the RWRM scheme

Organic contaminants in fresh produce irrigated with reclaimed wastewater: Human exposure and health concerns

Evyatar Ben Mordechay, Tali Sinai, Tamar Berman, Rita Dichtiar, Lital Keinan-Boker, Jorge Tarchitzky, Vered Mordehay, Yehoshua Maor, Orly Manor and Benny Chefetz

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Irrigation with reclaimed wastewater is a growing practice intended to conserve freshwater resources. Despite the obvious benefits, reclaimed wastewater irrigation exposes the agricultural environment to organic pollutants that were not completely removed during the wastewater treatment. Once introduced into a field via irrigation, a number of fate-determining processes may occur to these contaminants, including sorption (primarily to soil organic matter), degradation (primarily biodegradation), transport towards groundwater, and uptake by plants, which introduce them into the food chain. The current study estimated the unintentional exposure of the Israeli population to organic contaminants (mostly pharmaceuticals) due to the consumption of fresh produce crops irrigated with reclaimed wastewater using dietary data obtained from a National Health and Nutrition Survey (Rav Mabat adults; 2014-2016) and the concentration of organic contaminants in produce crops irrigate with reclaimed wastewater in Israel. Human health concerns were estimated using two approaches, the acceptable daily intake (ADI) and the threshold of toxicological concern (TTC).

The highest human exposure to organic contaminants was demonstrated for subgroups consuming high amounts of leafy vegetables such as vegetarians and Israeli Arabs, as leafy vegetables exhibited the highest contaminant concentration. For the extreme scenario (calculated as maximum contaminant concentration times the 95th percentile consumption), lamotrigine, carbamazepine, and epoxide-carbamazepine (a therapeutically active metabolite of carbamazepine) exhibited the highest exposure levels of 29,100, 27,200, and 19,500 ng/person/day, respectively. Almost all contaminants exhibited exposure levels below the two thresholds (ADI and TTC). However, for the extreme scenario, the exposure level of

carbamazepine was higher than its ADI level (7,000 ng/ 70 kg person/day). In addition, the extreme exposure levels of lamotrigine and epoxide carbamazepine were higher than the TTC level for genotoxic compounds (10,500 ng/70 kg person/day). These findings do not indicate immediate human health concerns but rather the need for further human health study. Reducing reclaimed wastewater irrigation of leafy vegetables would considerably reduce human exposure to wastewater-derived organic contaminants.

Field comparison of nitrogen cycling between three agricultural managed groundwater recharge sites

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Agricultural managed aquifer recharge (Ag-MAR, on-farm recharge), where farmland is flooded with excess surface water in winter to intentionally recharge groundwater, has received increasing attention by policy makers and researchers in recent years. However, there remain concerns about the potential for Ag-MAR to exacerbate nitrate (NO_3^-) contamination of groundwater, and the public health risks associated with elevated NO_3^- concentrations in groundwater and related greenhouse gas emissions. In this study, we compare nitrogen cycling processes between three Ag-MAR field sites in California to quantify the effect of Ag-MAR on nitrogen transformations and losses in the soil (e.g., NO_3^- leaching, N_2O losses) for different soil types and cropping systems. The first two Ag-MAR experiments were conducted on two raisin grape vineyards with different soil textures, which were each flooded for two weeks and four weeks, respectively, for two consecutive years. The third site was a fallow field, which was flooded for eight days, and then planted with processing tomatoes. Each site's instrumentation included a suite of soil moisture sensors, water level loggers and flow meters. Other measurements (down to 1-m depth in the vineyards and to 2.5 m in the fallow field) included: redox probes, oxygen sensors, suction cups for pore water sampling, and static flux chambers for nitrogen (N_2O) and carbon-related (CO_2, CH_4) atmospheric fluxes. Soil samples were taken before and after Ag-MAR events to determine soil N species (TN, DON, TOC, NO_3^-, NH_4^+), pH, EC, and soil texture. Plant and yield were also measured to determine the effect of Ag-MAR on grape and tomatoe physiology and to close

the N-mass balance. Results indicate that: (1) during flooding NO_3^- leaching was the main process with an additional but smaller contribution of denitrification; (2) there were no greenhouse gas emissions observed during the Ag-MAR treatment; (3) soil texture and crop type determined the magnitude of NO_3^- leaching at each site.

Session 5:

Plastics in agriculture

(impact and treatment practices)

Conveners:

Roy Posmanik and Ines Zucker

Aging of Microplastics in Agricultural Soils

Raz Lev and Benny Chefetz

Department of Soil and Water Sciences; Institute of Environmental Sciences; Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem

Plastic pollution is one of the emerging threats to our plant. Plastic particles, as well as micro- and nano-scale plastics, have been found almost in every environmental niche. However, data and knowledge about processes of microplastic in soils and specifically in arable soils are still missing. In this study we aimed at examining the aging process of microplastic originated from debris of low-density linear polyethylene (LLDPE) in soils. The LLDPE was cut to 1-0.7 mm size and was incubated (1% weight) in 3 Loss soils for 18 months. Incubation was performed in bare and planted soils. The aging process was studied by investigating the surface modification of the microplastic using FTIR, SEM, thermal gravimetric analysis (TGA) and differential scanning calorimetry (DSC) analyses.

Microplastic samples, before and after 6 months of incubation, obtained a typical IR spectrum of LLDPE and vinyl acetate with distinct peaks related to C-H vibrations at 2914, 2846, 1465 and 717 cm^{-1} and peaks in the range 1020-1300 cm^{-1} related C-O vibrations (assigned to vinyl acetate). The effect of incubation is evident in the increase in absorption intensity in the 1020-1300 cm^{-1} range. The peak intensity ratio (1033 cm^{-1}/2914 cm^{-1}) was 0.13 before incubation; after 6 months of incubation the ratio increased to 1.01 and 0.56 for the samples incubated with plants and without plants, respectively. This suggest surface oxidation or enrichment of the LLDPE surface by C-O containing compounds. Removing bound organic matter by hydrolysis (using sulfuric acid) led to a decrease in the ratio (1033 cm^{-1}/2914 cm^{-1}) to 0.48 and 0.39 for the samples incubated with plants and without plants, respectively. The current data show that microplastic in the soil is modified with time – both direct oxidation and organic matter coating was observed. These processes can result in modification in the microplastic reactivity in soils.

Polyethylene mulch in agriculture: what is it good for and can we avoid it?

Amnon Cochavi

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The usage of polyethylene sheet mulching in agricultural fields became a common practice which contribute to the crop and the farmer in many aspects. It reduces water evaporation from the soil surface, and prevents weed germination for some species. Additionally, it enables high and stable soil temperature, that accelerate crop growth in the early cold season. This effect has a significant y on crop pricing at the market. However, using polyethylene in agriculture results in the accumulation of 40,000 tons of plastic pollution per year in Israel alone. These plastic remains are impossible to recycle since they are contaminated with soil, vegetation and mainly chemicals (pesticides and fertilizers).

Melon growth in Israel is commonly done using this practice. we wish to develop a multidisciplinary approach that will allow to avoid the plastic usage in the field, without causing any damage to the melon yield and quality. First, in order to maintain the plant growth in the early season, we aim to identify melon accessions that demonstrate tolerance to low temperatures and use them in specific breeding programs. simultaneously, we wish to develop a method for weed management without causing any damage to the crop, by using precision weeding methods that remove the weeds as close as possible from the plant.

A new practice combining crop breeding and precision weeding can assist farmers to grow melons without plastic mulch. We believe that in the future this approach will be relevant to other crops as well, avoiding the use of plastic sheets in the field and reducing plastic pollution.

Microplastic textile fibers accumulate in sand and are potential sources of micro(nano)plastic pollution

Nirrit Cohen

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Agricultural soils have been identified as sinks for microplastic fibers, however, little information is available on their long-term fate in these soils. In this study, polyester and nylon fibers were precisely cut to relevant environmental lengths, using novel methodology, and their behavior in sand columns was studied at environmental concentration. The longer fibers (>50µm) accumulated in the upper layers of the sand, smaller fibers were slightly more mobile, and nylon showed marginally higher mobility than polyester. Previous studies have overlooked changes in microplastic morphology due to transport in soil. Our study is the first to show that fibers exhibited breakage, peeling, and thinning under flow conditions in soil, releasing smaller, more mobile fragments. Furthermore, the peelings exhibited different adsorption properties than the core fiber. This suggests that microplastic fibers can become a source of smaller micro(nano)plastics and potential vectors for certain molecules - risking continuous contamination of nearby soils, surfaces, and groundwater.

Tracking Micro- and Nano-plastics through soils using single particle ICP-MS: A New Approach to Bridge the Analytical Gap

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Large quantities of microplastics and nanoplastics (collectively MNPs) are continuously entering agricultural soils through the use of agriplastics, irrigation with MNP-containing treated wastewater, and the application of plastic-contaminated biosolids. These MNPs may be mobile through the soils, and may alter soil physical properties of even reach the groundwater. Often, they contain additives which pose a further threat to the environment. Current methods for the environmental detection, characterization, and quantification of NPs (< 1 µm) and the smallest MPs (< 1 - 5 µm) are expensive and labor intensive, often requiring their separation from environmental matrices. These factors make it difficult to identify the MNP characteristics that influence the transport and fate of environmentally relevant MNPs of varying polymeric compositions. By synthesizing a suite of metal-tagged polymers, which are cryomilled to create polydisperse particle suspensions, single particle ICP-MS (spICP-MS) can be used to determine MNP particle size and concentration in controlled fate and transport studies. Careful selection of each metal tag, each paired with a different polymer, allows us to track mixtures of polydisperse MNPs of irregular shape through virtually any matrix, assuming little or no background concentrations of metal in the matrix.

This study demonstrates the use of metal-tagged MNPs in saturated sand column experiments to investigate the movement of two plastic types: hydrophobic polystyrene (Sn-PS) and hydrophilic polyvinylpyrrolidone (Ta-PVP), and compares their behavior to fluorescent carboxylated monodisperse PS beads (Fl-PS). The use of spICP-MS allows us to investigate size-dependent transport for each polymer, showing that larger particles were filtered more quickly than smaller ones. The hydrophilic properties of the PVP allowed it to transport more effectively than the hydrophobic PS particles. Furthermore, the addition of humic acid to the carrier solution improved the colloidal stability of both NMP suspensions, resulting in much greater elution from the column than in deionized water or a modified hard water (ionic strength = 5mM). This suggests that in organic-amended agricultural soils, the potential mobility of microplastic contaminants in the environment may be high.

Plastics and Microplastics in Agriculture: The Visible and Invisible

Ji-Dong Gu

Environmental Science and Engineering Program, Guangdong Technion (GTIT), Shantou, China

Plastic mulching films become part of the new agricultural practice to increase yield and early maturity of the produce for better price, as well as to eliminate the weed. Actually, the whole ecosystem of the earth is embracing the man-made materials with a constant increase of total quantities. This new class of anthropogenically-synthesized materials is very high in molecular weight and has its own physical form with high persistence in the ecosystem. Its occurrence in different parts of the ecosystems namely water, soil and air, is evident. Degradability of plastics post utilization is a recognized major environmental issue facing both the scientific community and the society for sustainable development and protection of the natural environment. Mulching films can be disintegrated over the exposure to sunlight and microplastics are often detected and reported. Though plastics and microplastics have been received greater coverage by media and many research investigations have been made on this topic in an attempt for biodegradation of them by different microorganisms and insects. Currently available research information on this topic suffers from a serious weakness on the basic polymer chemistry and essential data of the plastics/polymers used, composition. Of the products. Current available data do not support the degradation of covalent carbon-carbon bonds in highly polymerized plastics and, at the same time, there is very little information on the mechanisms or biochemical reactions responsible for the claim degradation. In addition, plasticizers in the plastics and their impact on the soil microbial community or rhizosphere microbiome have not been looked into for the agricultural system. Plasticizers are leached out from the plastics over time and they can be utilized by indigenous microorganisms, but it is important to know that these plasticizers are endocrine-disrupting chemicals and may have more pronounced impact on the animals of the agricultural ecosystem. Furthermore, on microplastics, their effects on soil nutrient dynamics and status have not been examined in

detail, especially for agricultural production purpose. It is clear that the public has been focused on the visible issues of plastics, but the invisible ones also deserve attention for a complete picture.

Microplastic contamination in sand and the associated challenges in risk assessment

Andrey Ethan Rubin

Planery talks

Soil Science in the time of carbon sequestration

Ronald Amundson

Department of Environmental Science, Policy & Management,.University of California, Berkeley

The large mass of organic C stored in global soils has inadvertently propelled segments of the soil science community into the complex issues of global climate change and its stabilization. This is a societal problem of such enormous scope that soil science, like most natural sciences, has little prior experience to draw on. There are few ground rules in place for guidance, and the resulting paths and community practices are sometimes novel.

Due to the interest in natural climate mitigation strategies, it is an opportune time for science to push a "pause" button and examine the robustness of the science, and the social structures needed to ensure scientific integrity and plausibility of outcomes. Some urgent points of discussion include:

- How robust are the best estimates of C sequestration rates, and can the community make more transparent, and testable, the assumptions and parameters embedded in the key model scenarios?
- How will climate change, and the positive soil C feedbacks, affect sequestration estimates?
- How can the community, and the scientific establishment, create adequate firewalls between science and advocacy/business/COI, a boundary that is blurring in this emerging problem?
- What constitutes Conflict of Interest in the modern world of funding and social media?
- How can natural science partner with the relevant social sciences to prevent what has been termed "legitimizing the unbelievable", or creating policy based on technical proposals lacking in practicality of application?

Understanding the combined effects of ozone pollution and climate change on crop yield and nutritional quality

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Department of Environment and Geography, University of York, UK

Ozone pollution and climate change are extremely likely to threaten future crop production in important agricultural regions around the World with the Mediterranean, South and East Asia and mid-West US being particularly at risk. Modelling methods used to assess risk of ozone pollution have developed in recent years away from empirical approaches based on dose-response relationships towards more process-based models. The DO3SE-Crop model has developed from an ozone deposition and effects model (having used flux-response relationships to assess damage) to a crop model capable of assessing the effect of ozone on photosynthesis and carbon allocation. The model has been calibrated and evaluated against experimental ozone fumigation datasets for wheat cultivars from Spain (Mediterranean Europe), China and India and is able to assess the influence of climate variables on crop growth and yield as well as the effect of ozone on instantaneous photosynthesis and senescence. We find that the ozone effect on senescence is the primary determinant for yield loss in wheat. We are further developing the model to assess ozone effects on nutritional quality since we know that ozone is an important limiter of translocation of nitrogen to the grains. The establishment of DO3SE-Crop will allow assessments of the future impacts resulting form the combined effects of ozone and climate change on supply and nutritional aspects of food security. Importantly, this can include an assessment of the yield improvements between current and near- to mid-term future conditions for a range of adaptation options proposed for wheat in response to climate change including management of irrigation, growing season and development of new varieties from crop breeding with targeted physiological traits such as enhanced gas exchange and improved water use efficiency.

Session 6:

Adaptation to climate change and resulting environmental conditions

Conveners:

Yael Dubowski and Eran Tas

Back to the Wild Roots of Wheat Climate Adaptability

Zvi Peleg

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Water deficit is one of the major environmental constraints on wheat production. This situation is increasingly aggravated by climatic variation and poses a serious challenge to global food security. Recent progress in breeding efforts to improve wheat yields under drought has been mainly directed toward above-ground traits. Root traits are closely associated with various drought adaptability mechanisms, but the genetic variation underlying these traits remains untapped, even though they hold tremendous potential to improve crop resilience. Here, we examined this idea by re-introducing ancestral wild wheat alleles and studied its impact on root architecture diversity under terminal drought stress. We compared a wild emmer introgression line (IL20) and its drought-sensitive recurrent parent (Svevo) using an active sensing electrical resistivity tomography approach under field conditions. IL20 exhibited greater root elongation under drought, which resulted in higher root water uptake from deeper soil layers. This advantage initiates at the pseudo-stem stage and increases during the transition to the reproductive stage. The increased water uptake promoted higher gas exchange rates and enhanced grain yield under drought. Overall, we show that this presumably 'lost' drought-induced mechanism of deeper rooting profile can serve as a breeding target to improve wheat productiveness under changing climate.

Cereals adaptation to climate change from trait to crop level

Ntawuguranayo S. [1,2], Almhdy R. [1,3], Zilberberg M. [1], Peleg Z.[2], Sade R.[2], Herman I.[2], Piñera-Chavez F. J.[4], Reynolds M.P.[4], Bonfil D.[6], Ben-David R.[1]

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Water deficit and heat stress are the major abiotic factors limiting cereal production worldwide. This productivity is finally defined by yield per area of land either as biomass for animal feed or grains for both humans and animal consumption. In Mediterranean agro-systems, terminal drought and heat dictating shortening of crop growth season. Hence, under climate change predicted scenarios this productivity challenge become radical. An integrated breeding and agronomy research might provide solution that will stabilized cereal productivity under dryland both at crop and agro-systems levels. Here we present two case studies from our recent field work which might illustrate some benefits of such integrated research approach: (1) at crop level we investigate structural biomass investment in bread wheat and its association with grain size and yield under terminal drought and heat stress. We show that selecting for highly adapted wheat genotypes with stem water-soluble carbohydrates and increase investment in structural biomass demonstrate a useful strategy to offset the grain weight and grain yield reduction under water deficit and high temperatures. (2) at crop level we perform comparative study of biomass productivity under arid environments. The comparison include two small grain crops, wheat and barley each represented by modern verities and traditional tall landraces. Here we show barley superiority in biomass production under water deficit compared to wheat. We also show that tall landraces are more productive

then their commercial semi-dwarf counterparts under severe drought. We will provide evidence to how varietal and crop selection might improve agro-system productivity and sustainability in dryland.

Spectral assessment of chickpea morpho-physiological traits from space and ground

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Chickpea (Cicer arietinum) is an important grain legume in semi-arid regions and water-stress is a major constraint to its productivity. The area under chickpea cultivation is growing but higher precipitation instability risks yields. The ability to assess water potential can support irrigation decisions and promote more efficient irrigation. The current study aims to assess leaf water potential (LWP) and leaf area index (LAI) by spaceborne and ground spectral sensors. Field experiments were conducted in locations representing different climatic conditions in Israel. Six irrigation regimes were applied, from 0%, 50%, 75%, 100%, 120% and 140% of Penman-Monteith evapotranspiration were implemented at the Gilat and Neve Yaar research stations as well as in commercial fields. Plants were characterized weekly for morpho-physiological traits and grain yield data was obtained at the final harvest. Canopy reflectance was acquired with a MicroSatellite VENµS (11 spectral bands, 420-910 nm) and a field spectrometer dual-field of view system at ground level (ASD, 350-2500 nm). The VENµS and ground level hyperspectral data were divided to calibration and validation data sets. Partial least squares regression and artificial neural networks were used to quantitatively estimate the morpho-physiological traits. The coefficient of determination values of independent validation models for the LWP and LAI estimated by VENµS were 0.60 and 0.67 and hyperspectral 0.66 and 0.80 with root mean square error (RMSE) of 0.24 Mpa, 0.95, 0.23 Mpa, and 0.83, respectively. The VENµS and hyperspectral ground-level data are useful for the evaluation of morpho-physiological chickpea plant traits.

Climatic Perspective to Weed Management- Untangling the Effect of Local, Management and Climate Factors on the Infestation of Amaranthus Species Along a Climatic Gradient

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Weeds are a major pest in vegetable and field crops worldwide. Determining the factors affecting weed infestation in arable fields is complicated by the considerable spatiotemporal variability of agricultural systems. A possible solution lies in regional-scale studies of weeds in commercial fields to provide insights into the influence of field properties (i.e. soil type and field shape), climate, and weed management practices on the efficacy of weed management. The current study focused on *Amaranthus* species – noxious weeds infesting many crops worldwide – in processing tomato fields in Northern Israel, a geographical region characterized by a significant climate gradient. This gradient provides an ideal opportunity to study the effect of climate on weed infestation and management. This study aimed to investigate the associations between *Amaranthus* infestations and local (field properties), climate, and management factors in processing tomato fields. A survey of 103 commercial tomato fields was carried out in 2018 and 2019 throughout the four major tomato-growing areas in Northern Israel: the semi-arid Beit-She'an Valley in the East; the Jezreel Valley, stretching from East to West and gradually transitioning to a Mediterranean climate; the Zevulun Valley in the West and the Hula Valley in the North, both characterized by a Mediterranean climate. The spatiotemporal change in infestation for fields surveyed both pre- and post-weed control was evaluated relative to management and climate variables. A

bootstrapped model selection for beta regression models with varying dispersion was performed to determine factors associated with weed infestation before and after weed management. The analysis showed that the application of sulfosulfuron pre-planting, could potentially reduce *Amaranthus* infestation depending on environmental and local conditions of the field; management comprising of more intense control measures reduced infestation; and precipitation led to an increase in mean infestation when occurring before planting, but a decrease when occurring after weed management. In addition, the onset timing of weed control was found to be negatively correlated with precipitation occurring post-treatment. Our findings show that management actions are key factors in controlling *Amaranthus* infestation but that these actions are affected by the local climate conditions. Overall, this study provides valuable insights into the factors affecting *Amaranthus* infestations in processing tomato fields, which can contribute to more effective weed management practices. In addition, this work indicates the need for a regional-scale perspective when making weed management decisions, especially in light of climate change, which is expected to drive desertification processes in the eastern Mediterranean region.

Tree Hydraulic Limitations and Morphology, and the Relative Importance of Latent Energy Dissipation in Urban Environments

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This study investigated transpirational cooling of urban trees in Munich, Germany (temperate climate) and Beer Sheva, Israel (hot arid climate) during 2020 and 2021. Trees were mature individuals of *Acer platanoides* and *Tilia Cordata* in Munich and *Prosopis alba* and *Tipuana Tipu* in Beer Sheva, located in various planting categories (park, street and square) with contrasting natural and sealed ground conditions. Sap flux densities in all trees were similar (due to hydraulic limits), but crown projected area (CPA) was larger in Beer Sheva. Regressions of mid-day canopy resistance on VPD were highly significant at all tree labs, and slopes, which are proportional to tree hydraulic resistance, were higher in the arid climate of Beer Sheva (0.25-0.44) as compared to the temperate climate in Munich (0.1 to 0.18). We take these findings to indicate that urban tree hydraulics limit their transpirational cooling. The contribution of the transpirational cooling to the energy budget was studied as the ratio between the latent heat and the net radiation at the sites. The latent heat contribution to the energy balance is about 40% less significant in summer noon hours in the hot dry (Beer Sheva)

than in the temperate climate (Munich). Thus, the absolute and relative importance of shading for energy dissipation is greater in hot dry climates. The linear relationship of mid-day canopy resistance as a function of VPD was useful for comparing water consumption and evaporative cooling between local trees in different climatic regions.

Session 7:

Adaptation to climate change and resulting environmental conditions (cont.)

Conveners:

Yael Dubowski and Eran Tas

The Hula valley and Lake Kinneret: Ecologcal-Rivalry or Friendship?

Moshe Gophen

Migal-Scientific Research Institute, Kiryat Shmone, Israel

Brief Historical review: 1933 – Kinneret south dam construction; 1964 –National Water Carrier inauguration; 1957-Drainage of the Hula valley - demolishment of natural wetland and old lake Hula ecosystems followed by the establishment of agricultural development system; 1967–Salty water diversion from the Kinneret input; 1994-2006-Implementation of the Hula Reclamation Project confirmed the management obligations for Kinneret water quality protection and the inevitability of agricultural development in the Hula valley. 2022-Under construction proposal of desalinated sea water input into lake Kinneret;

Intensified public awareness aimed at potential deterioration of Kinneret water quality resulted by the Hula drainage was repulsed scientifically: Oxygen level was not depleted and fluctuated within acceptable natural ranges; the domination of migrating nitrogen from the Hula valley into lake Kinneret shifted from ammonium to nitrate after drainage. Nitrogen is a limiting factor for the efficient growth rate of the dominated Kinneret bloom forming *Peridinium*. External supply of nitrogen is presently dominated by nitrate as the result of peat soil oxidation. Ammonium impact on *Peridinium* growth efficiency is better than nitrate. Therefore, future management renovation of increasing reductive (anaerobic) habitats in the Hula valley are recommended. Nitrate migration is a dependent of climate condition and decline of rainfall and river discharges suppressed external nitrogen inputs and enhanced *Peridinium* decline. The friendship between Hula Valley and lake Kinneret is partly confirmed by the low contribution of phosphorus comprised below 10% of the total input. Although nitrates inputs were enhanced after the drainage their migration is a dependent of climate conditions. Increasing river discharges enhance nitrate migration which is beneficial for the desirable *Peridnium* growth rate. The major source of the minor content of phosphorus in the Agmon-Hula effluent is due to vegetation decomposition. Ecological friendship between post drainage Hula valley and Lake Kinneret was therefore not deteriorated and threaten on water quality was not indicated.

During July 1994 an outbreak of Harmful Cyanobacteria (HFCB) was first time recorded in the history of lake Kinneret. Inoculum seeding in lake Kinneret sourced in lake Agmon-Hula was suggested but was rejected because the hydrological networks were not yet established. The vast stock of sulfate in the peat soil, its migration into lake Agmon-Hula and river Jordan confirmed its dependence on river discharges. Recent studies confirmed advantageous of sulfate in suppression of HFCB bloom formation. Therefore, enhancement of sulfate migration into lake Kinneret might enhance suppression of HFCB blooming. The winter migration of 56,000 cranes improved eco - tourism and did not enhance phosphorus contribution into lake Kinneret. It is a significant support to the ecological friendship between Hula valley and lake Kinneret.

Ecological integration between agricultural management and Kinneret water quality protection is successfully implemented. The natural old Hula valley ecosystem can never be rehabilitated as was in the past and agricultural land use will continue. Although nature was damaged by the drainage the beneficial eco-service for human welfare is confirmed.

The Post - Drainage Hula valley and Lake Kinneret are Eco- Friends.

Identification of Relevant Variables for Agricultural Drought Prediction

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Agricultural drought refers to the deficiency of soil moisture, which leads to the lack of availability of minimum moisture requirement for plants. Agricultural drought adversely effects the agricultural production and cause significant crop damage. Accurate prediction of agricultural drought with sufficient lead time can aid agricultural planning and reduce losses in agricultural production. The selection of possible predictors of agricultural drought is an important task in the prediction process. This study include the identification of potential predictors of agricultural drought in the Palakkad district of Kerala, India. Monthly precipitation and maximum and minimum temperature data from the India Meteorological Department (IMD), soil moisture, humidity and wind speed data from Global Land Data Assimilation System and large scale climatic indices from National Oceanic and Atmospheric Administration (NOAA) were used to compute the predictors. The autocorrelation of soil moisture data, correlation between soil moisture and various meteorological variables like precipitation, maximum temperature, minimum temperature, specific humidity, wind speed and various global climatic indices were carried out at different temporal lag, to identify the potential predictors of agricultural drought in the study area. The variables showing strong correlation with soil moisture is considered as a potential predictor of agricultural drought. The results obtained from this study can provide useful information for early agricultural drought warning and formulating proactive agricultural drought mitigation strategies.

Landuse land cover change detection and analysis

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The land use and land cover of the state of Kerala, India has changed considerably over the years. These changes may be attributed to several reasons like population increase, agricultural expansion, and changing climate. This study examines the changes that has happened in the land use and land cover of Kerala over the years and also predicts the future land use land cover scenarios. The decadal land use land cover maps for the years 1985, 1995 and 2005 that are downloaded from the Distributed Active Data Archive Centre of NASA, which had a resolution of 100m is used for the study. The changes that took place between the years were analysed by using the Terrset Software and change matrices are prepared to understand the changes that took place between different land cover classes over the years. The land use and land cover maps for the years 2005 and 2030 were projected by considering the available decadal land use maps as a reference using the CA_ Markov analysis module in the Terrset Software. The projected map of the 2005 is used for the validation by comparing it with the downloaded decadal land use map of the same year. The changes that would occur by 2030 is analysed and corresponding change matrices are also prepared to know the changes that might happen between land cover classes. The decadal land use map shows that the state of Kerala is dominated by the land use class of plantation followed by the land use class of forest. Over the years 1985 to 2005, the land use land cover map shows maximum increase in the plantation and built-up and there is maximum decrease in forest. The projected land use land cover map of the year 2030 also indicates the same trend of increasing plantation and built-up areas and decreasing trend in forests. Significant area of land changed from forest to plantation and plantation to built-up which area may be attributed to increase in urbanisation and the economic development that took place over the years. Considerable areas of forests in the Western Ghats regions of Wayanad District of the State is found to be converted to plantation over the years which may be due to the impact that plantations has

on the economic development of Kerala owing to its export potential, employment generation and rural development. Agriculture is the largest source of livelihood in India. This study can be helpful in implementing measures to improve agricultural practices in developing countries like India.

Predicting Flowering levels in 'Barnea' olive trees based on winter temperatures

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A major developmental factor determining the yield of olive trees (*Olea europaea*) is the number of inflorescences forming on the tree in springtime. This number, in turn, is known to depend on the sufficiency of cold periods during the preceding winter. It is empirically known that temperatures in the range of 4° C-18° C facilitate flowering and maximal flowering was achieved following 80 days under 10°C - 13°C. In contrast, trees that were kept under temperatures outside that range did not flower.

Mediterranean winter is characterized by varying temperatures. Specifically, warm periods occasionally occur during winter time, as was the case last year in the Negev which led to significantly low yield. With climate change, such warm periods might become longer and more frequent, potentially reducing olive yield, to the extent that its commercial growth might become non-profitable in some regions.

Despite the basic understanding regarding the relationship between cold winter temperatures and olive flowering, a satisfactory quantitative model forecasting the expected flowering under natural temperature profiles is still lacking. Previous models attempted to sum the number of 'cold hours' the tree accumulates during winter, or the net number of cold hours, subtracting the number of warm hours from the total number of cold hours. However, such summation models overlook the exact sequence of cold and warm hours, which has been shown to impact flowering. Indeed, summation models exhibit only a mediocre agreement with empirical values and are specifically inaccurate under marginal conditions with intermediate to low flowering.

In this project, we collected flowering data of 'Barnea' cultivar olive trees grown either outdoors in different locations throughout Israel or under controlled temperature conditions in the years 2014-2021 as well as the corresponding temperature profiles. To forecast flowering, we constructed a dynamical model, comprising a hypothetical pathway in which a flowering factor is produced and degraded. The crucial ingredient in the model is an intermediate factor that is produced and degraded at temperature-dependent rates, such that it accounts not only for the number of cold and warm hours but also for the exact sequence in which they occur. We used the flowering and temperature data we collected to fit the model parameters, applying numerical optimization techniques. Leave-1-out validation showed excellent agreement between the model and single experiments. In the future, we plan to augment the empirical database which will improve the model forecasting capacity. Applying the model to additional olive cultivars will enable rigorous comparison between their heat resistance and compatibility with climate changes.

New active materials based on nature-sourced polysaccharides

Elena Poverenov

ARO, The Volcani center, Israel

Nature-sourced biodegradable polymers can be utilized as active films, coatings and delivery systems. For instance, biopolymers-based active packages can protect food products from physical, mechanical and microbial damages. Such materials respond to customer demands for safe and healthy approaches for food quality management and satisfy environmental concerns. In addition, biopolymer-based active coatings can be used for post-modification to provide the already prepared materials with desired properties. We utilize nanoemulsification, sonochemical deposition, layer-by-layer approach, covalent linkage to control physicochemical properties and functionality of the resulted biodegradable materials. In this lecture, we will also present delivery systems based on rationally modified polysaccharide derivatives that could encapsulate molecular cargoes of various polarities (from highly hydrophobic to ionic compounds) in aqueous and lipid environments and transport them through biological barriers, opening up numerous potential applications in various fields such as medicine, cosmetics, food and agriculture.

Controlled Release of Fertilizer Nutrients Using Fe-Based Metal Organic Frameworks (Fe-MOFs)

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Due to the controlled delivery function of metal organic frameworks (MOFs), iron based MOFs (Fe-MOFs) showed great potential in fertilizer industry, and the challenge to apply Fe-MOFs as new fertilizer in practical crop production remained. In this study, Fe-MOFs were hydrothermally synthesized both in laboratory scale and in pilot scale, and the structure and components were characterized using varied spectroscopic techniques, then the nutrient release and degradation behaviors of the Fe-MOFs were investigated, respectively. Results showed that Fe-MOFs were successfully synthesized in both scales with the similar yields around 27%, and the Fe-MOFs showed the similar structure with the molecular formula of $C_2H_{15}Fe_2N_2O_{18}P_3$ as well as the monoclinic system of *P21/c* space group; the nutrients of N, P and Fe were involved in the Fe-MOFs with the average contents of 6.03%, 14.48% and 14.69%, respectively; the nutrients release durations of more than 3 months in soil were achieved through the degradation of the Fe-MOFs structure, which was mainly influenced by temperature; the nutrients release rate and pattern were well matched with the crop growth, which greatly promoted rice yield. Therefore, the environmental friendly compounds of Fe-MOFs could be industrially produced used as an innovative fertilizer with the unique features of varied nutrients and controlled release.

Session 8:

Advances in the estimation of carbon sequestration and emission in the agro-environment

Conveners:

Oz Kira and Yael Laor

Agriculture as an option for mitigating climate change

Carlos Eduardo Cerri

"Luiz de Queiroz" College of Agriculture (ESALQ), Department of Soil Science, University of São Paulo (USP), São Paulo, Brazil.

The interactions of land use, management and environment create a varied picture of soil organic carbon (SOC) dynamics across the globe. Globally, the amount of carbon in soils, commonly represented by the mass of carbon, is estimated to be about 1500 Pg C (1 Pg C = 10^{15} g carbon) in the top 1 m of soil, which is 3 times the amount present in the vegetation and twice the amount found in the atmosphere. The amount of SOC has strong physical and biological controlling factors. These include climate; soil chemical, physical, and biological properties; and vegetation composition. Brazil is the third agribusiness leader worldwide, following European Union and the United States. This presentation will include both an integrative view of global patterns on the distribution and trends in SOC as well as research in South America, specially in Brazil, focusing the impact of land use change and management practices on SOC. Land use change, mainly for previous agricultural practices, has often decreased in SOC stocks due to enhanced mineralization of soil organic matter (mainly to CO_2). A significant fraction of the ~32% increase in atmospheric CO_2 over the last 150 years stems from the breakdown of soil organic matter after forests and grasslands were cleared for farming. This process increases greenhouse gas (GHG) concentrations in the atmosphere, exacerbating global warming. Conversely, adoption of "best management practices", such as conservation tillage, biochar application, can partly reverse the process – they are aimed at increasing the input of SOC and/or decreasing the rates at which SOM decomposes. This mechanism has been called "soil carbon sequestration" and can be defined as the net balance of all GHG (CO_2, CH_4 and N_2O), computing all emission sources and sinks at the soil-plant-atmosphere interface. It must be noted that CO_2 fluxes are evaluated trough C stock changes in the different compartments and CH_4 and N_2O fluxes directly measured, or estimated with the best available estimates. Finally, this presentation will show that agricultural best management practices constitute important strategies for mitigating climate change.

Evaluating the role of planting density and plant size of field crops on dry matter production and sequestration of atmospheric carbon

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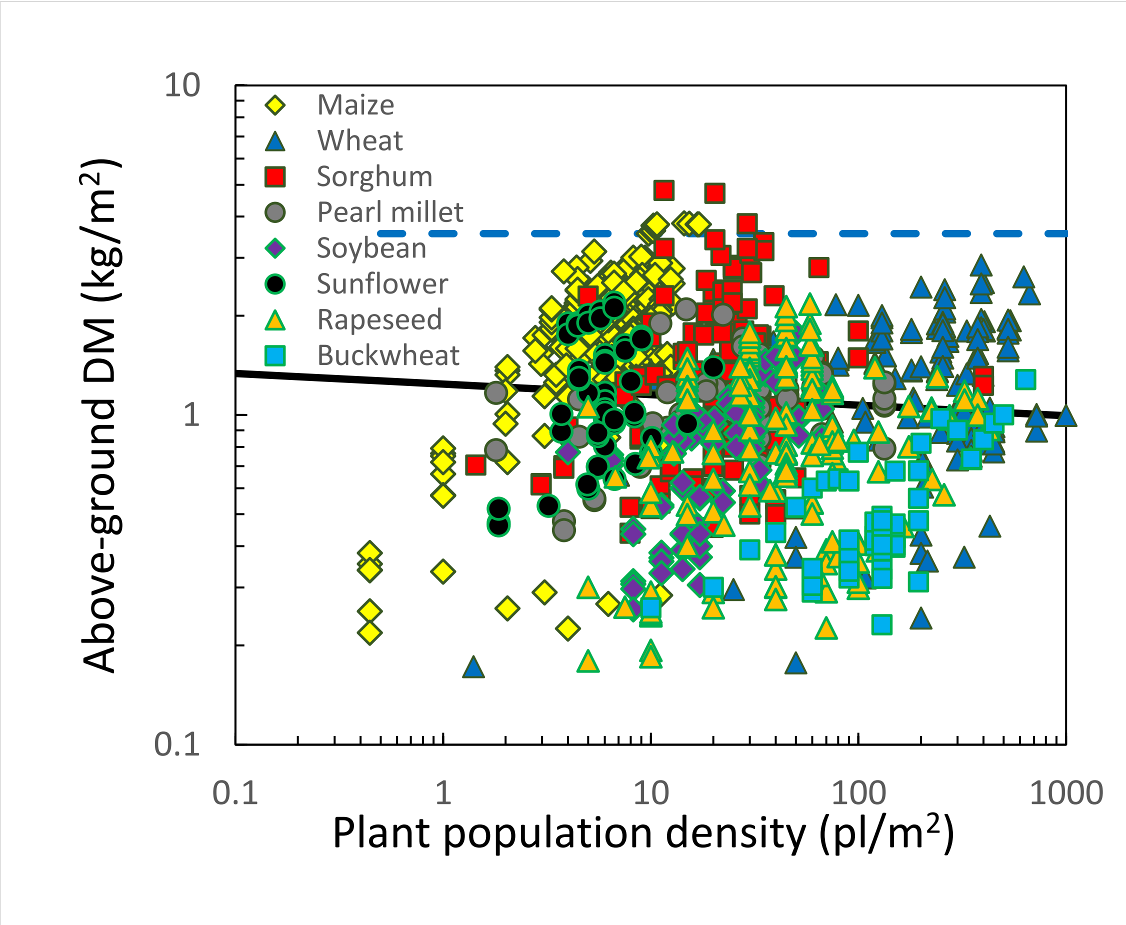
Field crops, irrigated and rain-fed, constitute the majority (about 90%) of cropland worldwide, and photosynthesize about 12 PgC/y, approximately 10% of global photosynthesis rate. The dry matter production rate during the short growing period of a few months is one of the highest in the plant kingdom, and, on average, about 1.75 g of atmospheric carbon is sequestered for each 1 g of dry matter produced. Therefore, it is important to evaluate the contribution of different field crops, and the effect of the various agricultural management factors, not only for human food and farm animals feed (and for energy production), but also to carbon fixation from the atmosphere to the soil within the global C cycle.

One of the important agricultural variables that determine the production of dry matter and the sequestration of atmospheric C of field crops is the density of planting (/seeding). In the lecture I will describe a meta-analysis of data from the literature of dry matter production per unit area (DM_a, kg/m^2) or per plant (DM_p, kg/pl) against plant population density (N, pl/m^2) ($DM_a = N \cdot DM_p$) for 8 main field crops: 4 cereals: wheat, corn, sorghum and pearl millet, and 4 from other families: soybean (legumes), sunflower (Compositae), rapeseed (Brassicaceae) and buckwheat (Polygonaceae).

When combining all 8 field crops together, it seems that the areal DM production is practically independent on the plant population density, $DM_a = 1.24 \cdot N^{-0.03}$, namely, an apparent constant-yield-looking-like trend. However, when analysing separately each of the 8 crops there is a clear trend of DM_a increasing with N for a given crop, $DM_a = a \cdot N^b$, with a mean exponent (b) of about 0.25. The exponent (b) for the 8 different crops increases systematically with a decrease in the average planting density, from approximately 0 for N of 1000 pl/m^2 to approximately 0.5 for N of 1 pl/m^2. The relationship between the areal DM and the single-plant DM (for the averages of the 8 field crops) is described statistically by the power function $DM_a = 3.4 \cdot DM_p^{0.38}$, and if functional meaning can be attributed to this generic, "field cropic" relationship, deviations from it indicate that maximum wheat production (and atmospheric C sequestration) is achieved mainly by higher seeding density, while maximum corn, sunflower and sorghum production is achieved mainly by high individual plant size.



Soil carbon sequestration – ways of monitoring and implementation

José Grünzweig

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Natural and managed ecosystems can participate in the global effort of lowering the atmospheric carbon dioxide (CO_2) burden and mitigating climate change. Soils play a particularly prominent role in this effort because soil organic carbon (SOC) constitutes the main carbon pool in most ecosystems worldwide. This pool can broadly be divided into particulate organic carbon (POC) and mineral-associated organic carbon (MAOC). While POC can theoretically be accrued at infinite amounts, it is labile and has a relatively high turnover time (low residence time). On the contrary, MAOC is more protected from microbial decay, but is limited by mineral adsorption surfaces, and thus a saturation state can be reached. Soils under most land use types have a large carbon sequestration potential because they are far from carbon saturation. Among them, agricultural soils have the largest degree of undersaturation in MOAC. Therefore, these soils have a large potential for sequestration of both POC and MOAC, and are considered effective in storing MOAC. The point of MOAC saturation is a helpful tool to assess the carbon sequestration potential of agricultural fields and forests.

Actual soil carbon sequestration or loss can be monitored by different approaches, such as chronosequence and sequential inventories. The former method evidenced, e.g., large and rapid losses of SOC from agricultural land use change in boreal forests. The latter approach showed substantial carbon sequestration in a planted semiarid forest. In addition, fresh plant residues isotopically labelled with ^{13}C can be used to trace the efficiency of soil organic matter formation and SOC storage. Such methods should be used to track the long-term fate of carbon in soils, especially as affected by different measures of land management designed for enhancing soil carbon sequestration. However, for agriculture and forestry, a life cycle analysis is ultimately essential for drawing an overall budget of the carbon-related activities in a managed system.

Confronting the soil profile: Towards a process-based framework for interrogating depth dependent soil OM chemistry

Ronald Amundson

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In many settings on Earth, soil OM chemical profiles (C, N, ^{14}C, ^{13}C, ^{15}N) all have roughly exponential trends with soil depth, characteristic of the result of reactive-transport processes that move and process OM downward. While there is a body of seminal papers that recognize this, and present numerical ways to interrogate soil OM chemistry, the interpretation of the growing numbers of OM chemistry depth profiles remains diverse and sometimes ad hoc. Depth profiles reflect the integrated OM diffusivity, OM decomposition rates, OM pools, etc. Due to the number of unknown parameters in reaction-transport models which reflect these processes, many of which are not well studied in many settings (e.g. diffusivity of differing OM pools; OM advection rates, rates of partitioning to slower cycling pools; etc.), it remains challenging to ultimately derive the key parameters of greatest interest to soil OM scientists in a human impacted environment: *the size and decomposition rate (k) of decadal cycling pools and its changes with depth*. As a result of complexity, box models of the whole soil, or individual layers, are commonly used to interpret data. However, it should be recognized that these models generally lead to the interpretation that the pervasive increases in OM age with depth is driven by associated significant decreases in k. In contrast, a reactive-transport perspective invariably attributes part of the increasing age with depth to the downward winnowing of aging C, and observed depth profiles of C and ^{14}C can be at least partially replicated with constant (or slightly changing) k values with depth. To further our ability to better constrain soil OM temporal responses to perturbations suggests a need for: (1) careful depth sampling of soil, (2) the continuation of the present laboratory efforts to partition C into physical distinct pools, and (3) evaluations of the data through reaction/transport frameworks. In the interim, simplified process-based evaluations of the wealth of existing data can offer novel (yet incremental) improvements in our understanding of the complex soil system.

What is the limit for organic carbon accrual in Israel's soils?

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With the rise in atmospheric CO_2 concentrations due to anthropogenic activity there is increased demand for nature-based solutions to capture CO_2. Initiatives such as the "4 per 1000" aspire to capture CO_2 in the form of soil organic carbon (SOC) at an annual rate equivalent to ~4 Pg C yr^{-1}. To better understand the viability of such initiatives it must be recognized that soil has a finite organic Carbon Carrying Capacity (CCC). In this work we present current theories on limits to carbon accrual: (1) An ecological carrying capacity arising from the dynamic change in SOC degradation to match SOC inputs. (2) A physiochemical constraint to the formation of mineral associated SOC (MAOC) which is protected from rapid degradation. We will then present initial findings from work aimed at defining the limits to SOC accrual in Israel's soils. The research involved a survey of 18 sites along the precipitation gradient of Israel ranging between 260 – 800 mm yr^{-1}. In each site SOC levels were measured to a depth of 40 cm in forested as compared to uncultivated non-forested sites. In addition in the forested sites a semi-organic soil horizon was sampled from below the litter layer and to a depth of 2 cm. We regard the MAOC in this semi-organic layer as representing the soil CCC. The relation between the CCC and soil physiochemical properties and the differences between the CCC and SOC in the deeper soil layers will be discussed. We will also propose two more storage options for SOC in soil which may increase the soil's CCC.

Reuse of dredged streambed sediments in agricultural fields

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Many intensively cultivated areas suffer from soil losses, due to accelerated soil erosion processes, which eventually deposit in the stream channel. To prevent flood risks, the deposited sediments are routinely dredged from the streambed, and due to the lack of a cost-effective solution, piled upon the stream bank. Dredged sediments (DS) piles disturb the ecological balance in the riparian habitat, serve as a reservoir for weed seeds and may enable the further establishment of invasive species. Studies have shown that DS tend to be richer in organic matter and plant nutrients compared to the adjacent local soil, thus DS might be used as amendments to agricultural fields. However, the seedbank in DS may contain harmful weed species that threaten farmers from applying this valuable soil. The main objectives of the current study are: 1. to assess the quality of DS as an agronomic substrate and its potential risk for weed invasion and establishment in the agricultural environment, 2. to examine the efficiency of soil solarization in reducing seed viability of DS applied upon an agricultural field. DS that were piled (0.6-1.2 m height) on the eastern bank of Nahalal stream (Jezre'el Valley) were sampled along the bank, from a section of 1 km in 10 transects at three depths (top, middle, bottom). The upper (0-20 cm) soil layer at the adjacent agricultural field (AF) was sampled in parallel to the DS transects and along the hillslope Catena. The soil seedbank was characterized for DS and AF samples using a germination assay. The soil seedbank characterization revealed that the seed bank density (Number of seeds / m2) was 11 times higher in DS compared to the adjacent AF, and the species richness was greater. We concluded that applying the current dredged sediments in agricultural fields with no pre-treatment might contribute 29 new weeds species to the AF seedbank. The efficiency of soil solarization in reducing the viability of DS seedbank was tested under a field experiment in which DS were applied upon a commercial agricultural field in a layer 10 cm thick, with and without solarization treatment. The soil temperature and water content were monitored along the experimental period and seeds/rhizomes were buried at two depth (5 and 10 cm) in the different experimental plots. Soil samples were collected from each treatment and germination assays were conducted in order to evaluate the seed viability in the different treatments. In addition, vegetation surveys were conducted during the winter growing season in order to assess weed infestation rates in each treatment. The results shows that the solarization dramatically reduced the viability of DS seedbank. We suggest soil solarization as an effective, non-chemical tool, for reducing seedbank viability for safely reusing DS in agricultural fields.